A Case Study of the Strategies and Practices Used by School Personnel in STEM-Focused Elementary Schools in an Urban Setting

A Dissertation submitted to the
Graduate School
Valdosta State University

in partial fulfillment of requirements for
the degree of

DOCTOR OF EDUCATION

in Organizational Leadership

in the Department of Leadership, Technology, & Workforce Development of the
Dewar College of Education and Human Services

May 2021

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ABSTRACT

Over the past decade, less than 20% of 12th-grade high school students in Georgia had proficient science knowledge. The lack of content knowledge makes it difficult for high school students to compete for high-paying jobs in a global economy driven by innovations in science and technology. Such innovations are essential components of science, technology, engineering, and mathematics (STEM) programs and result from the synergistic working of STEM content. An insufficient number of science-proficient high school students to fill the available STEM positions necessitates a more robust pursuit of STEM programs throughout the nation. The purpose of this study was to determine the strategies, practices, and relevant experiences of school personnel responsible for increasing student science proficiency at a certified elementary STEM school in urban areas in Georgia. A case study using purposeful selection and snowball sampling served as the foundational pieces to examine the success of a STEM program. School leaders may be able to use the findings of this study to develop a model for STEM programs with personalized modifications to increase the speed and accuracy of future program development. Increased student exposure to STEM concepts is a means of providing STEM education to more students from varied backgrounds. Students with more STEM education may have increased proficiency and develop into the innovative thinkers needed for success in the 21st-century workplace. Administrators, members of boards of education, and university and college program developers may also benefit from this study.

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Acknowledgements

I appreciate my committee members who have helped me complete this dissertation journey. Thank you, Dr. William Truby, for agreeing to serve as my committee chairperson. Your support and immediate feedback will always be appreciated. Please continue to be a straight shooter with constructive comments to help students understand what is expected at this level of academia. Thank you to my study partner and “road dawg”, Melanie Mitchell, for encouraging me to keep going when the road was looking too long and rough. Our Spiritual connection has fostered into a friendship that I will forever cherish. Thank you, Dr. Green, for your dedication to helping me even after you retired. Thank you, Dr. Lairsey, for your thorough review of my dissertation although we never met personally. Your feedback is greatly appreciated. Thank you, Dr. Bochenko, for serving as a teacher and committee member who has helped me complete this dissertation journey.

I would also like to acknowledge several individuals who prepared me for this journey through their support in biomedical research beginning in undergraduate school. Dr. Asoka Srinivasan (Tougaloo College), Dr. Carolyn Cousin (University of the District of Columbia), Dr. Randal K. Buddington (Mississippi State University), and Dr. Jesse Roman (Washington University Medical School and the Atlanta VA Medical Center) for allowing me to assist you and teaching me the fundamentals of scientific research.

Dedication

This dissertation is dedicated to my family. Thank you to my parents, James and Mildred Williams, for being an example of two individuals who were willing to do all that they could possibly do to excel in life and provide a good life to their children. Thank you to my husband, Robert Darren Little, Sr., for consistently providing me with love and support as I embarked on this longer than expected journey. Thank you to my first son, Robert Darren Little, II, for often giving me a friendly reminder to stay diligent with my doctoral studies pursuit by asking me, "How is the dissertation going?" and being willing and able to help me in any way that I asked. Thank you to my second son, Herbert James Little, named after his two grandfathers, for encouraging me to complete this journey because I was the only person he knew who has ever taken on such a challenge. Thank you to my daughter, Iesha, for your bravery and honesty. You have helped make it clear that we as a system of education can do and be better for those we serve. Thank you to my cousin, Rosewitha Shelton, for your willingness to help me on this journey even though you just recently completed her own doctoral studies. Your direct questions and advice helped me focus on what is important. Thank you to my niece, Tori Bowie, for your editing and wording advice to help my dissertation read more clearly to the general public. Thank you to my niece, Vivian Williams, for assisting me with proof reading and encouragement. The love and encouragement of other family members has served as a great motivator, and I will forever be grateful to you all.

Chapter I INTRODUCTION

Overview

In 1957, Soviet Union officials successfully launched a beach-ball-sized satellite named Sputnik that weighed about 184 pounds (Bracey, 2007). The Sputnik launch occurred during the time of friction between the United States (US) and the Soviet Union known as the Cold War (Powaski, 1998). American government officials were alarmed by Sputnik's launch because it indicated that their nation was no longer the technological leader of the world (Divine & Divine, 1993). The following year, Congress passed the National Defense Education Act to improve science and math education by adding depth and rigor and broadening its reach to all students (Zhao, 2009).

Despite being the first nation to have a man on the moon on July 16, 1969 and possessing the most massive rocket built at the time, the US had much room for improvement in science and technology (Fishman, 2019). On August 26, 1981, Secretary of Education Bell created the National Commission of Excellence in Education to research the "quality of education in the United States" (Gardner, 1983, p.1). The goal of the national commission was to define and suggest solutions for the educational problems in the US. The commission delivered the final report, *A Nation at Risk: The Imperative for Educational Reform,* in April 1983, a 65-page document presenting the stark reality of the need for significant work to improve the U.S. educational system.

A Nation at Risk resulted in the development of many policies, committees, and organizations to improve the American educational system. At the 146th Annual Meeting of the National Academy of Sciences (NAS) in 2009, President Obama proclaimed that the economy in the US needed a robust science, technology, engineering, and math (STEM) workforce to compete in the 21st century (Obama, 2009). STEM immersion in American schools indicates that STEM-literate young people are the future of the workforce (Gomez & Albrecht, 2013; Kelley & Knowles, 2016; Lyon et al., 2012; Subotnik et al., 2009). Ertmer (1999) and Chesloff (2013) found that the public school system was the best place to reach and train the greatest number of young students.

From the inception of public schools to the present, the goal of the educational system has been to prepare an adequate global workforce (Reese, 2011). According to Fayer et al. (2017) and the US Bureau of Labor Statistics (2021), careers are projected to increase at a rate of 28.2% in mathematical science occupation groups compared to a 6.5% projected increase in non-STEM careers between 2014 and 2024, followed by a 12.5% increase in computer science. According to the US Bureau of Labor Statistics (2021), the median annual salaries for STEM occupations and non-STEM occupations are estimated to be $89,780 and $40,020, respectively, between 2019 to 2029. There are many unfilled jobs due to a lack of workers with the skills needed to perform the associated tasks (Buckner & Boyd, 2015; National Association of Educational Progress (NAEP, 2019). Increased STEM education and exposure to more students from varied backgrounds is a way to increase students' chances of STEM proficiency and develop them into the innovative thinkers and workers needed for success in the 21st-century workplace.

Problem Statement

Over the past decade, less than 20% of 12th-grade students in Georgia were assessed to be proficient in their knowledge of science (GOSA, 2021), making it more difficult for them to compete for high-paying jobs in the global economy driven by innovations in science and technology, which are essential components of STEM programs.

STEM careers are abundant, yet there are not enough individuals who possess the foundational and cognitive skills necessary to carry out the duties required in these careers (Committee on STEM Education, 2018; National Center for Education Statistics [NCES], 2011). The international need for more students who are proficient in science has prompted the development of organizations with a vested interest in what students know and are able to do. Since 1995, Trends in International Mathematics and Science Study (TIMSS) has conducted a math and science study every four years to assess science and math achievement of 4th and 8th grade students. National Assessment of Educational Progress (NAEP) focuses on science and math achievement of 4th, 8th, and 12th grade students in the US. Each state has benchmark assessments designed to assess what students know and can do in all core subjects.

Twelfth grade students in Georgia scored proficient on state benchmark assessments with an average of 18% on the Biology End of Course (EOC) assessment and 15% on the Physical Science EOC assessment. Nationally, 12th graders scored slightly above basic during the assessment years 2009 and 2015. And the TIMSS of 8th grade students showed that students in the United States ranked 11th in 2011, 2015, and 2019, while 4th graders ranked 6th in 2011, 10th in 2015, and 8th in 2019 (TIMSS, 2021). TIMSS data (2019) indicated that between 1995 and 2015 there was an overall increase of nine points through several fluctuations in increments of four-year periods and revealed a decrease in the number of students who indicated that they liked science between 4th grade to the 8th grade. The lack of motivation to learn science concepts has been revealed in several studies (El Nagdi et al, 2018; LaForce et al., 2017) and leads to the conclusion that students need to be exposed to science concepts that they are motivated to learn.

According to the Programme for International Student Assessment (PISA) data, in the past decade, American students have decreased math scores and have no change in science scores as compared to countries of the Organization for Economic Cooperation and Development (OECD) (2018). The National Academy of Science (2014) observed that an insufficient number of students were being prepared for STEM careers. Policymakers have responded to deficient math and science scores by calling for STEM focused approaches to teaching (National Center on Education and the Economy, 2017).

The best place for specialized STEM training for high school students is in school during regular school hours (Doubet & Hockett, 2015). Most schools providing STEM education focus on gifted and accelerated students, who tend not to be low-income or members of minority groups (Subotnik et al., 2009). This focus perpetuates the lack of knowledge in STEM by the students most in need of an advantage in securing jobs. This is an area of concern (Change the Equation, 2021). The National Research Council (2014) and many other organizations have identified several reasons for this gap. The gaps lead to limited opportunities for students to attend college in STEM majors, for Americans to compete for jobs in STEM fields, and for the US to compete in a global society saturated with STEM-related opportunities (Holdren et al., 2010). The US Bureau of Labor Statistics data (2017) supports these concerns seven years after Holdren's article, providing statistics about employment requiring STEM knowledge and skills in scientific and professional services in every region of the US. Holdren's report titled, *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future* indicates the US needs to strengthen both proficiency and interest, which coincides with the terms *prepare* and *inspire* stated in the title of the report (Holdren et al., 2010).

Purpose Statement

The purpose of this study was to determine the strategies and practices used by school personnel responsible for increasing student science proficiency at certified STEM elementary schools in urban settings in Georgia. Science was selected because it is the content subject that I have studied and taught throughout my career, and it has not been a significant area of focus by major educational policy initiatives for the past 20 years. The No Child Left Behind (NCLB), initiated in 2001, and Every Student Succeed Act (ESSA), initiated in 2015, both identified math and ELA as the major core content foci. The Criterion Referenced

Competency Test (CRCT) assesses science proficiency in the fifth grade and were the scores used to determine proficiency at the participating schools in this study. In this research, strategies are the actual steps taken throughout the change process. Strategies describe what occurred, such as obtaining STEM certification. The practices are the actions taken to accomplish the strategies, such as teachers' daily use of the STEM certification checklist to guide lesson planning.

Implementing more specialized STEM programs can help expose more students to STEM skills and content, as well as the STEM career pipeline (Erdogan & Stuessy, 2015). Even with more STEM-focused schools developed each year, there is not enough information about the instructional and institutional practices of these schools to provide a clear understanding of what makes them effective (Tofel-Grehl, 2013). The rich, lived experiences of the leader of a STEM-focused school can provide insight into the practices relevant to the program's success in this unique learning environment (Bruce-Davis et al., 2014). The researcher purposefully selected STEM leaders who had recently been involved in a successful pursuit of STEM certification for their schools. This decision was complementary to this study in many ways. Each participant expressed motivation and pride in sharing their story. They also expressed high esteem for their principal.

Many of the barriers to STEM education, such as gender and economic inequality, have begun to dissipate due to increased STEM education and exposure. However, according to the Alliance for Science & Technology Research in America (ASTRA; 2017), 43.3% of boys showed an interest in pursuing STEM careers compared to 15.8% of girls. Furthermore, in Georgia, data identified Asian

Americans as taking the lead in STEM career interest, followed by Whites, Hispanics, American Indians, and Blacks. The male to female ratio in the schools in this study averaged 50% for each (GOSA, 2021) which potentially may indicate a higher percentage of girls pursuing STEM careers.

Historically, the challenges obstructing the progress of STEM education have been the inability to motivate students to choose careers in STEM education (Wang & Degol, 2013), STEM teacher shortage (Hutchison, 2012), and the lack of knowledge of the importance of STEM education by individuals outside of the educational setting (LaForce et al., 2017). Data collected from this study revealed that students are interested in learning more about the topics of study, potentially satisfying the need to motivate more students to choose STEM careers. The teachers at each of these schools were provided with a plethora of professional learning opportunities throughout the school year that may transform them into highly qualified STEM teachers, potentially decreasing the STEM teacher shortage. The extensive recruitment of community stakeholders and parent participants in this study may potentially spread knowledge of the importance of STEM education to individuals outside of the educational setting.

Although each participant shared their opinion that there is much room for improvement, the challenges to STEM education seemed to diminish as the STEM program became anchored within each school. The information collected during this study has significant potential to help educators and policymakers lower the activation energy required to produce more STEM-focused schools in urban settings.

Research Questions

The following research questions were used to guide this study. I created them in order to reveal details related to the STEM implementation process and the school leaders' perception of the process. Strategies and practices used by STEM personnel who directly worked with students in the schools included in this study may be used by others who are attempting to create future STEM programs. Any barriers shared by the leaders, were identified as things to avoid or counteract in future models used for implementation of STEM programs.

RQ1: What are the lived and career experiences of school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ2: What strategies are used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ3: What practices are used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

Significance

There is an insufficient number of high school students with adequate science proficiency to fill the STEM positions available in the global economy. Educational leaders and policy makers at the national level, indicate the need for more STEM programs (Office of Innovation and Improvement, 2016), but there is little documentation of success. For the purpose of this study, STEM programs are considered successful when they result in an increase in student achievement which can be measured in several ways, such as an increase in assessment scores, student participation, and motivation to learn. This case study was a means to determine the strategies and practices used by school personnel in STEM-certified urban elementary schools. The schools purposefully selected for this study have demonstrated increased student science proficiency and confidence since implementing their STEM-certified programs. Increased student exposure to STEM concepts may provide STEM education to more students from varied backgrounds, increase equity and proficiency in this area, and help develop students into the innovative thinkers needed for success in the 21st-century workplace.

Conducting this research in an urban setting provides the conditions that may be found throughout American because urban settings have several common conditions such as poverty, high rates of absenteeism and discipline problems in school, high numbers of minorities, and lack of college-educated role models in the home. These conditions are often thought to hinder a student’s educational and career options, however, with enough intervention providing STEM-focused community-connected learning experiences, students may gain enough real-world practical knowledge to pique their interest to learn more.

The hands-on, interactive, STEM-focused lessons that were provided for the students at each participating school influenced exposure of STEM concepts to students without them focusing specifically on science, technology, math, or engineering. The engineer design method is heavily immersed with inquiry, and it gives students problems to solve or questions to answer that require a certain amount of knowledge about each subject working together. The students’ ability to solve the problem supersedes their need to gain more STEM knowledge and adds fuel to the learning process. Once students gain foundational knowledge it can be used as prior knowledge to continue to build on the STEM curriculum, thus providing students with the confidence of knowing that they can become scientists, technologists, and engineers.

As the researcher applied purposeful selection, participants who had direct daily contact with students were revealed. The principals provided information from the administrative viewpoint and the STEM teacher leaders provided rich data obtained directly from students, parents, and community stakeholders. A certain amount of bias was expected from the participants because they often described success in more thorough detail than any barriers. This was expected and guided my interview questions to probe for any barriers that may have been experienced during the implementation process.

The experiences revealed by the faculty and students at the two schools in this study may be able to serve as a guide to success for future programs. Although there are many different elements that can be included in a STEM program, this research has revealed some elements that potentially led to the success of the programs of each of the two STEM schools.

Conceptual Framework

Concerns-Based Adoption Model

The Concerns-Based Adoption Model (CBAM), proposed by Hall and Hord (2001), was the conceptual framework used to create interview questions to explore school personnel's perceptions and experiences of STEM program development.

Hall and Hord compiled 12 change principles for guiding the change process and the three stages of the full implementation of a new initiative. The literature review in Chapter II presents the principles and steps in detail. Assessments are provided by Hall and Hord to be used throughout the change process to measure stages of concern, levels of use, and innovation configuration. Intervention tactics are also provided to help participants progress throughout a change process positively. Information contained in the CBAM can influence the perception of change and remove the guilt, anger, or resistance often associated with change.

Each participant in this study provided details about the difficulty of STEM program development. Each shared that the process requires a large amount of energy and time. The stages of concern usually started with uncertainty of how to implement the program and why it was even necessary. Early in the process, there was often a sense of resistance from some teachers, which seemed to dissipate as the process became more functional and familiar. The STEM leaders shared that each of the teachers in the building understood the benefit of STEM implementation prior to certification and most did not want to teach any other way after implementation was complete.

The second step in the CBAM is levels of use. A close look at the implementation process revealed that as professional learning activities began to support the move toward STEM integration the level of use increased. The collaborative nature of the lessons provided a certain amount of responsibility to each teacher to do their part as planned during their weekly planning meetings. The challenge of providing materials and other resources to the teachers was managed by the lead teachers and supported by the district. Innovation configuration is the final stage in CBAM, when the STEM culture became the new culture for each school and was evident prior to STEM certification in each participating school.

The STEM implementation processes in each of the participating schools can be modeled by other schools during their implementation process to guide and assist the process. Since the change process had already taken place prior to this research study, the CBAM framework was used to organize responses and observations to assist in the analysis of the data. Each of the steps can be elucidated from the responses and support the idea that this is a useful model and that this change process was conducted professionally and with fidelity. Future program development can incorporate the CBAM from the beginning to act as a guide to success.

Fullan Change Model

The school-wide implementation of a STEM program in an urban elementary school requires many changes. The Fullan change model (2012) was the conceptual framework used for this study because it addresses the deep theoretical reasons for change and the processes that work collectively to implement change. Fullan's change model was initially developed in 1995 and is the basis for the CBAM, previously mentioned; therefore, these theories were a good match for this study.

The five essential parts of Fullan's framework for leaders as change agents are identification of the moral purpose, understanding change, developing relationships, knowledge-building, and coherence-making. The most important part of Fullan's model is the moral purpose of the change. Fullan used purposeful reform for change and focused on the role of the leader during the change process. The purpose of the Fullan model is to assist leaders in putting change into action to improve a situation. The STEM crisis is a critical situation that requires examination for the success of American citizens academically, economically, and socially. Each stage of the model provides foundational information to progress to the next stage.

After identifying the moral purpose for the change, Fullan emphasized the need for all stakeholders to understand what the change will involve. Relationship building next is necessary to ensure a sense of responsibility for everyone to do their part. Knowledge creation and sharing in a collaborative setting is considered the important capacity building stage. Coherence making completes the change process and is followed by sustaining the change within the organization. Therefore, Fullan's model was an appropriate conceptual framework to ground the research and to consider the strategies and practices used to implement the STEM programs.

A close look at the strategies and practices that were used to implement the STEM program at participating schools revealed the application of each of the stages of Fullan's (2012) model of change in rich detail. Although this model was used to evaluate this program's development after it had been accomplished, it is often applied in organizations as a part of the plan from the beginning of program development. Use of this model from the beginning may also provide more confidence in the process and therefore decrease some of the concerns expressed by participants during the CBAM.

Fullan's framework for leadership shows an inclusive diagram that represents the relationship between leaders, members, and the results of the changes taking place by incorporating the five levels of change. Overshadowing the five levels of change are descriptive terms for the possible associated moods in Figure 1.1 pg. 4 (Fullan, 2012) such as enthusiasm with the first two levels, hope with the second two levels and energy with the final level called coherence building.

Methodology

I chose a comparative case study to collect rich, thick data to reveal the strategies and practices used by school personnel in urban Georgia STEM-certified elementary schools that demonstrated increased science proficiency (Governor's Office of Student Achievement, 2021). Seidman's (2013) three-part interview system guided one-on-one conversations with the purposefully selected participants. Audio recording the interviews allowed me to review the conversation multiple times to capture the abundant amount of information and to identify common themes. Engaging Creswell's (2014) method of immediate data analysis directly following each interview, entailed listening to and coding each interview.

The researcher employed triangulation (Merriam & Tisdell, 2016) to strengthen the validity of the study by using different sources of data to justify the themes. The six participants provided data, responding to the same open-ended questions through the semi-structured interview protocol (Merriam & Tisdell, 2016). Additional data sources used were the school websites and memos developed throughout the study. Member checking was implemented to ensure the accurate presentation of the participants' stories. There was no external auditor used because the participants verified the accuracy of words and themes through member checking of the transcripts. A professional peer and recent doctoral graduate provided many useful comments and asked probing questions to steer me in the direction of deep discovery through peer debriefing. This process is called peer debriefing is a method for validating accurate results (Creswell, 2014).

Qualitative reliability involves consistent approaches across different projects (Creswell, 2014). In this study, all participants received consistent approaches. Clear and thorough documentation of the methods and steps taken to conduct research adds to the reliability of a study (Yin, 2009). A professional transcription service, Rev.com, was employed to transcribe the audio recordings. Constant comparison of interview audio and transcripts helped maintain a consistent interpretation of the themes and ensure a clear definition of what the theme represented. Responses by participants from the same school, as well as those from different schools, were similar throughout the study. This information may be useful to create an informed starting point for a STEM program implementation process in other schools.

Limitations

According to Merriam and Tisdell (2016), qualitative research has "the greatest promise of making a difference in people's lives" (p. 1) because it provides the direct perspectives of the individuals involved. Merriam and Tisdell regarded qualitative research as the method of choice for enhancing the practices of the individuals dealing directly with the lives and well-being of individual clients. A focus on the perspectives of leaders and other personnel at STEM-focused elementary schools required many probing and open-ended questions. One limitation of this study was that only two urban public elementary schools in

Georgia had completed the STEM certification process and increased science proficiency. The study's small sample size of two schools and six participants resulted in limited information reflective of the general population. Another limitation was the time needed to conduct a study with in-depth knowledge of personnel members' perceptions. The school districts had several time limitations on research with personnel and a tight timeline for collecting data was given (see Appendix A).

My goal as a researcher was to gain foundational, initial information upon which future scholars can expound through in-depth studies of individual schools. Although this study did not include all possible strategies and practices used in STEM education, saturation occurred, as all participants reported the same basic methods that were used at the two participating schools. Glaser and Strauss (1967) defined saturation as "criterion for judging when to stop sampling a group pertinent to a category" (p.61). In this case, the researcher believed three participants from each school was sufficient and this proved to be correct. One school district contained both elementary schools meeting the study's inclusion criteria. The personnel I interviewed had direct contact with the students receiving STEM education; therefore, bias was possible due to their intimate relationships with their projects, students, and schools. Personal experiences and knowledge can influence data interpretation (Maxwell, 2013). Therefore, my experience in STEM education may have had an influence on data interpretation because my career pathway has been immersed in STEM as a teacher, medical lab technician, and biomedical researcher for over 40 years.

There were limitations for verifying the information collected through the interviews. Data analysis is a labor-intensive process of categorizing and coding (Merriam & Tisdell, 2016). This was a limitation due to the possibility of mistakes being made. Participation in this study was voluntary and participants had the option to withdraw their participation and data at any time and was explicitly described in the consent agreement (see Appendix B). The study was conducted in May, which is a busy time of year for teachers and administrators which had the potential to distract them from focusing on the interview. The COVID-19 pandemic caused a shutdown of schools, preventing face-to- face interviews. The interview was conducted with a cell phone call and audiotaped on an iPad with permission from each participant. More school site observations to collect data may have been possible if there had not been a shutdown.

Definitions of Terms

The following is a list of the critical terms used throughout this study:

Collaborative planning. According to the Georgia Department of Education (GADOE) (2021), collaborative planning is a meeting among teachers to discuss lesson plans, assessments, and discussing teaching strategies for struggling learners to better facilitate learning.

Science proficiency. According to Nationsreportcard.gov (2021), proficiency is a performance level on standardized tests above basic but below advanced. The level is characterized by an understanding of specific knowledge and skills relative to the subject being tested.

School personnel. According to lawinsider.com (2021), school personnel are persons employed by, on contract with, or who volunteer in a school district, charter school, or non-public elementary or secondary school.

STEM certification in Georgia. Step-by-step process that demonstrates that a school has met STEM certification criteria. A whole school or a program within a school can receive two types of certification criteria: (a) GADOE (2021) certification "dedicated to STEM education and curriculum" and (b) AdvancEd certification for the use of a "research-based framework for assessing the quality of STEM educational programs" (Proudfoot et al., 2018).

STEM education. According to GADOE (2021), STEM and STEAM curriculum is multidisciplinary and based on project-based learning driven by student inquiry and investigation.

STEM subjects. Subjects include some degree of science, technology, engineering, and/or math (LaForce, 2017).

Urban school. According to National Center for Education and Statistics (NCES) (Lippman, 1996), urban schools are those in central cities of metropolitan statistical areas
(MSAs).

Summary

This qualitative case study was an exploration of the experiences of STEM teachers and leaders implementing a STEM program at their schools. The case in this study covered the periods of initiation, implementation, and institutionalization, which Fullan (2020) considered the time frame for change. STEM program development spanned three years at both schools studied. Only two schools in Georgia met the criteria for inclusion. This chapter presented the significance of STEM program implementation. The urban setting was appropriate because it has the greatest need for more STEM program development.

The outlook for America in meeting the demand for more STEM-educated individuals to fill STEM jobs is improving with more research and professional development. The race to be the best continues worldwide as more assessment tools are available to measure achievement. Public schools are a preparation site to provide youth with the knowledge and skills needed for success in the global workforce. The change in necessary workforce skills has prompted a change in the content and method of teaching in schools.

Two conceptual models, CBAM by Hall & Horde, 2001 and Fullan's change model, 2001 provided a foundation for this study focused on identifying critical components to support the changes needed for schoolwide STEM program implementation. The case study approach was ideal for capturing information relative to personal and professional life experiences that may have shaped the leaders to increase their success potential. This study's findings may contribute to improving education in the US by examining the strategies and practices of personnel at STEM-certified schools in which science proficiency increased during implementation. Applying this information may allow other school personnel to model the pedagogy used by personnel at the two participating schools to increase the number of STEM schools in America.

Chapter II LITERATURE REVIEW

This chapter contains a review of the existing literature relevant to STEM program development. There has been an extensive amount of research done in this area in the past 20 years, but there are still several gaps in the literature needed to be filled. This chapter includes the history and purpose of STEM schools, inclusion of different genders and ethnic groups, five models of STEM schools, successes and challenges of STEM program implementation, and administrator and teacher perceptions of the implementation process.

Since 1954, large populations of minority students at urban elementary schools have struggled to meet standardized test requirements (Parker et al., 2015). Anderson (2017), Becker and Park (2011), and Bencze (2010) found that the students whose teachers exposed them to STEM integration excelled academically on standardized tests compared to students without such exposure. According to stemgeorgia (2021.b), STEM and STEAM curriculum is multidisciplinary and based on project-based learning driven by student inquiry and investigation.

The saturation of technology in most fields suggests that all students—not just those planning to pursue STEM professions—can be productive members of the workforce (Committee on STEM Education, 2018). Utilizing technology education to integrate disciplines, such as science and mathematics, across curricula may be beneficial in motivating students to learn about STEM-concentrated topics (Cotabish et al., 2013).

Teachers who incorporate science and mathematics into their daily lessons teach students the processes, meaning, and importance of integrating technology across disciplines (Anderson, 2017; Becker & Park, 2011; Cotabish et al., 2013); however, practitioners have different theories about how to best integrate STEM into the classroom (Cotabish et al., 2013). Robinson et al. (2014) and Keeley (2009) found teacher professional development and rich problem-based inquiry were the most vital components in cultivating scientific minds during the early years of education.

The purpose of this study was to determine the strategies and practices used by school personnel responsible for increasing student science proficiency at certified STEM schools in urban settings in Georgia. This case study focused on two Georgia-based urban elementary schools' STEM program development and implementation, including their curricula, methods and resources, allocations, challenges, and successes. This literature review presents information relevant to the research questions in this study and had a significant influence on the creation of the interview questions (see Appendix B).

Conceptual Framework

STEM schools have significant potential as productive learning environments for students (Erdogan & Stuessy, 2015; Kasza & Slater, 2017). Hall and Hord (2001) and Fullan (2001) offered conceptual frameworks for understanding how educational leaders can change traditional school environments to STEM-learning environments. The CBAM, created by Hall and Hord in 2001, was the conceptual framework used to address the perceptions of leaders and other school personnel during the implementation of STEM programs in two urban, public elementary schools in Georgia. Hall and Hord compiled a list of the 12 principles essential to change (2006, pgs 4-14):

1. Change is a process, not an event.
2. There are significant differences in what is entailed in development and implementation of an innovation.
3. An organization does not change until the individuals within it change.
4. Innovations come in different sizes.
5. Interventions are the actions and events that are key to the success of the change process.
6. There will be no change in outcomes until new practices are implemented.
7. Administrator leadership is essential to long term change success.
8. Mandates can work.
9. The school is the primary unit for change.
10. Facilitating change is a team effort.
11. Appropriate interventions reduce resistance to change.
12. The context of the school influences the process of change.

According to Hall and Hord (2006), the implementation of a successful change process has three stages: The stages of concern (SoC) component include using instruments to assess attitudes and feelings about a new initiative. Levels of use are broken down into levels from nonuse to advanced use of the new initiative. Innovation configurations (IC) assess the level of implementation with full implementation as the ultimate goal.

CBAM has a rating system for measuring the level of IC and evaluating the participants' actions after implementing the change (Hall & Hord, 2006). IC maps are a way to measure the incorporation of the specific components of the change. Each component is a valuable and intentional monitoring tool for measuring staff buy-in. Hall and Hord (2006) also provided details about an intervention useful within each stage. If needed, effective and fair intervention administration can occur without resistance when the subjects thoroughly understand the process. CBAM includes intervention strategies for people who adopt the change at different rates.

Fullan's (2001) change model was the second conceptual framework applied in this study. The primary purpose of the model was to identify the deep theoretical reasons for change within organizations and schools. Refocused in 2006, the updated model provides a process for creating change in schools. One deep theoretical reason for change within schools in the US is to promote academic, social and economic change to meet the needs of our nation's workforce by incorporating STEM education in schools. The change model was an appropriate framework to identify the strategies and practices used by school personnel responsible for increasing science proficiency during the implementation process at certified STEM schools in Georgia.

Fullan (2001) asserted that organizations must be drivers of change with leaders whose visions include a commitment to capacity-building, stakeholders united in a moral purpose, and visions that guide operations. All key leaders overseeing a change must have training and support to understand the necessary components of changes (Fullan, 2001). Individuals should have assigned roles and role relationships that contribute to improving the organization (Fullan, 2001). Fullan stated that building capacity within an organization requires the change drivers to connect with other organizations in the district to provide mutual support and a shared sense of identity while using data to influence business organization and improvement. When productive conflict occurs, Fullan recommended treating the conflict as an opportunity to explore differences in opinion (1993). Fullan also suggested creating a demanding culture through high expectations, involving external groups to support the change process and assist with coherence-building and that organizational leaders should focus on financial investments by devoting and using new funds to support future accountability issues (Fullan, 2001). Additionally, Fullan noted that change connects closely to local needs and that leaders must prioritize rather than try to change everything.

Fullan's overlapping phases of the change process, first described by Miles et al. (1987), have three stages of a simplified grouping of the major components in the change process utilized by leaders to incorporate the necessary adjustments required: initiation, implementation, and institutionalization. During the initiation phase, the drivers of the change must tie the change closely to the local needs indicated by a needs assessment. The problem emerges during the initiation phase. The implementation phase is when change occurs with the development of a plan, strategies, and practices. During the institutionalization phase, the drivers of the change embed the change into the organization. Fullan noted that change processes usually take three years or more for full implementation (2001).

Organizational change is identified by Fullan as a necessary response to internal or external forces and an essential component for staying true to an organization's purpose. He expressed that modification to organizations can include adapting to new technology, changing or crafting new cultural values, or becoming more competitive or socially responsible. However, at a deeper level, he describes an organization as a complex bundle of interactive human processes and an environment in which processes can collide. When organization leaders implement change, such as by restructuring an existing organization or merging two organizations with different values and norms, the change attempt often disrupts or damages the informal networks and connections people have created to accomplish everyday tasks. Disruptions in relationships often result in negative emotions such as confusion and (Fullan, 2001) but can also be channeled into meaningful solutions (Fullan 1993).

Fullan's (2001) change model has gone through several changes and contributes to organizational change in schools in several ways. Fullan identified seven core practices that work well to create powerful leaders regardless of the organization (2011). They are listed throughout his book titled, *Change Leader: Learning to Do What Matters Most* as key insights #1-7.

1. The effective change leader actively participates as a learner in helping the organization improve.
2. Effective change leaders combine resolute moral purpose with impressive empathy.
3. Realized effectiveness is what motivates people to do more.

4. Collaborative competition is the yin and yang of successful change. Collaborate and compete.
5. Change leaders are more confident than the situation warrants but more humble than they look.
6. Statistics are a wonderful servant and an appalling master.
7. Simplicity is salvation for an intricate world.

These core practices are what Fullan has found to be vital for leading organizations while considering their complexity. Previous key points that Fullan has made relevant to schools and organizations are expressed specifically or insinuated throughout many of his earlier literary works prior to reaching these key core practices. A focus on capacity-building in the early stages is key to motivation (Fullan, 2001). Capacity-building is a way to develop skill, clarity, and motivation. The degree of successful content interactions between students and teachers is useful in determining capacity.

Identifying and defining the link between professional development and capacity requires organizational leaders to understand capacity, how to attain it with professional development, and the resources available or needed. If investments into capacity-building can contribute to improvement directly, leaders must root the definition of capacity in instruction. Fullan (2001) concluded that the mark of a principal at the end of tenure is not just the impact on student achievement, but also how many good teachers the principal leaves behind. There must be stability and continuity of effective leadership, and the system leaders must develop leadership succession policies with this goal in mind (Fullan, 2001). Fullan also suggested that reform efforts include internal accountability that directly links to external accountability.

Internal accountability occurs in organizations that align individual responsibility, collective expectations, and accountability data. In comparison, external accountability includes professional development for individuals to better understand student assessment data and to clarify goals and each player's role in achieving those goals. Understanding student assessment data provides each player with a tool for improvement, allowing them to link performance data with changes in instruction or the actions needed to increase achievement (Fullan, 2001).

Organizational leaders must also establish conditions for the evolution of positive pressure. One important aspect shared by Fullan in reference to the development of positive influence is that it consists of taking away all the excuses. He had the opinion that when adding new resources and capacities, organizational leaders should provide examples of similar organizations with success, and reduce distractions, such as unnecessary paperwork, ineffective procedures, and uncomfortable labor relations (Fullan, 2001). Finally, Fullan (2001) contended that organizational leaders build public confidence. Transparency regarding the elements of the implementation process can be a catalyst for increased public confidence in the organization (Fullan, 2001).

The number of STEM schools in K–12 education is growing; however, there is insufficient documentation of their successes and contributions compared to traditional schools (Honey et al., 2014; Kasza & Slater, 2017). Everyone's perception of success is different due to the variety of personalities possessed by all.

Fullan (2001) established a list of "good things" that he considered relevant to schools. They included, "enhanced student performance, increased capacity of teachers, greater involvement of parents and community members, engagement of students, all-around satisfaction and enthusiasm about going further, and greater pride for all int the system". It is necessary to better understand the ingredients for successful implementation of STEM programs in school settings to increase achievement and interest in STEM-based fields. Increasing STEM programs may increase students' opportunities for success in a global economy (Hansen, 2013; Oner & Capraro, 2016; Tofel-Grehl & Callahan, 2014).

History of STEM Schools

Thomas and Williams (2010) defined STEM schools as institutions with specializations in science, mathematics, and technology. According to Schachter (2012), STEM schools are vocational-technical schools that focus on technical career education, such as mechanics, cosmetology, and carpentry. Erdogan and Stuessy (2015) identified STEM schools as having a professional career focus and providing a STEM education in which students can engage in hands-on, technical, career-oriented classes and mathematics, science, and engineering courses. The incorporation of cross-curriculum content and real-life applications is also a focus of STEM education (Erdogan & Stuessy, 2015; Morrison et al., 2015).

The concept of STEM schools began in the early 1900s (Eisenhart et al., 2015; Erdogan & Stuessy, 2015). Established in 1904, Stuyvesant High School was the first STEM academy in New York, followed by Brooklyn Technical High School in 1922 and Bronx High School of Science in 1938 (Kasza & Slater, 2017).

They went on to say that technical schools in the US had success in response to the Cold War and provided workers with opportunities to acquire specific skills.

The Sputnik launch in 1957 led American leaders to focus more on STEM education in school systems (Jolly, 2009). The immediate threat to national security and the symbolic battle for technological superiority resulted in an increased need for national assessment data of student proficiency in science and mathematics. The 1983 *A Nation at Risk* report and standardized assessments, such as the TIMSS, NAEP, and PISA, indicated worse performance by American students than their international peers (Banning & Folkestad, 2012; Hossain & Robinson, 2011). Students in the US continue to perform below the levels of many developed and developing nations worldwide, causing concerns for economic and national security (Carnevale et al., 2011; Riccards, 2009).

The ability of the US to compete in global markets requires success within STEM or STEM-related occupations (Hossain & Robinson, 2011; Morrison et al., 2015). There is a consistent drive to maintain technological superiority in research, development, and military technology to avoid lagging behind international competitors. An example of such a drive is broadband technology. In 2011, the US was the 28th-ranked country among developed countries in internet speed and service (Hossain & Robinson, 2011). Current rates of technological progress suggest that it will take 15 years for the US to catch up to the internet speeds of South Korea (Hossain & Robinson, 2011).

The growing void in the STEM-related job market, along with an increasing demand for STEM careers worldwide, is a mounting concern in the US (Fayer et al., 2017). Salzman et al (2013) argued that there are enough future workers to fill the positions, albeit with a disproportionate number of individuals from various socioeconomic groups prepared to fill the positions. Often, students in low socioeconomic groups lack role models who have attended college and therefore do not have goals and aspirations to pursue a college degree. In a guidebook for faculty and future faculty, Horowitz (2019) discussed the challenges of teaching first-generation college students. Horowitz identified a clear difference between first-generation students and those with role models in their families who have gone to colleges, providing advice for teaching them effectively.

In response to the lack of more varied representation in STEM fields, the federal government in the US has launched and funded reform efforts to stimulate student interest and performance within STEM fields (Moore, 2007). The 2011 federal budget included $3.7 billion for educational policies focused on STEM and another $4.3 billion for STEM as part of Race to the Top (Johnson, 2011) funding. Despite the billions of dollars invested into the K–12 school system, there have not been changes in the number of students pursuing STEM-related careers nor student performance on standardized testing in science and mathematics in 30 years (Mack et al., 2019; Morrison et al., 2015; Scott, 2012).

The importance of STEM remains vital from both economic and national security perspectives, despite seemingly ineffective efforts to motivate student interest and performance in STEM-related fields (Wang & Degol, 2017). As a result, examining the implementation of educational STEM reform efforts is a high priority (Bybee, 2010; Johnson, 2011). There is a need to establish the criteria of successful

STEM program implementation that contributes to student performance and interest in STEM (Shernoff et al., 2017). Several local, state, national, and international organizations address and provide achievement data in science, such as the Governor's Office of Student Achievement in Georgia, GADOE, NCES, and TIMSS. The reports generated by these organizations are used to measure the success of promoting STEM education.

There has been an increasing number of STEM schools since the 1980s. According to Eisenhart et al. (2015), the number of STEM schools increased from 15 to 100 between 1988 and 1999. Means et al. (2008) counted approximately 315 STEM schools in the United States, and Tofel-Grehl and Callahan (2014) tallied about 358 STEM schools nationwide. However, there remains a shortage of STEM teachers (Burke & McNeill, 2011; Fuller & Pendola, 2019; Scott, 2012).

Vereen and Vereen (2015) conducted a preliminary evaluation of Georgia elementary school teachers' willingness to obtain certification in science or mathematics to achieve school-wide STEM certification. In 2016, Georgia STEM certification guidelines required more than 75% of school staff members to have or be working toward a science or math endorsement (requiring 160 hours of coursework in a certified program) or certification in science or mathematics. Teachers also had to pass the Georgia Assessments for Certification of Educators. The Professional Standards Commission is the governing body that indicates the requirements for maintaining STEM certification for the teachers in the state. After schools and teachers receive certification, teachers must engage in additional professional learning and receive feedback on implementing classroom tools and techniques to achieve STEM certification program objectives.

In response to the shortage of qualified teachers within STEM content areas, President Obama announced a commitment to bolstering the number of teachers in mathematics and science and addressed the importance of STEM education in the US (Burke & McNeill, 2011). In 2009, Obama announced "Educate to Innovate," a nationwide campaign for excellence in STEM education was included in the Race to the Top initiatives. The goal was to improve STEM education through partnerships with nonprofit organizations and companies within the private sector to increase STEM literacy, enhance teaching quality, and expand educational strategies and practices. Companies, such as Time Warner Cable and Discovery Communications, and programs, such as *Sesame Street*, included a focus on STEM as part of the Educate to Innovate initiative (Burke & McNeill, 2011). Private and nonprofit enterprises donated approximately $500 million, and the federal government provided another $250 million for various STEM-related programs.

Initiatives to increase STEM education in America also included a focus on teaching. In addition to a myriad of businesses providing shadowing and internship opportunities for students, 10,000 new teachers received training in STEM content areas from significant public institutions and organizations, such as Intel and PBS (Burke & McNeill, 2011). The push to train teachers occurred after the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (COMPETES Act) in 2007. The COMPETES Act provided funds to train 70,000 new teachers in Advanced Placement and

International Baccalaureate courses and increase the training and interest of college and university students to pursue STEM degrees (Burke & McNeill, 2011). The purpose of these initiatives is to improve the American educational system by improving STEM delivery to students and dramatically enhancing the overall pipeline of students pursuing STEM careers. There is a need to focus on the student pipeline to address the growing concerns of the innovation and economic viability of the US in the 21st century (Campbell & McKenna, 2017; Smith et al., 2018; Wassell et al., 2017).

Many of the original STEM schools are state-run institutions on college campuses due to the high cost of specialized equipment and curriculum development. Before 1999, STEM schools had very selective and competitive admissions (Campbell & McKenna, 2017; Smith et al., 2018). Only 10% of applicants were accepted, and those accepted were mainly White men (Carter & Burgin, 2018). The goal of STEM schools is to provide high-performing students with advanced programs and to contribute research on the best methods of teaching STEM to provide models for other schools (Kasza & Slater, 2017). However, within the last decade, there have been many models for providing members of low-income and minority groups with opportunities to join the STEM workforce (Eisenhart et al., 2015).

Notwithstanding its popularity, the STEM acronym lacks a universal definition (Heil et al., 2013) beyond its four component words—perhaps a fitting occurrence, as the term's origins are equally nebulous in branding and educational priorities. Dr. Ramaley, Assistant Director of the Directorate for Education and

Human Resources at the National Science Foundation, suggested the acronym STEM for science, technology, engineering, and math curriculum (Koonce et al., 2011). This history of the STEM acronym is a reminder that discussions of what constitutes a positive image and process may not solely depend on academic and pedagogical considerations; instead, they could focus on more malleable, publicly accepted brands. Moreover, STEM continues to undergo evolution as a brand, acronym, and educational approach (Xie et al., 2015).

Purpose of STEM Schools

According to Erdogan and Stuessy (2015), the purpose of STEM schools is to provide students with rigorous coursework in mathematics and science to pursue technical careers. Toward the end of the 20th century, decades after the 1957 Sputnik launch, there was increased emphasis on STEM education (Gardner, 1983). Consequently, policymakers implemented statewide and nationwide initiatives to create more science, mathematics, and technology (SMT) schools (Stephens, 1999). Early SMT efforts included creating residential summer programs for gifted students; these later became specialized SMT schools, such as the North Carolina School of Science and Mathematics, created in 1980 (Pfeiffer et al., 2010). Similar initiatives occurred throughout the US (Pfeiffer et al., 2010; Stanley, 1987). In 1988, the National Consortium of Secondary STEM Schools (NCSSS) emerged as a result of the collaboration of several SMT schools to advance STEM education in the US (Olszewski-Kubilius, 2010; Thomas & Williams, 2010). NCSSS provides teachers, students, and communities with resources to succeed in today’s technology-enhanced society. Presently, the consortium offers services for 100 schools with about 40,000 students, and there are 1,600 teachers and educators actively working with colleges, universities, foundations, and companies to transform STEM education in the US (NCSSS, 2017).

Carmichael (2017) analyzed STEM education policies in K–12 schools and found that many individuals embraced STEM education in the US. Research on STEM schools from the last 10 years has shown community stakeholders' concerns about the ability of schools to provide for the demands for more STEM-literate individuals for the American workforce (National Academies of Sciences, Engineering, and Medicine, 2016; U.S. Department of Commerce, 2011). Policymakers and researchers have different opinions about how to improve the quality of the workforce by increasing the number and quality of STEM schools (LaForce et al., 2017).

Carmichael (2017) explored the models used in 50 states to define STEM education policies. The models consist of (a) a disciplinary approach in which educators teach each STEM discipline independently or use an integrated disciplinary approach to combine and teach STEM disciplines to promote critical thinking, (b) use of both independent and integrated models, and (c) no use of a specific model when defining STEM education. The study found that only 10% of schools had a disciplinary approach, and 42% had an integrated approach. In comparison, 30% of schools had both integrated and disciplinary models, and 18% did not have any definition in their policies (Carmichael, 2017). Carmichael (2017) found that 78% of the schools presented STEM education in alignment with the workforce, 68% suggested that STEM education was open to multiple populations, 56% indicated that STEM education should include minority groups, 30% presented STEM education as career and technical education, and 18% had after-school programs as their sources for STEM education. Only 16% of the schools provided advanced placement courses for improving STEM education.

Texas officials started a STEM program in 2005 through an executive order (Texas Executive Order No. RP53, 2005), authorizing funds to prepare students for college and careers. The state has partnerships with universities, corporations, and foundations for the Texas STEM (T-STEM) initiative. Texas has 70 T-STEM programs that provide services to more than 40,000 students throughout the state (Texas Education Agency, 2016). T-STEM schools focus on advancing instruction in secondary schools to increase student performance in STEM fields. The overall goal is to attract more students to STEM studies and careers by incorporating innovative technology and engineering into mathematics and science teaching (Texas Education Agency, 2016).

Educators at TSTEM schools have a STEM blueprint that they can use for implementation and as an observation instrument (Texas Blueprints, 2021). Written in 2005 and updated in 2008 and 2010, T-STEM contains rubrics and glossaries. The rubrics are means of self-assessment for T–STEM schools and include a growth system with four stages: developing, implementing, mature, and role model (Texas Blueprints, 2021; Texas Education Agency, 2016).

Many economic and political factors have contributed to the development of STEM schools (Thomas & Williams, 2010). STEM schools have received attention in the US over the last decade due to growing competition in the global market and advancing STEM education in other nations (Duran et al., 2013; McClure et al., 2017). Therefore, many citizens have called to improve STEM education in the US to provide the next generation of workers with the STEM skills to improve their job prospects and become more competitive (Eisenhart et al., 2015). Specialized schools, referred to as STEM schools, provide interventions to raise students' STEM performances, improve their global competitiveness, and prepare them for 21st-century jobs (Kasza & Slater, 2017; Oner & Capraro, 2016). As a result, the number of STEM schools in the US is increasing.

According to Tofel-Grehl and Callahan (2014), the US has about 358 STEM schools within K–12 education. However, there is little research on the implementation, organization, and function of these schools (Scott, 2012). There are many gaps in the literature on the impact of STEM schools on improving STEM education and their outcomes (Hansen, 2013; Oner & Capraro, 2016; Tofel-Grehl & Callahan, 2014; Wiswall et al., 2014). The purpose of this study was to determine the strategies and practices used by the school personnel responsible for increasing student science proficiency at certified STEM schools in urban settings in Georgia.

A prominent STEM research initiative funded by the National Science Foundation is a 2014 report on STEM integration by the National Academy of Engineering and the National Research Council (NRC), a public advisory body in science and technology. The reports' authors failed to establish a consensus about the definition of STEM, but they did find common ground in a framework for STEM stakeholders. The frame is a useful way "to identify, describe, and investigate specific integrated STEM initiatives in the US K–12 education system" (National Institute of Standards and Technology, 2014, p. 31). The conceptual framework, a high-level analytical tool for the examination of STEM programs, has four interdependent features: STEM goals for elementary students, STEM outcomes for elementary students, the nature and scope of STEM integration, and STEM implementation.

The "ability to make connections among STEM disciplines" (National Institute of Standards and Technology, 2014, p. 32) is a variable included in the goals of elementary and general students. This variable, with its focus on the dynamic connection between STEM subjects, is a relevant component to the integrated STEM education or STEM approach that contrasts with the siloed, weighted, or cross-disciplinary approaches discussed. The integrated STEM approach is a way to prepare learners to push past interdisciplinarity into the transdisciplinary problem-solving distinct to STEM. In a report on K–8 STEM education, the NRC (2014) suggested a transdisciplinary approach characterized by learning experiences transcendent of the formal classroom by integrating informal and after-school educational sectors.

Many approaches to STEM integration are referenced in the literature, but existing research provides minimal evidence of the superiority of integrated STEM approaches over instruction focused on individual STEM disciplines (NRC, 2014; Collins & Jones Roberson, 2020). There is a need for more empirical studies, and STEM researchers may want to examine how to define and measure outcomes (Collins & Jones Roberson, 2020).

Advances in information technology and computing have resulted in incorporating innovative practices into the classroom (Carmichael, 2017; LaForce et al., 2017). As of 2013, many American leaders have adopted the Next Generation Science Standards (NGSS), which includes engineering (Carmichael, 2017). Adding engineering to NGSS provides a systems approach to learning and teaching that includes problem-solving, modeling, and design-processing skills (Cowen, 2013). Furthermore, research indicates that economic and political conditions have resulted in more focus on STEM disciplines; such conditions are also the drivers of educational policies in STEM education (Carmichael, 2017; LaForce et al., 2017). Members of various educational policymaking and advocacy groups have called for improvements in STEM education in the US by increasing graduation rates in STEM fields (Committee on Science, Technology, Engineering, and Mathematics [CoSTEM], 2016).

According to Carmichael (2017), there is a discrepancy between researchers' findings and the narrative advanced by members of the advocacy groups controlling STEM policies. Research indicates that there is a strong focus on STEM at the high school level, with advanced courses in mathematics and science as graduation requirements (Salzman et al., 2013). Salzman et al. (2013) offered that there are sufficient STEM graduates in the market, and as a result, many STEM graduates end up working in non-STEM-related jobs. Therefore, calling for increasing the number of students graduating in STEM has not been the solution to the STEM workforce shortage.

CoSTEM and NSF are vocal advocates for improving STEM education in the US. In their report, *Charting a Course for Success: America's Strategy for STEM Education*, The Committee on STEM Education (2018) presented the following goals: (a) increase the numbers of STEM degrees, especially for minorities and women; (b) augment the STEM workforce with a focus on underrepresented populations in the STEM workforce, and, (c) advance STEM literacy for all students.

Gender and Ethnicity in STEM

Gaps in gender and ethnicity pervade the STEM workforce (Erdogan & Stuessy, 2015). There is a clear connection between education and careers in the STEM workforce (Knowles, et al, 2018). Research suggests that women, Blacks, and Hispanics earn fewer STEM degrees than men, Whites, and Asians (Mau, 2016). Women represent only a small fraction of the STEM workforce, as White men fill 69% of the STEM jobs; Blacks and Hispanics occupy 5% and 6% of STEM jobs, respectively (National Science Foundation [NSF], 2013). The differences in earned STEM degrees are due to numerous factors, including parental involvement and fewer opportunities for minorities and women to take STEM courses in high school and college, which directly relates to a lack of qualified STEM teachers (Rogers-Chapman, 2014).

Recent studies suggest that closing STEM performance gaps and increasing underrepresented students' interest in STEM fields and careers requires schools to provide exposure and better academic preparation for students in STEM. According to Bottia et al. (2015), many students decide to pursue STEM careers in high school.

Bottia et al. analyzed data from a 2014 high school class in North Carolina. They found that high school STEM experiences and rigorous academic preparation and reinforcement in high school were vital factors in students' decisions to graduate in STEM, especially for young women. Therefore, there is a need to augment exposure to STEM for members of underrepresented populations (Bottia et al., 2015).

Data from the myCollegeOptions (2017) website indicate that of the six million high school students who express interest in STEM fields, 30% want to pursue STEM-related careers. According to the Alliance for Science & Technology Research in America (2017), 43.3% of boys showed interest in pursuing STEM careers compared to 15.8% of girls. STEM in Georgia is making a contribution in decreasing the disparity of STEM education for girls and minorities, with girls making up 58% of students in STEM/STEAM-certified schools and 37% being minority students (stemgeorgia.com). These numbers are significant because they are calculated from the students who attend 216 schools across Georgia.

STEM School Outcomes

Scott (2012) conducted a comparative case study of 10 STEM schools from various states across the US to examine the main design elements of STEM schools. Scott explored the STEM schools' coursework, student population and performance, school visions, academic programs, and admission requirements. The findings are a resource for school district leaders considering implementing a STEM school or program. The questions Scott sought to answer pertained to the characteristics of STEM schools, selection criteria, student populations, and program and graduation requirements. Scott concluded that the STEM schools focused on coursework and

STEM-related electives. Scott also found that students from STEM schools performed better than their peers in traditional schools and completed internship programs and real-world projects as part of their graduation requirements. Additionally, the findings indicated that a considerable number of the students who completed a rigorous STEM program were members of minority groups.

According to Dubin (2014), Hougham et al. (2015), Morrison et al. (2015), and Schachter (2012), students who attend STEM schools are more prepared for careers and perform better in high-stake mathematics, reading, and science assessments than their peers in traditional schools. Also, students who enroll in STEM schools exhibit more interest in learning and pursuing STEM degrees than students in traditional schools (Dubin, 2014; Erdogan & Stuessy, 2015; Hougham et al., 2015; Schachter, 2012). Furthermore, as Erdogan and Stuessy (2015) noted, although underrepresented students from various ethnic backgrounds benefit from attending STEM schools, they might not automatically pursue a STEM college education. However, students who attend STEM schools have more chances of accomplishing their college goals than their counterparts in mainstream schools.

Despite the popularity of STEM schools, there is scant documentation of their implementation, practices, and effectiveness (Tofel-Grehl & Callahan, 2014). The lack of information about STEM implementation in high schools presents a challenge for researchers to further investigate STEM schools. There is a need for a thorough analysis of STEM schools' applications, practices, and features to understand the driving mechanisms of their successes and challenges. It is also necessary to compare STEM schools to traditional schools and to analyze and synthesize their outcomes to evaluate their effectiveness.

Lynch et al. (2013) focused on inclusive STEM schools and STEM education policies and opportunity structures, proposing a framework with design and implementation practices. There is much diversity in STEM school designs; however, Lynch et al. identified 10 shared elements in STEM schools: STEM school curriculum, a reformed teaching approach, innovative technology, a blended learning environment based on formal and informal instruction, early exposure to college-level courses, careful training of STEM teachers, a comprehensive mission, an administrative organization, support for minority students, and community partnerships. Lynch et al. considered the 10 elements critical in designing successful STEM schools focused on helping students master STEM subjects.

Tolliver (2016) conducted a causal-comparative study to examine the effect of STEM education on fifth-grade math and reading standardized assessment scores in a Central Maryland urban school district. Tolliver used a Mann-Whitney U two-sample test to compare the progress of fifth-grade students in two PK–8 schools. One school had a STEM initiative, while the other had a traditional elementary education curriculum. Tolliver used archival 2014 MSA reading and mathematics data of fifth-grade students from the STEM school and the non-STEM school. The MSA data highlighted the effect of STEM education strategies on student achievement, as compared to traditional elementary education strategies in one district. The Mann-Whitney U test showed no significant difference between the math MSA scores between STEM school and non-STEM school students. Tolliver found that the fifth-grade students who received interdisciplinary, project-based STEM education had greater academic achievement in reading than the fifth-grade students who received traditional elementary instruction. However, Tolliver did not find an effect of STEM education on mathematics scores.

The “A” in STEAM represents the arts. Often arts courses, such as architectural design and computer assisted design are included in STEAM programs. Data were collected from 216 STEM/STEAM schools across Georgia in seven years from the 2011-2012 school year until the 2017-2018 school year. Some of the successes of STEM/STEAM schools in Georgia obtained from the stemgeorgia.org website (stemgeorgia, 2021.a) include a steady increase in math proficiency from 2015 to 2016 when STEM/STEAM student data were compared to non-STEM/STEAM student data. The combined data of grades 5 and 8 indicated a 4.0% higher number of math proficient STEM/STEAM students over non-STEM/STEAM students in 2015. In 2016 7.8% more in 2016. In 2017, 5.3% more in 2017, and 7.1% more in 2018.This steady difference led to the conclusion that “when schools transform their learning cultures to STEM or STEAM learning environments by implementing best practices in transdisciplinary teaching and learning, students benefit greatly and student learning increases”. This information was included in a power point presentation titled: Implementation of STEM/STEAM in Georgia shows a “Promising Results”, slide number 2. (stemgeorgia, 2021.a).

Common Learning Goals for STEM Schools

A review of literature revealed three common learning goals for STEM school implementation: problem-solving, soft skills, and collaboration. In STEM schools, there is a focus on providing students with opportunities to use critical-thinking skills in meaningful and engaging curriculum-based instruction (Morrison et al., 2015). According to Olson and Riordan (2012), college leaders want students with both soft and critical thinking skills. Harris and Rogers (2008) described soft skills as sociability, language facility and communication skills, integrity, enthusiasm, and openness to learning. In addition, Tofel-Grehl and Callahan (2014) found four common patterns in six STEM specialized schools: intellectualism, the value of research, inquiry use, and personal responsibility.

Five Models of STEM Schools

The literature revealed five central models of a STEM school implementation: school-within-a-school, pullout, stand-alone, residential, and university-based schools (Tofel-Grehl & Callahan, 2014). A school-within-a-school, also referred to as a cohort, offers specific STEM classes to selected students who remain in the same school as their peers. This provides opportunities for social and educational interactions between students within and outside of their cohorts. In a pullout setting, students attend external STEM schools for STEM courses every day or part of the day, but still take non-STEM classes in their home schools. Stand-alone schools are fully independent institutions similar to traditional schools but focused on teaching STEM courses. In residential schools, students live and learn STEM in the school environment. Residential schools offer unique learning experiences that focus on STEM and relationship building. University-based schools are a collaboration of a school and local university that allows students to enroll in advanced college STEM courses. According to Tofel-Grehl and Callahan (2014), STEM school models do not significantly impact student outcomes.

Successes and Challenges of STEM Implementation

The literature indicates the many successes and challenges in implementing STEM schools. According to Kasza and Slater (2017), addressing the best practices and key learning objectives of successful secondary STEM schools requires a flexible learning framework based on an in-house curriculum developed by teachers with STEM backgrounds. In addition to teacher collaboration and in-house STEM curriculum, a research project-based learning approach is a vital component in engaging students to learn STEM (Honey et al., 2014). Another success factor of STEM schools consists of engaging the community through internships and mentoring programs. Kasza and Slater conducted many interviews with educators from STEM schools in the US and discovered myriad challenges related to scheduling conflicts in larger schools and difficulties in creating a cohort approach to teaching STEM.

Administrator and Teacher Perceptions of STEM Implementation

Tofel-Grehl and Callahan (2014) investigated the experiences of administrators, teachers, and students in six STEM schools to study the shared and divergent features of STEM high school communities. In the study, administrators from the six schools expressed a similar belief about their roles in creating academically focused school cultures focused on providing students the skills they needed to become problem-solvers and great communicators. According to Tofel-Grehl and Callahan, the administrators articulated the importance of research experiences in preparing students for real-life expectations and challenges in STEM studies and careers. The participating administrators suggested that the ability to conduct research and learn from real-world applications differentiates STEM schools from non-STEM schools. The administrators also noted teachers' experiences in STEM research, in addition to degrees in the content areas and experience with lab experimentation, as essential and a decisive factor for recruitment. Moreover, administrators emphasized the roles they played in shaping school culture and in creating supportive learning environments.

Turner (2013) examined the perceptions of STEM education in K–8 educators in Tennessee. Perceived needs, implementation practices, access to STEM resources, STEM definitions, and STEM conditions also underwent examination. Administrators and teachers in elementary and middle school settings completed surveys. The closed- and open-form survey consisted of 20 research items grouped by five core research questions. The quantitative data underwent analysis using single-sample *t* tests. A 4-point Likert scale was the means used to measure responses with a 2.5-point neutrality rating. Turner summarized the open-ended questions and recorded them for frequency.

Turner (2013) found that the Northeast Tennessee K–8 educators perceived a significant need for STEM education. However, many of the educators did not feel prepared for implementation, and they reported the lack of professional development opportunities and STEM assets as areas of need. The teachers reported the implementation of inquiry-based problem-solving activities in their classrooms. Most of the participants shared that the STEM education in Northeast Tennessee did not provide for the needs of 21st-century learners. They described the challenges of STEM instruction as insufficient funding, insufficient professional development for STEM teachers, and lacking or inadequate STEM education in K–8 schools.

Owens (2014) conducted a descriptive case study with a sample of 12 elementary teachers purposefully selected from a pool of K–5 teachers at two schools in North Carolina. The primary research questions focused on the teachers' perceptions of STEM education, their competencies, and professional development. The data collection consisted of interviews, document analysis, and field notes. Owens analyzed the data using the qualitative method. The study's findings suggested that (a) teachers have different perceptions of STEM education based on experience; (b) most teachers lack confidence in their knowledge and abilities to effectively integrate STEM; (c) teachers feel the need for STEM hands-on training and professional development; and (d) teachers lack the time, leadership, and guidance to integrate STEM effectively. Owens recommended that skilled STEM leaders drive curriculum development and teacher preparation for STEM programs.

Hernandez (2014) studied STEM implementation to improve instructional practices, providing quality STEM instruction to students and increasing teacher self-efficacy (i.e., a teacher's perception of personal ability to instruct students in STEM disciplines). The study addressed the history of low student math and science achievement scores at the research site. The study had one overarching question: "How does the implementation of a STEM learning team increase teacher self-efficacy?" The results indicated that elementary learning teams can have a positive impact on teacher self-efficacy. Hernandez also found positive outcomes for participants regarding self-efficacy. Participants collaborated as a structured group to improve their instructional performance and student performance and indicated that ongoing meetings may assist with further learning of elementary STEM education.

Icel (2018) explored the integration of NGSS and Project Lead the Way (PLTW) policies to identify the qualities involved in their implementation using Fullan's (2012) change theory as the theoretical lens for the exploration. Icel reviewed teacher lesson plans, standardized test scores and monthly activity logs and found that successful implementation of the STEM policies was heavily dependent on "staff motivation, administrative support, professional development, and team lesson planning (pg. 7)."

Summary

This literature review focused on the history, prospects, and policies of STEM schools, the genders and ethnicities in STEM education, and the status of STEM schools in Georgia and in the US. The literature review also addressed the implementation and design principles of STEM schools, their outcomes, learning objectives, and models. The research indicates that STEM education is an effective way to enhance student outcomes and achievements (Honey et al., 2014; Olson & Riordan, 2012). There are increasing numbers of STEM schools in the US and ongoing efforts to provide students with more exposure to STEM in K–12 education. However, little research exists on how to best implement STEM schools and the successes and challenges of these schools. There is a need to examine the functions of STEM schools and their achievements and challenges to better understand the practices of implementing STEM schools in Georgia. Such research on STEM school implementation may be an essential part of developing an implementation framework that provides school districts with the information they need to guide such an effort.

This case study contributed to the existing literature by indicating the best practices of STEM implementation in elementary schools in Georgia and their successes and challenges by focusing on two certified STEM elementary schools in Georgia. School administrators may use the results of this study and the implementation framework to identify the best practices in implementing STEM programs in schools. This framework may be a driving force in creating more STEM schools, achieving the state's goal of providing more students with schooling options, and shrinking the performance gap among students. Furthermore, this study's findings contribute to the existing literature and fill gaps in the research by providing new knowledge about STEM school development.

Chapter III METHODOLOGY

Introduction

Over the past decade, less than 20% of 12th-grade students in Georgia had proficient knowledge of science concepts (GOSA, 2021). The lack of proficiency presents high school students with difficulties competing for high-paying jobs in a global economy driven by innovations in science and technology. Innovative thinking is an essential component of STEM programs. The NCES (2011) indicated the need for plentiful STEM careers yet indicated that there are not enough individuals with the foundational and cognitive skills needed to carry out the duties required by STEM careers.

The lack of science proficiency has an underlying impact on national security (Obama, 2009). President Obama (2009) stated the need for a solid STEM workforce for economic stability in the US in the 21st century. NAEP (2019), better known as The Nation's Report Card, has a wealth of statistical data that indicates a stalled student proficiency in science. A Report titled: Results from the 2019 Science Assessment at grades 4, 8, and 12 (pg, 1) reveals 41% of twelfth graders scoring below the NAEP basic level in 2019 along with 27% of fourth graders and 33% of eighth graders. The trend for the past decade has shown student proficiency in science decreasing with age. The source of this information is: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), and various years, 2009–2019 Science

Assessments. There is a need to address this inverse relationship as early as possible in the educational process in order to reverse these trends.

The purpose of this study was to determine the strategies and practices used by school personnel responsible for increasing student science proficiency at certified STEM schools in urban settings in Georgia. The conceptual frameworks used to design the questions in the interview protocol were Fullan's (2001, 2006) model of change and the CBAM (Hall & Hord, 2001, 2006). The rich, lived experiences of STEM-focused school leaders provided insight into the characteristics and practices relevant to the success of the STEM programs in these unique schools (Bruce-Davis et al., 2014).

The implementation of specialized STEM programs is a potential means of supplying more students with exposure to STEM skills and content to the STEM career pipeline (Erdogan & Stuessy, 2015). Despite the fact that there are more STEM-focused schools developed each year, there is not enough information about the instructional and institutional practices of these schools to provide a clear understanding of their effective qualities (Tofel-Grehl, 2013).

Chapter III is comprised of 12 sections, beginning with the research questions used to guide the study. The methodology section includes the research design and rationale for embarking on this project, the relevance and attributes of the chosen setting, and the researcher's role in the study. Other significant components of the approach include the participant selection criteria, the instrumentation used for data collection, the data analysis methods, and the data collection and analysis procedures.

The chapter also presents reliability testing, issues of trustworthiness, ethical procedures, and a summary before transitioning to Chapter IV.

Research Questions

The researcher applied the following research questions to guide this study:

RQ1: What are the lived and career experiences of school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ2: What strategies were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ3: What practices were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

Research Design and Rationale

There is a lack of access to STEM subjects for minorities and students from low socioeconomic backgrounds (Nasir & Vakil, 2017). Few certified STEM schools demonstrated increased student proficiency in science (stemgeorgia, 2020). In Georgia, there are fewer STEM schools in urban settings ($n = 3$) than the overall number across the state ($N = 76$), which averages 4%. The focus on urban settings may present successful strategies and practices for teaching minorities and students of low socioeconomic status, leading more leaders in urban settings to take on the challenge of implementing STEM programs.

Qualitative research was the method used for this study. The goal of qualitative research is to gain an in-depth understanding of a particular event or interaction (Locke et al., 1987), which in this study was STEM program strategies, practices, and lived and career experiences. Qualitative research has "the greatest promise of making a difference in people's lives" (Merriam & Tisdell, 2016, p. 1) because it provides a direct perspective of the individual under study and a rich amount of discovery. Qualitative research is the method of choice for enhancing the practices of the individuals who deal directly with the lives and well-being of individual clients. The school personnel at STEM-focused elementary schools in urban settings matches this description due to their close associations with students. Having equitable and successful STEM program participation in urban communities is an enhancement pursued by policymakers on the local, state, and national levels.

A qualitative research method, based on a constructivist philosophical worldview was an appropriate approach for this study because it focuses on understanding a research phenomenon with multiple participants while considering the social and historical aspects (Creswell, 2014). Constructivists believe "individuals seek understanding of the world in which they live and work" (Creswell, 2014, p. 1). Inductive analysis (Patton, 2015) was the approach used to construct the meaning of the research data and to better understand the methods utilized to develop the STEM programs at the schools under study. According to Crotty (1998), this process often includes the use of the inductive process to capture a picture of what has happened and what the participants thought about the events based on their lived experiences.

A researcher seeking to better understand the meaning of a phenomenon from the viewpoint of a participant (Merriam, 2002) may conduct a case study. Merriam (2002) described a case as a single unit or instance. The case study design was appropriate for this study because it enabled the construction of a detailed description of the setting and the individuals related to the phenomenon, followed by an analysis of the data used to identify themes (Stake, 1995; Wolcott, 1994).

This case study commenced with interviews to better understand the meaning that the school personnel made of the process, strategies, and practices used during the STEM program implementation process. Several semi-structured, in-depth interviews with open-ended questions were held with leaders from two different public elementary schools that underwent a schoolwide STEM program implementation and who observed increased student science proficiency based on fifth-grade end-of-grade (EOG) test scores. The fifth grade EOG results were the scores used because fifth-grade students take the science test in elementary school (GADOE, 2020). College and Career Readiness Performance Index (CCRPI) scores were also indicators of the schools' demographics (The Governor's Office of Student Achievement, 2020). The use of rich, thick description received from the participants in response to the open-ended interview questions added to the validity of the study, as each participant shared similar responses.

Case studies consist of cataloging and classifying the components involved in the process under study (see Miles & Huberman, 1984). For this research, the case study design provided the opportunity to identify participant perceptions that may have influenced their actions during the STEM program implementation in their schools. Observations of two specific cases of STEM implementation at urban elementary schools were bound by the time frame of the implementation and sustainment process. The implementation process spanned from the decision to implement the program to the certification obtained and beyond. The sustainment period began at the time of the saturation of the STEM education program throughout the school. Data collected from both schools under study reached saturation with the three participants.

The websites of each school underwent a thorough review because they provided extensive documentation. The website included schedules and pictures of events and minutes for meetings throughout the progression of the implementation process. Documents can be used to substantiate the actions of participants and support the information obtained during case study interviews (Yin, 2009). These documents served as additional data sources used for triangulation. The study's findings may be useful for future STEM program development for elementary schools in urban settings because, as noted by Nasir and Vakil (2017), the members of this population receive insufficient STEM exposure.

Verification of validity is necessary in qualitative research due to the subjective information and the use of the researcher as the primary interview instrument (Merriam & Tisdell, 2016). Creswell (2014) recommended multiple approaches to "enhance the researcher's ability to assess the accuracy of findings as well as convince readers of that accuracy" (p. 201). A check for accuracy of findings in a study is necessary to ensure the credibility of the results (Creswell, 2014). I used member checking after each set of interviews. Each participant received a copy of the participant introduction developed by the researcher. Participants were directed to make any corrections or additions necessary. The peer review process was incorporated to provide me with a different lens through which to view the results and analyze the data. This method proved to be extremely beneficial due to the level of knowledge of my professional peers.

Reliability is synonymous with consistency or stability to provide enough information with which someone can conduct a similar study using the same steps (Cresswell, 2014). Closely documenting specific steps taken throughout a research study allows generalization of the findings to similar populations. This characteristic is one of the major differences between qualitative and quantitative research. The detail provided related to the single case addressed one of this qualitative study's limitations (Yin, 2009).

Setting

The initial plan was to conduct the interviews in the employees' natural setting (at work), as it may provide comfort, being the site where the participants experienced the phenomenon under study (see Creswell, 2014). However, the COVID-19 pandemic began two months before the interviews; thus, the interviews occurred via telephone with a speakerphone used for audio recordings. Therefore, the participants engaged in the interviews from random locations of their choice. Table 1 outlines the participants' school demographics.

Table 1

STEM Schools Demographic Information

Demographics	School (pseudonym)	
	Mae Jemison (School 1)	Katherine Johnson (School 2)
Participants	Myrtle, Willow, and Aster	Rose, Lily, and Iris
Grade levels	K-5	K-5
Year STEM certified	Cognia certified 2018/2019	GADOE STEM-2017; STEAM 2019; Cognia STEM 2018/2019
Title I	Yes	Yes
Student enrollment	350	550
% free or reduced lunch	100%	100%
Mode of transportation	Walkers, car riders, bus riders	Walkers, car riders, bus riders
Enrollment criteria	None	None

Purposefully selected participants from two elementary STEM-certified schools participated in this study based on professional references, the assessment data obtained through the GADOE website, school locations in urban settings, and the principals' willingness to allow interview access to the participants. The urban schools were in one of the top 10 largest school districts in Georgia. The area around the schools had the highest concentration of businesses in the state, which was a key reason for the schools' successful certification by the GADOE STEM coordinator (F. Cullars, personal communication, July 6, 2020). Business and community partnerships are critical success criteria for STEM certification and are a requirement for STEM certification. The criteria for partnerships is listed in the Georgia STEM/STEAM Partnership guide (p. 1 and 2) located on the stemgeorgia.org website.

The two participating schools had similar characteristics, such as urban locations, 100% of students receiving free or reduced lunch, and socioeconomically disadvantaged students (GOSA, 2020). The schools also had similar attendance, with around 50% of the students absent five or fewer days, 35% absent between six and 15 days, and around 10% absent more than 15 days (GOSA, 2020). The two schools had an average enrollment of 420 and 650 students, respectively. There was a lack of cultural diversity in both schools, with over 90% Black students. Each of the selected schools experienced progress in becoming high-achieving schools due to the implementation of their certified STEM programs. The school with the fewest students showed the highest gains in science proficiency.

Role of the Researcher

A researcher is a key instrument in a study and serves as an observer and participant (Creswell, 2014). As such, I immersed myself in the setting of the study to make better sense of the participants' perceptions and meanings (see Marshall & Rossman, 1989). I have served as a science instructor in Georgia and three other states for over 25 years, so STEM education is part of my daily life. Transitioning to administration at a STEM-rich school is a significant component in my career plans, so I highly respected the principals and employees interviewed in this study. My respect may have positively impacted the participants' transparency in answering the interview questions; however, it may have also caused bias, as the interviewees may have wanted to share positive rather than negative experiences. One ethical issue was my extremely positive demeanor toward STEM education. Member checking (Creswell, 2014) was applied to ensure accurate interpretations of the participants' answers to the interview questions.

Participant Selection

Purposeful selection was appropriate to recruit principals from qualifying schools in an urban area in Georgia. A list of STEM-certified schools in Georgia over the past 10 years allowed me to identify potential schools. The schools' fifth-grade science EOG scores underwent analysis for score increases during the three years before STEM certification, a phase that included implementing the program. A final criterion for school selection was that the schools had to be in an urban area. Only two schools had all of the qualities outlined in the selection criteria.

A mutual colleague introduced the study to the two selected principals. After informing me of their interest in participating in the study, the principals received formal invitations to participate via email and a follow-up telephone call. The principals agreed to participate by providing formal acceptance emails. Using the snowball effect, each principal was asked to recommend two other individuals who had direct contact with students from their schools. The recommended participants were instrumental in planning and implementing the certified STEM programs. All six invitees agreed to participate and scheduled their virtual interviews.

Instrumentation

The instrument used to collect data for this study was an interview protocol (see Appendix C). I conducted interviews via speaker telephone and recorded the audio on an iPad. I saved the audio recordings as MP4 files and uploaded them to Rev.com for transcription immediately after each conversation. Field notes occurred before, during, and after the interviews to record observations. In addition, document searches were means to obtain information from websites, meeting agendas, videos, and email communications.

Open-ended interview questions were appropriate to elicit detailed responses to answer the research questions within the timeframe provided by the school district. The conceptual framework served as a foundation for the development of the interview questions. The interview protocol included the research questions, interview questions, and conceptual framework components (see Appendix C). The interviews and the member checking process included follow-up questions to promote deeper, richer responses when necessary.

Procedures for Recruitment

Purposeful selection was the means to obtain the participants in this study. The goal was to find up to six school leaders involved in successfully implementing STEM programs in public urban elementary schools in Georgia. I identified the schools based on their receipt of STEM program certification through GADOE (see Appendix G) or AdvancED within the last 10 years. The STEM programs were required to have been in place for at least three years and to have shown an increase in science proficiency based on EOG assessment data. The two principals from the qualifying schools agreed to participate in the research via email. A second email was sent to each principal asking them to identify two personnel from their schools instrumental in STEM program planning and development.

The additional participants were sent an invitation to participate in the study via email. Once the participants agreed to participate, a follow-up email was sent to request a preferred date and time for the interview and a phone number for each participant. The interviews were conducted via phone due to the COVID-19 pandemic.

Data Collection

All data collection occurred at the interview virtual site via the participant's cell phone or landline. Virtual sites took the place of a face-to-face interview due to the COVID-19 pandemic. I used the voice recorder on an iPad to capture the participants' responses. Each participant in the study engaged in an audio-recorded interview. The researcher used a three-part interview protocol that required approximately 90 minutes to complete. The three parts of the interview protocol included the three research questions, the conceptual frameworks, and the interview questions relating to each (see Appendix C). The document review included pictures, websites, emails, and field notes. The study had a timeframe bound by the activities performed during the planning stages and the three years before the STEM certification process. According to Stake (1995) and Yin (2009, 2012), a researcher has cases bound by time and activity and must collect detailed information with a variety of data collection procedures over a sustained period.

The audio-recorded interviews were immediately saved as MP4 files and uploaded to Rev.com for professional transcription of the interview for analysis. I made observation notes of the documents used during the implementation process. The intent of the interviews was to collect information in order to assign labels (coding) and organize them to form themes.

Data Analysis

I printed the interview transcripts produced by Rev.com, hand coding them by bracketing chunks of text or images and writing words (codes) in the margins. The purpose of hand coding is to identify connecting themes with terms based on the actual language (in vivo terms) used by the participants (Rallis & Rossman, 2012). Data analysis included organizing the data from transcripts using the NVivo data analysis software purchased online. NVivo Version 12 data analysis software (QSR International, 2015) was the tool used to organize the text from interviews relative to the common themes developed during coding. The goal of qualitative research is to organize data into five to seven themes (Creswell, 2014). The handwritten field notes were subject to coding and observation for common themes. The data were assigned labels based on the source of the data via the coding process. All coded data eventually connected to one of the four identified themes with the inductive method. Interpretation occurred for the themes or patterns that emerged from the data (Creswell, 2014). After interpretation, the deductive method was the means used to work backward from the themes to the coded text for cross-referencing. Data saturation (Glaser & Strauss, 1967) occurred rapidly among the participants from the same school and between the participants of the two different schools to capture common teaching methods.

Issues of Trustworthiness

A check for accuracy of the findings throughout this study was necessary to ensure the credibility of the results, which Creswell (2014) considered qualitative validity. Verification of validity is necessary in qualitative research due to the subjective information and the use of the researcher as the primary interview instrument (Merriam & Tisdell, 2016). Creswell recommended multiple approaches to "enhance the researcher's ability to assess the accuracy of findings as well as convince readers of that accuracy" (p. 201). The researcher employed triangulation to strengthen the validity of the study by using different sources of data to justify the themes. The six participants provided data, responding to the same open-ended questions through the semi-structured interview protocol (Merriam & Tisdell, 2016). Additional data sources were the school websites and memos developed throughout the study.

I knew that my positive perception of STEM education may skew my ability to remain objective. The participants seemed comfortable sharing information with me, as I was a fellow STEM educator seeking to support the development of more STEM programs. They were respected experts who perceived me as a qualified researcher with a quest to share their knowledge to help others achieve similar success in the STEM implementation process. At times during the interviews, I reminded some of the participants of my responsibility for confidentiality as they expressed concerns about sharing too much. This fear likely added to the study's limitations.

Member checking occurred after the interviews. Each participant was sent a copy of the participant introduction developed by the researcher. Participants were able to make any corrections or additions needed. The use of rich, thick description received from the participants in response to the open-ended interview questions added to the validity of the study, as each participant shared similar responses. Audio recording the interviews allowed me to review the conversation multiple times in order to capture the abundant amount of information and to begin to identify common themes. There was no external auditor used because the participants verified the accuracy of words and themes.

A professional peer and recent doctoral graduate provided many useful comments and asked probing questions to steer me in the direction of deep discovery through peer debriefing. This process is a method for validating accurate results (Creswell, 2014). The peer review provided me with a different lens to view the results and analyze the data. This method proved to be extremely beneficial and was due in large part to the extensive knowledge of my professional peer.

Qualitative reliability involves consistent approaches across different projects (Creswell, 2014). In this study, all participants received consistent approaches and interview questions. Clear and thorough documentation of the methods and steps taken to conduct research added to the reliability of this study. Audio recordings of the conversations and their immediate review ensure accurate documentation of the interview (Creswell, 2014). A professional transcription service, Rev.com, transcribed the audio recordings. Constant comparison of interview audio and transcripts helped the researcher maintain a consistent interpretation of the themes and ensure a clear definition of what the themes represented. Closely documenting specific steps taken throughout a research study may provide generalization of the findings to similar populations (Cresswell, 2014). This characteristic is one of the major differences between qualitative and quantitative research. The detail provided related to the single case addressed one of this qualitative study's limitations (Yin, 2009). Responses by participants from the same school, as well as those from different schools, were similar throughout the study. This information may be useful to create an informed starting point for a STEM program implementation process.

Ethical Procedures

Several different methods were utilized by the researcher as means to ensure that ethical practices were applied to protect the welfare of participants in this study (Cresswell, 2014). The Valdosta State University Institutional Review Board (IRB) granted approval for the study (see Appendix D). The researcher completed the Collaborative Institutional Training Initiative (CITI) Program which was a requirement for IRB approval. Evidence of the successful completion of this program is the CITI certificate (see Appendix E). The participating school district provided permission to the researcher with limitations on the times when participants could be interviewed (see Appendix A). Principals at the school where the participants worked provided permission via email to interview their personnel. The participants had the consent form read to them before the interviews to inform them of the study and to ensure that they knew they could withdraw at any time (see Appendix B). There were no ethical concerns related to recruitment materials or data collection activities. The participants, schools, and school districts chosen remained anonymous, with pseudonyms used to protect their identity for reference in this study.

Limitations

According to Merriam and Tisdell (2016), qualitative research is the method of choice for enhancing the practices of the individuals who deal directly with the lives and well-being of clients. A focus on the perspectives of the leaders of STEM-focused elementary schools required the participants to answer probing and open-ended questions. One limitation of this study was that it included only six school leaders of public urban elementary schools in Georgia because only two schools in the state met the inclusion criteria. Data saturation occurred with only three participants from each school. The small sample size may present readers with a limited ability to generalize the results to their situation.

Time was a limitation due to the period needed to conduct a study that would produce in-depth knowledge of the school leaders' perceptions. The study did not include all of the strategies and practices of STEM schools use due to the limited time; however, it provides an opportunity for a justifiable follow-up project with the schools that showed the most improvement. The criteria of elementary schools in an urban school district produced a limited number of schools with the required qualities. The location also resulted in the limited generalizability of the study. The school leaders were the only employees interviewed, and bias occurred due to their intimate relationships with the project and their students. Positive personal experiences and knowledge about STEM education influenced the interpretation of the data (see Maxwell, 2013).

Verifying the information collected through the interviews had limitations. The analysis process is often labor-intensive and consists of categorizing and coding (Merriam & Tisdell, 2016). Data triangulation was a means to provide internal validity and credibility of the information collected during this study through a careful look at multiple data collected from the interviews, document reviews, and observations made. Data triangulation is a method to ensure trustworthiness. Member checking occurred throughout the study (Merriam & Tisdell, 2016). Maxwell (2013) regarded member checking as the best way of ensuring the alignment of the interviewee and interviewer's meaning of the information.

Summary

My goal as the researcher was to conduct a qualitative study framed by Fullan's (2012) model of change to identify the strategies and practices used by the school leaders responsible for successfully increasing science proficiency at certified STEM schools.

The CBAM, developed by Hall and Hord in 2001, was the conceptual framework used to explore the elementary school leaders' perceptions of the implementation of STEM programs. The study settings were urban STEM-focused elementary schools in Georgia, where the leaders shared responsibility for successfully increasing student science proficiency. The participating institutions were outstanding STEM-certified schools because they had increased numbers of students reaching science proficiency based on the Science EOG assessment data for three years before STEM certification.

Qualitative studies enable the development of categories into patterns or generalizations with varied endpoints and the comparison of the patterns and generalizations to a researcher's personal experiences and the existing literature of the topic (Creswell, 2014). The perceptions of the leaders in this study may provide insights for others preparing for the STEM implementation process. The strategies and practices used during the implementation process may give school leaders a comprehensive set of tools for future STEM program development.

Chapter IV BACKGROUND OF PARTICIPANTS

Introduction

During his address to attendees at the 146th Annual Meeting of the National Academy of Sciences in 2009, President Barack Obama offered a challenge to leaders in educational institutions to increase STEM education in America (Obama, 2009). The meeting focused on the need for a STEM-saturated workforce equipped to meet the needs of the American. economy in the 21st century. GADOE officials accepted President Obama's challenge by constructing a framework for schools to earn STEM certification for more students to experience an education focused on creativity and innovative thinking. School leaders began making the changes needed to receive STEM certification.

During the 2011–2012 school year, Georgia schools began receiving STEM certification, with more STEM-certified schools added to the list each year. This movement has resulted in 76 STEM-certified schools in Georgia since 2012 (stemgeorgia.com, 2012). Dekalb County School District has been a state leader, with the most STEM-certified schools. The GADOE provides a rubric for the criteria required for STEM certification. As of February 1, 2020, the actual number of schools in Georgia in the process of earning STEM or STEAM certification was 43 elementary schools, 16 middle schools, and 17 high schools (N = 76). The Cognia K-12 STEM Certification Network is an international organization that has provided certification for 39 elementary schools, nine middle schools, and seven high schools in Georgia (N

= 55). Based on the information obtained from the GADOE website, Georgia has more than 2,200 STEM- or STEAM-certified schools.

This research was part of a journey to identify the strategies and practices used to help students obtain and retain STEM knowledge at two elementary schools in an urban setting in Georgia. Data from interviews, memos, and document reviews allowed me to develop a narrative of school personnel involved in STEM program development and implementation. This case study occurred in May 2020 during the COVID-19 pandemic; therefore, data collection consisted of audio recording interviews on an iPad from a mobile telephone speaker. Several reviews of the schools' printed information on their websites, and media coverage, provided the opportunity to better understand student faculty interactions and the STEM-rich ambiance of each school. This chapter presents narratives of the individuals who led STEM program development, implementation, certification, and sustainment in two elementary schools in Georgia.

Background

Purposeful selection was the means to identify two STEM-certified elementary schools in urban settings in Georgia. The students at the two schools showed increased science proficiency since the implementation of the STEM programs. Each participating school received STEM certification from either GADOE, AdvancEd (now Cognia), or both. The certification processes have in-depth and broad arrays of indicators (see Appendix F) for reviewing STEM programs during the certification process. After receiving approval from the schools' principals, I used snowball sampling, asking the principals to recommend two other individuals at their schools who were instrumental in developing the program and directly working with the students. Each principal recommended individuals who enthusiastically agreed to participate. Careful crafting of the individual participant narratives commenced to introduce the participants. Critical analysis of the participants' key characteristics allowed me to make sense of their actions and behaviors pertaining to the phenomenon under investigation. Systematic data collection was applied to gather information on the participants' backgrounds and educational journeys, their perceptions of STEM education in urban settings, their direct involvement in STEM program development, and school cultures. The rich data indicated the key components in the development and sustainability of the STEM programs.

Table 2 provides an overview of the participants' demographic information. The participants received pseudonyms to protect their identities in compliance with Valdosta State University's Institutional Review Board regulations regarding research. Various plants found in the schools' gardens were the inspiration for the pseudonyms, as plants tend to have feminine names, and all six participants were women.

Table 2

Demographic Characteristics of Participants

Pseudonym	Gender	Ethnic group	Years in education	Education	Age range	When decided to teach
Myrtle	F	AA	19	Ph.D.	40-45	In college
Willow	F	AA	7	Master’s	30-35	8–9 years old
Aster	F	AA	18	Master’s	40-45	Elementary school
Rose	F	AA	31	Doctorate	60-65	5–6 years old
Lily	F	CA	8	Specialist	35–40	10 years deep into retail work
Iris	F	AA	29	Master’s	55–60	Late 1980s

Narrative Profiles

Myrtle

Referred to me by a study partner, Dr. Myrtle was a young professional who expressed such dedication and care toward her students throughout her interview that she received the pseudonym of myrtle, as it is a flower thought to inspire lasting love. Teaching was not originally Dr. Myrtle’s career goal. She entered college as a sports medicine major, but the growing intensity of science-related coursework caused Dr. Myrtle to reevaluate. Luckily for her, she was surrounded by individuals who had built careers in education. She attributed the attraction of becoming a teacher to the fact that her mother, grandmother, aunt, and other family members were educators and strong, successful, well-rounded role models. Dr. Myrtle was determined not to lose her academic scholarship and chose to pursue education. She enthusiastically explained this fruitful decision:

> Once, I did a practicum in elementary school, [and] I said, "This is where I belong. This is my niche." So, I finally found something that really made me happy and that I was successful at doing. So, what I was trying to run away from ended up being exactly what I ended up doing.

After a December graduation, Dr. Myrtle began full-time employment at the school where she gained student teaching experience. She shared her knowledge and passion for teaching with her students and continued the trajectory of her career for the next three years in her hometown.

Dr. Myrtle accepted a teaching assignment at another local school where she had the opportunity to receive guidance from one of her former elementary school teachers who was now the school principal. This mentorship prepared Dr. Myrtle to become a strong leader, as her principal entrusted her to fill numerous teaching and leadership positions. Dr. Myrtle was not only a fourth-grade teacher but also a reading coach and curriculum specialist during her time at this school. Her additional supporting experience included a leadership support specialist position in the central office, where she assisted with supervising teachers in the absence of a substantive assistant principal in small schools in her district. She later became an assistant principal, then principal; the 2020–2021 school year was her fifth year as a principal.

Perhaps it was Principal Myrtle's original college interest that led her to focus on a STEM pathway. Her initial interest in sports medicine and biology did not disappear when she redirected her career focus to education; it contributed to her decisions as a leader. Every principal must have dedicated staff to make a vision a reality. A teacher at

Dr. Myrtle's school applied for and received a 21st Century Community Learning Centers (21st CCLC) grant, which provided $350,000 annually for 5 consecutive years for the progression of STEM curriculum. The 21st CCLC is a federal grant authorized under Title IV, Part B of the Elementary and Secondary Education, amended as ESSA. The program's purpose is to support academic achievement activities during non-school hours, such as before school, after school, and during summer break. The funding provided the opportunity to increase student exposure to STEM coursework from periodic activities to long-term dedicated lesson plans. The funding also enabled afterschool and summer school experiences for teachers and students. Dr. Myrtle expressed her confidence that students benefit the most from hands-on STEM teaching and it allows them to see learning and real-life application, real-world experiences, and to make connections to the content. She explained:

> They see what we're doing in math will help us in science, what we're going in science will help us in English language arts with the writing. I believe that STEM impacts and increases engagement because it's so visual. It piques the interest of our students' strengths as far as their creativity.

One of the most profound points that Principal Myrtle made about STEM education was that "often, students are learning experientially without really knowing that they are learning." She expressed that student participants in STEM activities ask and answer questions. She described the questions in the classroom as "inquisitive" and "specific." Principal Myrtle recalled some of the more visually impressive lessons, such as chemical reactions that caused miniature combustions. She shared that her instructors observed that the students were often able to store knowledge to activate later when they revisited the topic because of STEM practices. She believes that it first sparks their interests, and then they learn by not really knowing that they're learning. Dr. Myrtle shared some of the questions she has received from students, such as, "Why is it turning blue? Why is it rising? Why is it sinking?" In addition, she thinks that STEM helps them to make connections and comprehend better and longer. She identified some of STEM education's extensive qualities, saying:

> It makes [learning] more meaningful because they don't have a lot of the vocabulary or the prior experiences that some of their counterparts have. Those activities and tasks help prepare them for the next grade level or the next content area because now they can make connections.

Dr. Myrtle recalled memorable experiences of seeing her students engaged and actively learning due to the STEM-focused curriculum in her school. Now, having experienced success, Dr. Myrtle shared a moment of reflection when she recalled some initial challenges faced by her staff members. Although the children benefited from the changes, the instructors had to learn new materials to best equip the students. Learning additional content resulted in some natural pushback from staff members. The early difficulties showed Dr. Myrtle the resilient qualities of her staff members, as they embraced and continued with the challenge regardless of the difficulties. They are now reaching the eighth year of implementation. Dr. Myrtle recalled:

> We already had, at this point, three years of dipping our toe in the STEM pool. So, when we were required by my cluster and our district to be a STEM cluster, that gave me the ammunition that I needed to say we are required to do this. We will do this. It aligns with your evaluation. It is the expectation.

Dr. Myrtle's ability to mobilize her staff members to commit to a STEM school was a testament to her ability to lead. The job description for an open teaching position often presents the bare minimum, as educators regularly acquire multiple roles during their careers. The pressures of strenuous workloads often cause educators to feel reluctant about new responsibilities; however, a strong, encouraging, and faithful leader can ignite a powerful team. The potent mixture of Dr. Myrtle and her team was a synergistic force to create the first STEM school in the district that has become a model for neighboring schools.

Principal Myrtle and her instructors and students continued to bond. Others noticed their hard work. The school was a recipient of STEM and STEAM certifications from Cognia, a nonprofit organization internationally known for quality educational accreditation and consulting. As Principal Myrtle reflected on how she began, she took a moment to say:

> So, that really kind of made the ball start rolling, when [the team members] started seeing [that] we are really getting recognized for this work. Now it is a part of the fabric of our school; those who enter into the building enter knowing [that] this is us, this is what we do, and this is how we do it. The team runs a tight ship, and the curriculum is taking their students far. The STEM culture at this school is here to stay within their school walls and will follow the students out into the world beyond them.

Willow

Willow was the first personnel member to accept an invitation for an interview after a leader at her school recommended her. Her willingness to engage in an interview on a Friday afternoon was impressive and provided me an abundance of hope for a successful interviewing process. The willow is a plant known for its flexibility and graceful, slender appearance. This participant resembled the versatility of the willow because she had navigated with grace, some uncomfortable situations during her teacher training and initial employment as a classroom teacher.

Those who knew young Willow would not be shocked to learn that she became an impactful educator; as a young child, she regularly role-played as a teacher to her friends. At the time, her stepmother was a teacher, and there were several other educators in her family. Willow described her elementary-aged self as “literally a perfectionist in everything that pertained to school.” She stated, “Not only did I love school, but once I got home, I wanted to teach everybody else everything that I had learned.” The excitement of becoming a teacher did not immediately correlate with equal excitement for the projected salary range of educators. As she grew older, her childhood fantasies of becoming a teacher diminished as she considered pursuing more lucrative careers that would enable her to “make lots of money.” However, after beginning college and enrolling in unfulfilling courses, she committed to a major in education.

The student teaching experience is a rite of passage for young educators, and Willow summed hers as “a bit tumultuous.” She started the program with a supervisor who did not offer her much support. Fortunately, a strong sense of confidence and determination enabled her to stay on track to becoming a teacher. Willow quickly realized that she needed to stay focused and dedicated in order to earn respect in her new career. She explained that her focus and dedication was the force behind her rapid rise into leadership:

> My first principal wasn't as confident in my decision-making because I was new, and I was very confident. So, therefore, in my mind, I had to fight for every decision that I made. But it did not affect my effectiveness moving forward.

Now in her seventh year of teaching, Willow did not feel discouraged by her early teaching experiences and succeeded alongside her teammates. She remained at the same school, and of all the leaders with whom she worked, she spoke most highly of her current principal, who shared her passion for STEM-based education. Willow was the writing specialist for the third, fourth, and fifth grades. Her principal observed how well she integrated core subjects into her reading and writing lessons and tasked her with working closely with the STEM team to support the school-wide STEM initiative. Willow's primary school-wide responsibility was making assignments structured to gear students toward exceeding state standards.

As a young leader, Willow felt strongly that STEM education should occur in all urban elementary schools and happily reminisced about STEM initiatives at her school. She and her colleagues expected a difficult implementation because of the challenges her students faced in their core subject areas; however, they were pleasantly surprised by the success of the endeavor. Willow related:

> Right now, there's success in core subjects. Students were given activities to apply to things they were learning, and they showed that different learning styles of students came into play. Students were able to display their strengths outside of doing the traditional work and traditional learning.

The effort of rewriting the curriculum to reflect new goals was a team endeavor. As a leader in the process, Willow encouraged the team. In this position, she needed to delegate tasks, express graciousness for teachers giving their all, and empathize as many experienced similar hardships. Willow said, "Once the teachers became more comfortable with integrating subjects, doing their projects, and making it their own, they kind of gravitated toward the idea about or the beliefs in STEM. Everybody [has] leveled out."

Although her school had success with its implementation process, Willow believed that there was still room for growth throughout the educational setting. She suggested concrete ideas for stakeholders, saying:

> At the higher level, it should be a requirement that integration is encouraged, that teachers are helped and supported to actually implement integrated subjects into their classrooms. …Even with reading, we can teach students reading skills [and] reading standards; however, if we don't see them applied to other subject areas, then we don't truly know what they know.

Willow declared that STEM education is a global necessity and should receive treatment as such:

> We need to create state standards that are inclusive of real-world problems and problem-based learning at the core of STEM implementation. I think that on a national level, even a state level, just making sure that we are specific and intentional with the standards that we choose [and] making sure that there are resources there that help teachers understand how to cross curriculum and how to integrate things.

Willow was proud that her school had success with incorporating STEM in daily classroom lessons. The teachers succeeded with collaboration across all grade levels and content areas, common planning time to accomplish work, and support from parents and community stakeholders. The following are some of Willow's suggestions for community and business allies to enhance regular school programs while working to solve real-world problems, such as a lack of healthy foods. She said:

> We consider our area to be a food desert because there aren't many places that provide access to healthy foods, fresh fruits, and vegetables. There are lots of McDonald's and wing places and things of that nature. This is why we implement growth towers. We have a couple of gardens at the school [for] teaching the kids how to grow food in urban areas.

STEM certification requirements included engaging business partners to be a part of the school's daily functions. Willow's school had success with community support and business relationships because of active and consistent searches for participation, specifically, business partners. Willow shared:

> We have several partners. Porsche and Coca-Cola have been our partners. We also have a couple partnerships with a few urban gardening businesses that actually come out, talk to the kids about farming, and support us with our gardening. A local tree-growing organization has come and planted lots of trees around our school to help beautify the area and to also support with some of our problems that we've had as far as human activities and weather impact.

Willow reported a readiness at the school to present the successful STEM program through project-based learning via a popular television show platform for product development. However, this was an activity cut short due to the COVID-19 pandemic, which caused school closures throughout the country. The students had already begun forming teams and preparing to design and develop products to present to a panel of business partners. The students had begun preparing to compete to see who had the best idea. Willow vowed to make her creative project-based learning activity happen when school, once again, resumed in-person. Willow's perseverance is a testament to her commitment to providing opportunities for her students to excel while mastering curriculum-required content.

Aster

This participant received the pseudonym of the star-like Aster flower because of her success in securing over a million dollars for her inner-city elementary school. Aster's coworkers highly regarded her as the STEM specialist responsible for "all things related to STEM." Her coworkers described her as a strong, capable leader who continuously advocated for students, parents, and teachers.

As a young child, Aster aspired to become a teacher and join the cadre of educators in her family. However, once she entered college, she became curious about other professions. She relayed:

> I come from a family of educators. My mother, father, grandmother, and siblings are all educators, so I have always been immersed in the idea of education. Through elementary, middle, and even high school, I thought along those lines. However, when I got to college, I steered away from it and wanted to try something different.

Aster began pursuing an accounting major but returned to education because it was a natural skill for her. She then changed her major to early childhood education. After her student teaching, she felt certain that education was the best career for her although she had initially sought to escape it. Aster's teaching positions included kindergarten, second grade, and technology teacher. She had worked as the STEM specialist at her school for the past three years.

Aster first experienced STEM education through her son, who attended another STEM-focused elementary school in the same district where she worked. She saw firsthand, the impact of STEM on children and wanted every child in her school to experience "that same level of rigor" in learning. She realized that such rigor would require her teachers to change their mindsets. She helped her teachers gain several years of professional development and assisted with rearranging the school's curriculum to get buy-in for the STEM education revolution. She described the teachers' progression to a STEM school:

> The [teachers] weren't really comfortable with integrating a lot of content, nor did they understand what STEM [looked] like in the classroom. It's been quite a shift with professional development and them seeing how STEM impacts all the students. They saw how [the] students really enjoy[ed] what we provided through STEM education. And so, the personnel, staff, and especially the teachers are now engaged in the importance of STEM education.

The idea of a STEM program occurred to Aster in 2013, when she accepted the challenge to pursue funding for a STEM program to motivate students to participate in STEM-focused activities. She became the STEM program director after applying for and receiving 21st CCLC funding. The funding was the big push needed to propel the STEM program to success. As the program director, Aster directed the STEM after-school program and the STEM summer academy for five years. As a result, she turned the whole school into a STEM school with a problem-based learning curriculum to push students to solve real-world problems that were relevant to their lives. Aster described a relatively straightforward process of earning STEM certification, as the grant enabled a strong start for the school.

Aster's description of her role in the certification process indicated that a program director or a STEM specialist plays a big part in the overall STEM program implementation. She credited the teachers with doing an effective job in their content areas. Aster's great respect for STEM in schools enabled her to seek an appropriate method to make it happen. She said:

> My role in the certification process was to research problem- and project-based learning and provide training and development that allowed our teachers to move from non-content integration to full integration within our core content areas. [I trained them to use] science as the foundation and [to add] in math and ELA standards through the lens of science.

Aster was able to determine what STEM may actually look like in her school by going to other STEM-certified schools, attending conferences, and participating in professional development opportunities. She started with just trying to build the momentum of STEM. The teachers allowed students to participate in STEM activities one day at the end of each month. Aster coordinated different career professionals to speak to the students on those days. Having a whole day of engineering or being engineers was an exciting experience for the students and teachers. Aster also directed the after-school program. She explained that one of her next moves was to create a full functioning, after-school STEM program with STEM-centered courses and activities. An impressive number of 120 students were fully immersed in STEM during the afterschool hours. From there, Aster created a STEM-centered summer curriculum for the teachers and students. She described the development as a full-day STEM program.

The summer program for teachers was a significant factor in setting the foundation for the entire school to fully immerse in STEM education. The summer program participants spread their knowledge to their peers and coworkers because they had gained a strong foundation in STEM education. Aster recalled:

> Those teachers became the ambassadors who helped me transition the rest of the teachers throughout the school year. We started teaching the teachers how to create unit plans centered around STEM. Taking their units of study, the standard that they were to teach, and teaching them how to use the engineer and design process for those different unit plans is how we got to where we are today.

Aster planned to expand the STEM program to make the greatest impact on students in an urban setting. She was content with her professional life but still sought to discern her future career path. Moving forward on a STEM-focused career path, Aster reported her mantra as "exposure + experience = excellence" (the three Es). She committed deeply to making urban children STEM literate. She stated, "In an urban setting, STEM is always important because if they don't see it, then they can't become it." Of the three Es, she considered exposure the most important, and she focused on showing students the interconnection of all subjects in the real world instead of having them "learn in silos." Aster stated her belief that principals are the starting point for strong STEM education in urban elementary settings.

After Aster's efforts, STEM education became the norm at Katherine Johnson Elementary School (pseudonym), and was successfully integrated into all aspects of programming. She enthusiastically described her high regard for STEM. One of the key examples she shared was parent night at the end of each unit, which consisted of students teaching parents about what they had learned. The theme of this school was "Making a clean, green difference," with the school located in a food desert with plenty of fast-food restaurants but few grocery stores within walking distance. The staff members worked together to promote gardening because they wanted their students to know that they could grow fruits and vegetables themselves.

Daily school-wide broadcasts motivated staff and students with STEM-focused news and accomplishments. The educators chose and interviewed a STEM "student innovator of the month" and broadcasted the student interviews. The hallways featured posters with QR code links to the student interview for students to scan with smart devices, to access and listen to at any time. Art, music, Spanish, and physical education lessons included the STEM concepts related to the problems under study. Aster passionately described some of the ways that school personnel regularly engaged with students and revealed the success of the whole-school approach to STEM education: Our teachers are engaged with students throughout content and lessons and teaching and learning. Younger grade levels partner with the intermediate classes. Teachers expand learning from the classroom and incorporate STEM at a higher level. Art, music, and Spanish teachers incorporate STEM within their classrooms.

The interior of this contained a multitude of STEM-focused pictures and projects. Although the 21st CCLC grant project ended, the culture that it helped developed has remained. The school still provided many after-school and special programs that enabled the students and teachers to immerse themselves in the engineering and design process—and it had an international STEM and STEAM certification to show it.

Rose

Dr. Rose was the second principal interviewed in this series of six interviews. Several colleagues who knew of my interest in STEM in urban learning environments referred me to Dr. Rose. She was highly recommended on three occasions by others immersed in STEM education. Dr. Rose worked at a school well-known for rich STEM content and authentic learning that focused on the need for nutritious food for students and their families. The faculty members at her school taught students about plants and animals to grow and raise for nutritious food. The students handled live chickens daily and managed hydroponic vegetable gardens. This school was the first in the district to receive both STEM and STEAM certifications.

This principal received the name Rose because the rose is a symbol of love and beauty. Dr. Rose shared that one of the most enjoyable experiences each day is when she stood at the front of the line to welcome children into her school each morning with a hug, making it easy for students to connect with her personally. Dr. Rose's willingness to stop and talk with students in the hallways without hesitation, regardless of her schedule, showed students and their families that she cared about more than just test scores. The daily welcoming committee also included a lineup of personnel who greeted all students with a smile and checked to see how they felt. The goal was to ensure that every student knew that the staff members supported their well-being. Their goal was to ensure that each student receive the support they needed.

This participant generously opened her schedule for an interview. The request for an interview for this study was merely one of many requests for information about Dr. Rose's STEM-focused elementary school. Dr. Rose could not consent to all of the requests, and I received specific suggestions for gaining an interview with her. A mutual colleague advised including her name within the subject line of the email invitation because she had spoken to Dr. Rose about the research. Putting the colleague's name in the email was a means of ensuring that Dr. Rose would read the email and accept the request. Dr. Rose often had to multitask during the interview, which showed her busy schedule and her generosity in sharing her valuable time.

Principal Rose revealed that she knew that she would be an educator at a very young age. She shared some of the experiences that influenced her decision to go into the teaching profession, saying:

> Back in the day, there used to be a TV show that would come on. I must have been about five or six years old because I remember coming home from school, and my Mom would put this little science show on, and I would get my dolls and kind of spread them out, and as the science show was on, I would teach my dolls.

The fact that she vividly remembered teaching at such a young age showed that exposure to topics early in childhood can have a lasting impact on students applying their knowledge throughout their educational and professional careers. Principal Rose expressed surprise when she realized how far she could recall her love of science.

Although Principal Rose knew that she wanted to become a teacher, she listened to the advice of one of her college advisors, who told her that there were too many preachers, teachers, and postal workers from the Black community. She decided on an economics major but detested it. Dr. Rose entered the corporate world and worked her way up to the position of associate buyer in the executive management program of a large-scale retail company. Several of her family members, many of whom were educators, considered her career as respectable because they recognized the lack of Black professionals in executive positions. Over 14 years later, unfulfilled by her work, Dr. Rose still had a strong desire to teach. Her experience indicated how the efforts and advice of educators and counselors can affect the choices of students.

After becoming a mother, she felt a stronger desire to teach. Studying for an education certification while working in retail was the best way for her to transition to a career in education. Working full-time while going to school required tremendous determination and drive, but Dr. Rose had strong academic abilities as well as drive. Dr. Rose expressed the value of classroom teaching as she described a short-lived experience that led her to a leadership position. She used the lessons and ethics that she learned in the corporate world on her journey to becoming a principal, which had now been her role for 13 years. She summarized her journey into education with gratitude:

> Thank goodness I had somebody to offer me a provisional certificate, and then I was able to get hired as a teacher and then worked on actually getting my certification. From there, I moved into not only classroom teaching, which I still value all of that and use it every day, but [I] also became a district curriculum person and then a principal.

Principal Rose valued progressive STEM education in elementary schools in urban settings as a positive way to promote hands-on engagement. She indicated that increased parental involvement was a bonus. Principal Rose also found STEM education beneficial for visual and kinesthetic learners. She explained:

> You can't always align [what students learn] to a standardized test score. For me, my kids are brilliant. They're so smart. Maybe the test scores don't capture everything that they know. What I do know is that when they are engaged in STEM, [with] hands-on, project-based, problem-based learning, it makes sense to them because it's relevant and it's authentic. It just helps them to be able to grapple with and understand the curriculum.

Principal Rose felt confident that at least 50% of her staff members had as much passion for STEM as she did, and that they wanted to do their best to follow her lead in regard to creating engaging STEM lessons. She understood that she would always be grateful for staff members who showed up and put in the work. She used the term "staff" to refer to not only classroom instructors but everyone, from coaches to custodians. Dr. Rose expressed her devotion to the implementation process:

> Our district has units of study and sub-study, so when we are working on the curriculum, we all come together, and we find authentic, relevant problems in the community. For example, the farm across the street in our area by the school has a flooding problem. One of the last units that the third grade worked on before the COVID crisis was coming up with [the] ways [that the] children [could] help with this flooding problem at the farm. I know that's why kids believe in this curriculum: because it impacts their community.

Dr. Rose and her staff constantly sought ways to provide opportunities for community stakeholders to get involved with the school's daily activities. She enthusiastically recounted how the partners helped plant trees and supported students in understanding soil composition and erosion cycles. She also encouraged field trips for exposure to nature and the world at work.

The faculty members aimed to get students outside as much as possible, but in classroom activities were the most prevalent. Principal Rose recalled one instance when a visiting member of the school district described her classroom as “messy” during an observation made the same day as class experiments. Dr. Rose felt comfortable with the room’s disordered appearance and proud of the “mess” the students made as they researched their topics. The work in process, combined with collaborating to follow instructions, contributed to the richness of the connections that the students made. Dr. Rose recalled:

> Even when I was a classroom teacher, I so believed in science and hands-on, and we didn’t call it STEM then. It wasn’t a big thing, but I remember people from the district coming to my room. I remember one lady was like, “Your room is just so messy.” Well, she happened to walk in when they were doing an observation from the district, and I had the kids on the floor, and I had newspaper out. We were doing some experiments.

Reflecting on her science education background, Principal Rose recognized how she developed her attraction to authentic science during college-run summer programs. The summer programs enabled Dr. Rose to teach freely without rigid guidelines. The atmosphere provided a space for students to ask questions and for college educators to acknowledge that they still had to learn as well. She believed that teaching style, rather than content, was often related why some students loved science and others did not. She shared:

> I remember taking science classes when I was in high school, and I hated [them]. It was too [much] skill and drill and…[memorization]. But I also remember teaching summer camps during the summer. The teachers [had] the freedom to kind of teach it how they wanted to. I do feel like you have to not be so rigid and structured when you are teaching science. You have to be okay with kids making a mistake or asking questions, and you might not have the answers to it and that sort of thing.

This well-seasoned leader reflected in great detail on one of her early experiences after becoming a principal. She found an old science lab in her school used as a storage closet. She disliked the misuse of the room because the students had unsatisfactory science scores, and she believed that the students could do better if the faculty members put in more effort. Dr. Rose remembered:

> My first year as principal, we had a beautiful science lab full of old science projects. It was a storage room, basically. The [science] scores were unacceptable, and I knew then that I had to get people on board. …I remember teachers being upset with me when we emptied that science lab out, and I bought little kits that had little stained-glass animals. One of my faculty meetings was for teachers to come to the science lab and hang up all those animals in the ceiling. I was trying to get everyone to see [that] science is fun!

This experience demonstrated Dr. Rose's role as a leader in transforming her school into a STEM school. Dr. Rose continued to seek teachers with a passion for teaching science to ensure a strong, continuing culture of STEM education. Her leadership practices can serve as an example of practices to emulate.

The assessment data of fifth-grade students was a solid indicator of success, due to its steady improvement. The successes ultimately balanced with the ordinary struggles felt by Dr. Rose and the faculty members; she knew that faculty motivation would remain one of her biggest challenges. For this reason, Dr. Rose constantly sought opportunities to introduce fresh ideas by incorporating STEM activities into staff meetings.

Dr. Rose considered support from community stakeholders a significant strength of the school's STEM culture. Some community stakeholders had been partners for decades, whereas others were more recent collaborators. Many of her students came from socioeconomically disadvantaged households, and 100% came from Black or Hispanic backgrounds., Many students had deficiencies in reading, writing, and math and improvement in these subjects was apparent as STEM topics were infused in every lesson. The interview concluded as Dr. Rose extended an invitation to visit after the reopening school. Although excited about the opportunity, I felt that I had been there already, as she had described her school so vividly.

Lily

Lily and I connected right away; she answered the phone on the first ring after a long day of virtual teaching. Following a brief introduction, she noted that she did not have any questions but wanted to express her happiness that people like me were researching this topic. Her comment enabled me to relax and set the stage for an honest and candid conversation. I heard the sincere appreciation in her voice, which contributed to the anticipation of getting to know this STEM educator.

This participant received the name Lily because the lily is a flower with the Egyptian root name of lotus. The lotus flower sinks underwater at night and rises again in the morning, suggesting rebirth. Lily shared a part of her life focused on creating a new beginning for her career in education, which aligned with the meaning of the lily. The compassion and empathy she frequently demonstrated during the interview suggested that experiencing significant transitions contributed to her acquisition of these valuable qualities. Lily reported holding different jobs in varied occupational fields throughout her life. She reached a point when she wanted more than a job; she wanted a career. Lily vividly described when and how she knew she wanted to become a teacher:

> I knew [that] I wanted to become an educator when I was 10 years deep into retail. I had coached gymnastics. I had been an assistant at a company that translated documents into many different languages. I worked at Blockbuster. I did district training and store management. I also did merchandise management, which was a lot of analysis with zip codes and products. I was in the Air Force, and I was in surgical service technology. I realized that none of those jobs had given me what I needed as an employee.

Lily formulated a list of the characteristics she wanted in a career and realized that fulfilling, challenging, and appreciation were the top qualities she desired. While researching, she focused on education because “kids never fail to show appreciation.” She went back to school, earned a master’s degree in education, and embarked on a teaching career. She said, “It was the best decision I ever made.” She enjoyed the excitement that her students constantly expressed about learning and life in general. She felt motivated by the daily energy of teaching as she worked toward providing her students with the most fulfilling learning experiences possible.

Some life experiences that contributed to Lily's journey to becoming an educator were getting married, moving to Georgia, having children, and getting divorced. During her divorce, her children's teachers helped her and her children when she lacked emotional availability. Throughout this time, she realized the importance of having a network of people who can depend on one another. She saw how school personnel fit into that network, and she wanted to be part of something so powerful and uplifting. She said:

> I had three kids [who] were all little people, and I couldn't do ABCs with them. I needed extra help. It was those people, [the teachers], who saw me as a human being and loved my kids and helped support our family, and I just thought, you know what? One person doesn't make it in this world. It is committed people [who] love what they do, [who] put their heart into it, people who didn't know me before [who] gave their time and their hearts and their service to my kids.

Lily described her job title of STEAM Specialist as unofficial because she considered herself, first and foremost, a teacher. She taught a reading class in the morning and spent the rest of the day in the STEAM lab, instructing the engineering design process and creating problem-based learning activities focused on school initiatives. She worked with kindergarten, first-, and second-grade students, totaling approximately 150 students each day. She described teaching as her dream job. She called the lab her "happy place" because she worked with all types of animals, including chickens and rabbits, and could still teach reading. Initially certified for STEM, her school received an additional STEAM certification because the teachers and administrators knew they had the components to achieve more.

This highly motivated STEAM specialist shared that she did not see how to separate STEAM education in an urban setting from the curriculum and that quality education still exists. She described how STEAM requires critical thinking and that it was the best way for students to receive the material. Lily saw many students demonstrate talents beyond her imagination.

Lily not only taught science, but also, she was a scientist. She planned to finish her specialist degree during the following summer and considered earning her Ph.D.; however, she noted that she would always appreciate working in the lab with her students:

> I think that it's funny that STEM is an acronym that's become the buzzword of the time. For me, [STEM is] critical thinking. It's seeing problems and realizing that you have the power to make things, and if it doesn't work, having the perseverance to keep going. So, for me, I don't see how you can separate that from any quality education. And STEAM is the natural way to introduce that to children at a cognitive level that they can interact with successfully.

Lily noticed resistance from her colleagues early in the process of becoming STEM-certified. Further into implementation, she saw how STEM certification blended into the school culture. She said, "Everyone has embraced it and is now eager to help new people who come to work in our school learn about it quickly because it is the way we operate."

Lily identified a school-wide, joint-planning routine as the most compelling aspect of the school's success. Curriculum building was not a top-down approach, as the faculty members actively participated in planning units to mirror the standards and pacing guides. Everyone in the school was welcome to participate and provide input about what they could do to help students learn the content and skills required. Community partners visited the school and helped with each unit, as did content teachers from each subject area. The school had an astonishing and growing list of community partners. The STEAM program's certification process provided a checklist that resulted in additional success (see Appendix F).

Labeled a "STEM champion," Lily was a lifeline to the existence and progression of the programs at her school. As an educator, she rooted for the achievement of each student and exuded pure delight while speaking of her students. To her, it was important that each student had someone willing to go against the grain to help them challenge themselves beyond personal expectations. Challenging her learners often consisted of assigning a project that even her fellow grade-level teammates believed too substantial to handle. However, in true fashion, Lily worked alongside her students to attain completion. One example was when her students worked on English and language arts (ELA) assignments by digitally graphing the weather by season and discussing current global events. Lily shared:

> We took information from one day in February, and we just changed it to the same day in March. [We] did compare and contrast. They were looking at what's growing on this day around the world. And why are different things growing around the world. It was fun and challenging for the students. Everybody [in] my

> grade level was like, “That’s too big of a project. There’s no way.” And I was like, “You don’t understand. There’s a way.”

Lily shared the fact that students and their families began to take ownership of learning and raised expectations for themselves and for the middle school they attended after promotion. She described her fellow teachers as having a “full-on growth mindset.” Each teacher expended a significant amount of energy into helping students accomplish their goals. Some parents expressed that their children missed the previous authentic, relevant, and rigorous lessons they received in elementary school when they entered middle school. Thus, the members of the elementary team sought to collaborate with middle school instructors to help prepare them for the brilliant minds that they were about to inherit.

During the transition to full STEM, the teachers leaned on each other to immerse themselves in the new content and practices, instead of operating in isolation. Lily described some of the school’s successes:

> We not only got the certification [and] had our data show improvement; we have gotten to a place now where we have flexibility to continue building partnerships. …We have flexibility and freedom to say, “Okay, I want to shift this unit of study to this time of year because it naturally connects to this other topic that we’re studying.” We’re able to be more authentic in our teaching because the rigidity has loosened up.

A significant challenge Lily encountered early in the STEM implementation was the lack of support for some classroom necessities. However, Lily noted that the school received an abundance of help from some of the more solid community relationships, especially with the local four-year colleges that provide resources for support and new ideas. The parents engaged in daily activities, such as chaperoning small groups of students to the garden throughout the day to ensure that all students had the opportunity to help with planting, maintaining, and harvesting. Lily also felt grateful for help from the academic coaches for regularly providing learning opportunities, meeting with the content teachers, and sharing research-based strategies for effective teaching. The new tradition of collaboration had benefits, as the students appeared to gain far more from the STEM-focused learning environment than from the traditional learning environment. Lily discussed how she perceived her students' thoughts:

> They were so excited. We were painting and having conversations. I did have my own projects and things that I was doing in the lab, but when I transitioned to the STEAM lab position, it's not about just my lab. My position is a go-to sounding board, a collaborative board for each of those grade levels and classes. And they've got great ideas, so we just go for it.

Lily described the STEAM program as a well-oiled machine that was an integral part of the schools' functioning. During the interview, she clearly expressed her sincere devotion to her students and her desire to provide them with a quality education. She shared her theory of quality education begins with critical thinking that begins with noticing and wondering enriched with background knowledge and completed with crosscutting concepts and disciplinary core ideas. She extended an invitation to me to visit the school as soon as things go back to normal after the COVID-19 pandemic so she can show me the school, especially her STEAM lab and Problem-based Learning (PBL) night.

Iris

Iris was the last interview in a series of six within two weeks. The interview with Iris was the most extensive, at nearly an hour and a half, and contained an abundance of rich insights. There was no need for many of the prepared questions because Iris freely shared information about herself, the school, her students, and staff members. The name given to this participant was Iris because the iris is a flower that shows many different, deeply rich colors. This STEM champion eloquently described her school's partners and daily activities and routines. She expressed her feelings and emotions with each question, clearly presenting the great experience provided by this STEM-focused elementary school.

Iris knew that she would become an educator in the late 1980s. She denied her calling for years because she grew up in an era when many people from the Black community sought to obtain corporate careers. When Iris finished college with a psychology major, she did not want to teach; she planned to follow the crowd into corporate employment. Close confidantes acknowledged her personality and interests as the perfect match for the education field and presented teaching as a stable option. She felt that her degree in psychology did not prepare her for a pathway into education and did not know the next steps to take. After college, Iris accepted a position with a company and realized that she did not fit into the corporate world. She explained: I studied psychology, and I really didn't know what I wanted to do. So, when I finished college, I went on into the workforce, and the company that I worked for, it went under.

That left me a gap of time when I could do some reflecting. I didn’t really like that corporate environment, the desk, the paperwork, and the cutthroat business acumen. It just really wasn’t me.

Iris decided to try being an educator by working as a substitute teacher. She had reached a point in her life when she had many different options, but she wanted to feel sure of herself before investing in a teaching certification. She described her initial teaching experience:

> It was just so awesome. I loved the autonomy [of] being in a classroom. [I] could be as creative as [I] needed to be. When I started, autonomy and creativity were at the forefronts of individual classrooms. So, I really liked it a lot. After that one year, I went back to school and worked on my certification in elementary education. After I obtained that credential and passed the teacher certification test, I applied for a teaching position and was hired on early.

Iris completed her first year of full-time teaching at an elementary school in an area of profoundly low socioeconomic status. The school had a firm principal who genuinely cared about his students, community, and staff. He managed the school like a family. It was a small school with an innovative range of programs that required much effort. Iris described the school as “an awesome experience” and often wondered if she would have stayed in the profession if she had not gotten involved in such an environment early in her career.

Like the other teachers who had grown up in families of educators, she came into the profession confident and prepared to make positive contributions. The teachers at her school called her “the real teacher.” Iris had confidence in her teaching capabilities and did not shy away from lending stories and advice to others. She acknowledged that delaying entering education provided her with the time to gain the experience she needed to appreciate being an educator even more.

Iris was the STEAM specialist for grades three, four, and five and supervised a lab for students to visit for weekly 45-minute sessions. Students rotated through the STEAM lab to generate probable solutions to real-world problems. The students designed the projects collaboratively with innovation specialists, along with guidance from the entire teaching staff and student population. Teachers focused on fitting problem-based projects into lesson plans with a typical completion of four to six weeks. The curriculum included integrating STEAM fundamentals and a daily infusion of music, art, and foreign language classes.

The transition to a STEAM-certified school was a long, extensive journey. The teachers realized that STEAM was a relatable and effective way to teach; however, some of the teachers who did not entirely adjust to STEAM resigned and transitioned to other schools. Her school's principal actively aided the teachers who experienced troubles with adapting. Iris explained:

> When people don't want to be here, they just find some other options for themselves. And because we work in a high-needs school that can be stressful at times, especially if you've been there for years and years and years, our principal will help you find other options if that's really what you want to do.

Iris advocated for students continuing with STEAM into middle school, saying, "I believe that STEM education and exposure to STEM careers is essential for any child that is in school right now because in the next five to 10 years, those are going to be the careers that are needed." She often participated in conversations to help parents find more compatible schools for their children, even if they had to move to a new district. Iris described the disparities of continuing STEM education:

> A lot of our kids [who] left didn't go to the feeder schools because the parents were not pleased with the offerings at the middle school. Parents make comments like, "Our kids have done all of this over here. They've built robots. They designed games. They built bat houses. They learned all about agriculture. What are they going to do when they get over here?"

Iris noted that the middle school teachers had not yet found satisfactory answers to such questions. The rich STEAM culture at Iris's school demonstrated that STEM is a way to help students understand real-world applications of each subject. The school had a unique greeter who, for the last five years, met school visitors and co-existed with faculty and students. The unofficial mascot was a five-foot tall robot that was a major source of pride for the school. Iris said, "We have students who built a robot; his name is Ramsey. He walks and he talks. And he comes to all assemblies. He meets many the people who come in[to] our building." She told me that the fourth and fifth graders who built him had long been promoted. He usually wears a shirt with the school logo and if it's a special occasion, he'll wear a tuxedo shirt.

The faculty members and students had access to innovative technology, such as zSpace and Autodesk 3ds Max (formerly 3-D Studio Max). The school district's assessors involved in the STEAM certification evaluation process noted that students and faculty members at similar elementary schools generally did not use or have access to such advanced software. Iris stated, "When people come and visit our schools, they tell us that they don't usually see elementary students using those types of programs. They say they don't see that usually until high school."

Iris recognized the rare position of her school and acknowledged that the STEAM lab technology contributed to the continued success of her students. Overall, she shared that the organization among the staff was the foundation for the school's efficient functioning. The teachers and lab instructors, including Iris, engaged in a co-teaching method during lab time to maximize accessibility for students to ask questions and complete tasks. The use of the co-teaching model was a significant struggle early in the implementation process, but Iris reported about its eventual success and helpfulness, saying:

> [It] took a lot of muscle to get homeroom teachers to buy in to the notion that they had]…to come to the STEM lab with [their] class. …[They had] to plan with the STEM lab teacher. That was one of our biggest struggles. It got so tough because teachers felt like, "You're certified just like I'm certified, so why do I have to come in the room and work alongside you?"

The co-teaching model soon became revered as an ideal model because of the type of projects that were being done. Iris shared her belief that it was effective to have more than one adult in the room. She also mentioned that it gave the homeroom teachers the opportunity to learn some of the things that the STEM teacher was learning or teaching, especially concerning the engineer and design process.

Iris described a success story of students with disabilities (such as emotional and behavior disorders) who visited the STEAM lab. She believed that the running water in the hydroponic system and the animals appeared to have a calming effect on them.

Indeed, students with disabilities regularly visited the lab and excelled alongside their counterparts.

This elementary school had three STEM certifications to validate its success: a state certification for STEM, a state certification for STEAM, and an international STEM certification from Cognia. The three certifications together conveyed the accolade of the “triple crown.” A key contribution to the establishment of the STEM program was a solid relationship with their community stakeholders. The launch process of the STEM program plans commenced with roughly 80 individuals from several organizations joining together to brainstorm the school’s focus. The school is located in a food desert; therefore, community-wide hunger was the most significant issue identified, and a focus on agriculture and social justice emerged as the remedy. The brainstorming process produced the theme, “We are the world, conquering hunger through sustainability and creativity.” In retrospect, Iris reflected on the reality of stakeholders rotating through the program and appreciated a consistent group of influential, indispensable partners. The stakeholders included students’ parents, the science and education departments of postsecondary schools, employees of neighboring companies and organizations with an environmental focus, and government policymakers.

Iris expressed pride in her student’s success and consistency. She shared what she believed contributed to improved student science scores, explaining, “Our scores are increasing because the teachers teach science standards. We incorporate all of the science standards into our STEAM projects, so they get a double dose. The projects that we do in the STEAM lab mirror the standards.”

She witnessed a significant increase in parental involvement because of more opportunities for their involvement in the learning process. Many parents and guardians attended PBL nights, at which students became the teachers and parents became the students. Many of the parents indicated a desire to improve the quality of food for their families, as their children learned and retaught them information about foods, nutrients, and lifestyle choices. Iris's final reflections indicated her belief that success in education is a full-circle process that requires work from everyone. She finished with, "The bottom line is that parents get involved because their kids are involved."

Summary

This compilation of the lived experiences of six individuals who directly impacted teaching students in urban STEM-certified schools provided a plethora of information. A goal of this researcher was to share this information with others eager to accept the challenge to prepare students for the 21st century by using innovative STEM concepts. Individuals who seek to better understand what STEM education can provide may use this information to provide opportunities to students in urban settings who may be less likely to achieve them on their own. The goal of this researcher was to help provide equity in STEAM education. This study was an exploration of the actions that contributed to increased science proficiency among students in urban settings. Educators in urban and non-urban settings may use the strategies and practices found in this study to help implement or enhance STEM or STEAM programming in their settings.

The participants in this study expressed a passion for teaching with the engineering design process and consistently infused STEM into real-world topics relevant to the curricula. Many of the participants had similar lived experiences of an attraction to teaching and learning science, family members with teaching careers, and a high-caliber work ethic. The data gathered during this interview process led to the discussion of significant themes in the schools in Chapter V. The next chapter presents these themes to provide a foundational structure for future STEM program development.

Chapter V DISCUSSION OF THEMES

The 2018 report entitled, *Charting a Course for Success: America's Strategy for STEM Education* by the Committee on STEM Education, indicated STEM education as a way of "preserving peace through strength" (p. v) because it is a vehicle for producing innovation and technological advances in America. The report indicated that citizens' STEM knowledge significantly affects national and economic security. Three aspirational goals that can be helpful in supplying this need are: 1). Build strong foundations for STEM literacy, 2). Increase diversity, equity, and inclusion in STEM, and 3). Prepare the STEM workforce for the future. A solid STEM education culture in schools can serve as a method of fulfilling these aspirations.

The purpose of this study was to determine the strategies and practices used by school personnel responsible for increasing student science proficiency at certified STEM elementary schools in urban settings in Georgia. The research outlined the strategies and practices used during and after the STEM certification process that may have contributed to increased science proficiency in students. Educators may find this information useful when implementing STEM programs in their schools.

I analyzed multiple documents and sources of data to detect the characteristics of STEM-focused elementary schools in urban settings in Georgia. Telephone interviews, emails, websites, documents, and memos provided a wealth of information about the schools, their personnel, and their community partners. All participants, schools, school districts, and community partners referenced in this study remained confidential via the use of pseudonyms to protect their identities. The following research questions guided the interviews:

RQ1: What are the lived and career experiences of school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ2: What strategies were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ3: What practices were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

I began with purposeful selection to identify information-rich participants from the elementary schools that received certification within the last three years in an urban setting in Georgia. Patton (2015) stated that purposeful sampling is a method of obtaining an in-depth understanding of a case. Each school's principal received an invitation to participate; afterward, a more specific type of purposeful selection, snowball sampling, commenced. Snowball sampling is a means of identifying the participants who are most able to provide the information desired (Patton, 2015). Each principal recommended two other school personnel to participate in this study based on the selection criteria of direct classroom-level involvement with STEM education during the implementation process. A semi-structured interview protocol allowed me to gather adequate information to answer the research questions.

The interview questions provided the participants with opportunities to share background information about when and why they chose careers in education and how they were involved in the development of STEM-certified urban elementary schools. The interviews had three parts in which to capture the data for each of the three research questions (Seidman, 2013). The interviews ranged between 65–88 minutes in length. A speakerphone and a voice recorder were the devices used to capture the conversations on an iPad. The audio recording was transferred to a digital file and was uploaded to Rev.com for transcription. The transcripts underwent hand-coding after several readings and were organized into general themes related to the research questions (see Merriam & Tisdell, 2016). NVivo was the software used to organize the participants' words and phrases for easy access during the process of writing and seeking themes. A close look at the data indicated three major themes of the experience of developing and sustaining STEM-certified elementary schools: (1) intrinsic passion ignites effective leadership, (2) daily focus guides collaboration, and (3) success becomes evident.

A search of all STEM-certified elementary schools in Georgia revealed two schools in an urban area with increased science proficiency in students' EOG test scores since implementing the STEM program. For this study, an urban area was a region with a high population density, high concentration of minorities, high concentration of businesses, and low socioeconomic status (Lippman, 1996). A list of GADOE-certified STEM elementary schools underwent analysis, as did a list of Cognia-certified STEM elementary schools from a Cognia representative. The Governor's Office of Student Achievement in Georgia was the resource used to obtain fifth graders' EOG scores. Fifth grade scores were selected for analysis, as students take their first assessment of science content knowledge in fifth grade.

The two schools with the qualities required by the criteria were located approximately nine miles apart in the same school district. One explanation for the phenomenon of the schools' proximity was that a key component of STEM certification is proximity to business partners who can participate in daily school routines; this was an explanation shared by a STEM coordinator for GADOE (F. Cullars, personal communication, July 6, 2020). Although the schools in the study were the only two certified STEM elementary schools in Georgia meeting the research criteria, there are several other STEM-certified elementary schools in Georgia. According to combined GADOE and Cognia figures, there were 82 STEM-certified elementary schools in the state in 2020. Other schools are in the process of preparing for STEM certification in Georgia. Table 1 below presents the key demographic information about the participating schools.

Table 1

STEM Schools Demographic Information

Demographics	School (pseudonym)	
	Mae Jemison (School 1)	Katherine Johnson (School 2)
Participants	Myrtle, Willow, and Aster	Rose, Lily, and Iris
Grade levels	K-5	K-5
Year STEM certified	Cognia certified 2018/2019	GADOE STEM-2017; STEAM 2019; Cognia STEM 2018/2019
Title I	Yes	Yes
Student enrollment	350	550
% free or reduced lunch	100%	100%
Mode of transportation	Walkers, car riders, bus riders	Walkers, car riders, bus riders
Enrollment criteria	None	None

Table 3 lists the percentage of fifth grade students from participating schools who mastered science proficiency on the CRCT EOG assessment for six years. The fifth grade is the only grade during elementary school when science proficiency is evaluated and is the criteria that was used to identify schools that met the participation criteria for this study. The initial data used was from 2015, which was three years before both schools obtained STEM certification. Progress was evident, although there were several increases and decreases during the process. School #1, which had the smallest enrollment, demonstrated the greatest success, at times surpassing the district and state levels of proficiency.

Table 3

Percent Proficient and Above in Science in Fifth Grade

School	Spring 2015	Spring 2016	Spring 2017	Spring 2018	Spring 2019	Average last 3 years
School 1	21	20	60	37	29	41.9
School 2	10	22	26	16	31	24
District	28	31	31	33	38	34
State	36	39	39	39	40	39

Note. Obtained from GADOE.com.

Theme 1: Intrinsic Passion Ignites Effective Leadership

Borg and Ohlsson (2010) defined career exploration as a "crucial developmental task in adolescence which lays the foundation for informed career decision-making, self-determination, and achievement of vocational identity" (p. x). Borg and Ohlsson proffered that career development "encompasses the active reflection of personal interests, abilities and values as well as the exploration of possibilities in the world of work" (p. x). Each participant in this study was able to recount when they decided to pursue careers in education. Five of them planned to become educators during their early years. None entered education directly after high school. Three decided to pursue a career in education in college. Three participants noted that they did not work in education until after several years of working in other careers.

Each participant experienced an event that caused her to develop an interest in science, which was a catalyst for becoming leaders and STEM ambassadors in their schools. Research indicates that meaningful experiences early in a child's life have great potential for influencing the selection of a science-focused career (Osborne et al., 2003). The participants in this study shone with a sense of accomplishment when describing the STEM education that they provided for their students in an urban setting. Each of the participants expressed the need for more STEM schools and support on the district and national levels. They discussed the challenges of receiving STEM school certification but considered it well worth the effort for their students and the nation.

Each school in this study underwent multiple rounds of STEM certification and evaluation. Preparation for the different levels of the STEM implementation process is complex and time-consuming. Fortunately, the participants noted that although it was hard work, they found the rewards abundant. Schoolwide certification requires some degree of participation from all stakeholders in the school. Each educator in this study was qualified to participate because she met the inclusion criteria of being either a principal, STEM program coordinator, or a STEM specialist.

Theme 1, Subtheme 1: Passion Leads to the Right Career

Five of the six participants had one or several family members with careers in education who were their role models. The participants' extensive backgrounds, including the role of family members in influencing their career choices, is a topic covered in Chapter IV, Introduction to Participants. Dr. Myrtle, one of the principals of the STEM-focused elementary school in this study, recounted her journey to a career in education. She shared that her mother, grandmother, and aunts were all educators, so she did not want to do that. She majored in sports medicine at Georgia Southern Univeristy, and had a scholarship, but was not doing well in biology. So, in order to keep her scholarship, she changed her major to elementary education.

The students in Dr. Myrtle's school benefited daily from a caring principal who aspired to create an atmosphere that contributed to their self-confidence. The students knew they had a school leader who genuinely cared for them. Dr. Myrtle embarked on her journey to education with hard work, perseverance, and self-confidence, following her instincts to change her career to education. Exposure to professionals in the education field in her immediate family likely provided her with insight into the qualities needed to succeed in this career. However, education was not her first choice. She likely benefitted from her experience as a biology major at a four-year college and encouraged her students to aim high. Her video address from her principal's chair in her office on the school's website shows her strong, supportive desire for her students to maximize their potential in the present and the future. She did not stop with a four-year degree but continued to earn her doctorate.

In a study on the common and differing features of STEM high-school communities, Tofel-Grehl and Callahan (2014) investigated the experiences of administrators, teachers, and students in six STEM schools. The researchers found similar beliefs among participants, that their role was to create academically focused school cultures to provide students with the skills they need to become problem-solvers and great communicators. The principals in the present study stated their belief that STEM education was the best way for students to learn. They reinforced their beliefs with discussions about the depth and breadth of their efforts to include STEM in every aspect of teaching and learning at their schools. Although each principal presented evidence of success on many levels, each also knew she needed to be vigilant in promoting and supporting STEM education in order to sustain it at the maximum level in their schools.

One-on-one interviews can be a way to reveal the unknown to the interviewer and the interviewee (Seidman, 2013). A big *aha* moment occurred when talking to one of the principals who had never connected her passion for STEM education with her experiences as a child. Dr. Rose pinpointed what she liked about science and remembered several different interactions with science education on her journey in the education world. Dr. Rose said, “I never even thought about that, but obviously, it must have been the science thing.” She expressed her passion for science when she spoke about some of her childhood experiences. As she dug deeper into her love for science, she shared her philosophy on teaching it. Once Principal Rose decided to become an educator, her love of science and teaching and her years of working in retail management enabled her to catapult into leadership within a few years of teaching.

Principal Myrtle described her role, saying:

> My role was to educate the teachers on how to make connections. They would have to present [and know] what their unit was going to be about. It had to align to the standard. Once they got the hang of how to create integrated units based on the standards, it became easier.

Each principal identified a few individuals who demonstrated a commitment to taking the lead in the implementation and sustainment processes at the classroom level. In some instances, the committed persons did not have their own classes, allowing them to cater to each class in the building. Aster received the title of "STEM Coordinator." She focused on helping others in the building without having to teach classes, a rare occurrence due to budget restraints. Aster shared her role in the implementation process: I would go to different conferences, different professional development. I directed the after-school program, creating the summer curriculum for the teachers and students that was centered around STEM. Those teachers helped me transition the rest of the teachers throughout the school year.

In other instances, the participants retained some of their classes while supporting teachers at times, such as during collaborative planning meetings. In each of the schools, the STEM teacher leaders received titles of STEM/STEAM Coordinators or Specialists to set them apart from the general teacher population. When asked about their roles in the STEM/STEAM implementation process, all the participants credited everyone doing their part. Some of the participants saw the work of STEM education flowing freely between everyone, while others saw a more well-defined process for themselves.

Willow, whose role was to aid teachers across the curricula with writing, explained her role during the STEM development and certification process and how her love for science was an important factor in that role. She said:

> When we were getting certified, I actually created a cross-curricular PBL that [combined] seasons, our urban garden initiative, and geography. My role was collaborating with kindergarten, first, second, and pre-K [teachers]. …[We'd] pull out the standards and our teaching guides, and we would see what community partners could come in and show what they knew in these different modes.

Hernandez (2014) studied STEM implementation to improve instructional practices of providing quality STEM instruction to students and increase teacher self-efficacy, which is a teacher's perception of their own ability. Hernandez indicated the need for elementary learning teams to positively impact teacher self-efficacy. The findings from my study also demonstrated positive outcomes for participants' self-efficacy. As a result, the participants in my study continued to collaborate as a structured group after certification, to improve both their instructional performance and student performance. The data from the current study consisted of details of the school personnel's collaborative efforts and how they were instrumental in the success of the implementation.

Each of the participants expressed STEM as important and necessary for students to receive a quality education. Aster was a STEM coordinator whose experiences with her own child in a STEM school contributed to her belief in the value of STEM education. She had the passion needed to ensure that team-building and planning were key components of the professional development process of incorporating adequate exposure to STEM concepts at her school.

Aster said that first-hand experience of the impact of STEM on students caused her to desire that same level of rigor at her school. She said:

> Students are used to learning things in silos, like science or math, but they really don't understand the bigger picture of how those things actually work together in the real world. They don't know the impact that STEM has on their life and in the real world. So, for me, I think for the urban student, exposure is the most important [for] STEM.

All STEM leaders in this study followed their passion for science into careers in STEM education. Each participant had characteristics conducive to becoming STEM educators. Their characteristics were similar to those of STEM teachers in other emerging STEM schools, and included "collaboration, flexibility, awareness of students' needs," and advocacy of equity and inclusion (El Nagdi et al., 2018, p. 1). The opportunity for each of them to become involved as STEM educators was unplanned but welcomed. Once into the profession, the women felt motivated by their passion to be the best STEM educators possible.

Theme 1, Subtheme 2: Passion Is Fuel for Meeting Expected Challenges

The STEM leaders in this study led the efforts in STEM education and gave convincing arguments for its value. Many supporters were invested from the beginning of the STEM implementation process; however, a schoolwide STEM culture cannot succeed without cooperation schoolwide and beyond. The process of getting stakeholders engaged is a time- and energy-consuming venture, albeit one that produced benefits for these

STEM professionals. However, many faculty members did not positively respond to change, and this resistance to school-wide, curriculum-wide change contributed to the difficulty of the implementation.

Schools in the process of STEM certification usually require at least three years to transition to full implementation. According to Fullan (2001), most organizational changes require three years for implementation. All the participants were leaders in their buildings, having firsthand experiences with other faculty members. The participants shared their perceptions of how they responded to the change to a STEM-focused school. The educators expressed the difficulties of the STEM implementation, which they found easier over time. Before the official certification review, STEM education was the teaching philosophy of choice for most of the teaching staff at both schools. The participants were individuals purposefully selected for leadership positions because the principals saw their passion for science. The leaders relied on such individuals to share their passion with the rest of the faculty to obtain buy-in.

Lily happily shared her perceptions, some of which mirrored that of the other participants. She managed the STEM lab for the lower grades at her school, and students and their homeroom teachers rotated through her lab every day. She described STEM certification as a process. She noted that implementation required three years because it necessitated “building relationships and helping people feel confident, and really understanding how it is beneficial.” Lily shared that the first year that they were building up to STEM certification, there was much resistance. As they got closer to becoming certified, that resistance began to diminish. And then, once they became certified, the majority of school personnel experienced buy-in. Now, when new staff are hired, existing staff informs them that, “it’s just the way our school operates. Our kids love it.”

Kasza and Slater (2017) interviewed educators from STEM schools in the US and found myriad challenges in STEM program development. The struggles mainly related to scheduling conflicts in big schools and creating a cohort approach to teaching STEM. Many of the barriers to STEM education, such as gender and economic inequality, have begun to dissipate due to increased STEM education and exposure. However, according to the Alliance for Science & Technology Research in America (ASTRA; 2017), 43.3% of boys showed an interest in pursuing STEM careers compared to 15.8% of girls. Furthermore, in Georgia, data indicate that Asian Americans demonstrate the most STEM career interest, followed by Whites, Hispanics, American Indians, and Blacks. Historically, the challenges obstructing the progress of STEM education have been the inability to motivate students to choose careers in STEM education (Wang & Degol, 2013), STEM teacher shortage (Hutchison, 2012), and the lack of knowledge of the importance of STEM education by individuals outside of the educational setting (LaForce et al., 2017).

When asked to consider the progress of STEM education from a historical perspective, the participants in this study noted that there is much room for improvement. They had various ideas about their challenges. Dr. Myrtle considered the difficulty in maintaining partnerships an important barrier to overcome:

> It’s hard to kind of maintain strong partnerships because a lot of the big companies, they want to come in and do the activity for PR or say, “Oh, we

> partner with Title 1 schools." So, maintaining the partnerships with those people who are really serious about helping us may be difficult.

Willow wanted to see more state and national focus on the standards with a cross curricular connection to help all teachers. She said, "At the higher level, it should be a requirement that teachers are helped and supported to actually implement integrated subjects into their classrooms because that's the only true way that we know that instruction is effective."

Aster expressed the need for more authentic assessments for students in urban schools. She stated with an emotional tone that overall STEM certification appears different for urban schools such as hers. She told me the STEM certification process for the urban school looks quite different from non-STEM schools. Her perception is that it was vastly more difficult for urban schools to become STEM-certified than for non-urban schools.

Aster summarized that the biggest challenge is making STEM a priority. Principal Rose expressed the need to take STEM certification for schools more seriously by putting more district level support mechanisms in place. She also shared that there should be more recognition of their hard work within the administrative level outside of the local school building, including from board members and politicians. Lily provided insightful suggestions for growth in STEM education. She said, "We've always been supported when it comes to materials or doing what's best for kids. But we also have the rigidity that is very common with lots of school districts."

Iris contended that all public schools in the nation should have some type of

STEM curriculum for preparing students for success in the many colleges already focused on STEM education. She expressed that the STEM cluster approach in her school district had a positive impact on the future success of STEM education in her school and in moving education into the 21st century; however, she wishes it could be a nationwide effort.

Each school had less-varied and less-pronounced internal challenges than external ones. Dr. Myrtle indicated the need to address challenges and barriers, including departmentalization at the third, fourth, and fifth grades. She shared that in order to make this happen, “We started to have the teachers who were science gurus lead that work. I wanted to make sure there was a strong leader, someone who’s passionate about science and inquiry-based learning.”

Willow saw several challenges and barriers related to a lack of flexibility in the curriculum. Dr. Rose’s biggest challenge was keeping the teachers motivated to do the necessary work because a STEM or STEAM school requires intensive efforts. When asked about the existing supports to address STEM barriers at the school, Principal Rose stated, “Support would be just having open communication. I have an open-door policy, and I feel like my associate superintendent is very much open, [so] I can talk to her.”

Lily thought that educators from all grade levels should sit down with the expected STEM standards and submit proposals annually for their pacing. She said: I don’t think that we should be bound to teaching guides the way that it has been done in the past. Having to do weather, for example, in first grade, in August, and having that unit end the second week of September doesn’t give children an opportunity to get the depth of the experience of that unit when all they're seeing is 100-degree days in Georgia.

Lily described getting more children involved in STEM after-school clubs and programs as another barrier. She explained that they have lost kids who truly wanted to be involved with the clubs and compete in competitions, but their parents could not afford to enroll them in the after-school care.

A challenge for Iris was time, she said, “because it takes a lot of time to really plan and implement projects that yield quality products and flexible grading.” She said, “It would be nice if we didn’t have to grade the STEM [projects] like we grade the other subjects. And then the kids could be freer.”

Theme #1 was obtained through the analysis of data collected in response to interview questions targeting answers to RQ #1-What are the lived experiences of school personnel at STEM focused elementary schools in an urban setting. Each participant expressed their passion for science and STEM education. A passion for science and STEM education was part of the criteria that the principals used for selecting the teachers for leadership and was a major motivation for the principals to take on the challenge of transforming their schools into STEM focused schools.

Theme 2: Daily Focus Guides Collaboration

The transition from a traditional school to a STEM school requires several changes. Each participant in this study described the collective nature of decisionmaking. Dr. Myrtle expressed the need for ongoing discussions about the budget, the materials needed by teachers, and how to improve the overall facilitation of programming. She also revealed having a STEM committee comprised of a grade-level person and a STEM specialist. She said, “We also have our leadership team composed of all the different content areas and subgroups to provide input. It's definitely a collaborative effort." Dr. Rose added, "Yeah, we collectively make decisions as a team."

STEM-focused schools have the added requirement of collaboration because the creation of the project-based, engineering design-focused lessons often occurs based on global occurrences and students' learning styles and abilities. Monitoring must be a regular practice to ensure effective teaching. STEM education has an added feature, as each lesson must have evidence of STEM inclusion aligned to the standards within the grade cluster and unit. Dr. Myrtle described one of the most effective practices, saying: A unit critique. They present their units to other staff members. [We] also have gallery walks. Once the student work is posted, grade levels will go to other grade levels to say, "Is it aligned, is it evident, what do you see?" We utilize Google Drive so [that the] coaches have instant access to what's going on. [We ask ourselves, "Is this] the story that we're trying to tell?"

Lily elaborated on monitoring STEM education practices and shared that she believes monitoring is an effective way of building capacity. She shared, "Sometimes, you find your own blind spots. You go and you look at a different grade level, and you're like, 'Oh my gosh, we didn't incorporate this. Or, 'Oh, we forgot to do that part.' It keeps you honest. The collaboration of all these great new ideas being shared is wonderful."

Theme 2, Subtheme 1: School Is Influenced by Community Structure

The elementary schools in this study were in different urban settings; however, both had locations in food deserts due to a lack of nutritional grocery stores. The schools' themes conveyed a desire to produce food and conserve the planet's natural resources. The theme for School 1 (Katherine Johnson) was, "Making a clean, green difference within ourselves, school, and community." The theme for School 2 (Mae Jemison) was, "We are the world, conquering hunger through sustainability."

The development of a school theme is a collaborative effort between school staff members and community stakeholders. A school theme is a requirement of the STEM certification process, so each school had one. Both schools had similar themes, which suggests that many urban areas have similar problems. A school theme provides the foundation for the myriad projects and problem-based lessons that educators develop throughout the year. Each participant provided the school theme without hesitation.

Principal Myrtle shared the strategies she used to help students and teachers see how STEM impacts the community and how they can contribute to that. She explained:

We have urban agriculture, for one [because] we [are] in a food desert. Then two, because we are in the city. That was one of the focuses of the city, to start having more urban agriculture resources. We do a lot of recycling. We have maker spaces. We're able to make new things out of old things. We have the traditional gardens.

Theme 2, Subtheme 2: Planning and Teacher Training

Burke & McNeill (2011) discussed the need for more STEM-educated teachers and a remedy for the STEM educator shortage. Primarily, Burke pointed to the need to educate teachers to transfer knowledge quickly to the classroom. He shed light on the complexity of helping elementary school teachers gain confidence in teaching science, as they must teach all content areas and usually lack proficiency in science. Burke also provided historical perspectives to illuminate the efforts made thus far.

Lily's feelings about teacher training were aligned with Burke's (2011) philosophy. She shared, "The expectations at our school are that we are open to feedback, that we are embracing a positive environment where the students are collaborating and leading the discussion." To help build teacher efficacy, she said, "Our teachers go to regular trainings. Any time that we have [professional development], our principal tries really hard to keep it in-house, so it is tailored to what we are doing." When they attend district-wide professional development (PD), regardless of the core subjects they teach, they are asked to take at least one science offering.

Kasza & Slater (2017) addressed best practices and key learning objectives for successful secondary STEM schools. They found that a flexible learning framework based on in-house curriculum developed by teachers with STEM backgrounds was a major factor in the success of STEM schools. The collaboration of teachers and the creation of in-house STEM curricula with a project-based learning approach are vital for engaging students in STEM (El Nagdi et al, 2018; Honey et al., 2014; LaForce et al, 2018). In the present study, the principals at each school ensured that PD days included offerings tailored to STEM and STEAM.

STEAM and STEAM program success requires a leader with a clear focus on STEM education. The test occurs in the classroom with the teacher and students. Many studies on STEM program success indicate teacher training as a high priority (e.g., El Nagdi et al., 2018; Icel, 2018; LaForce et al., 2017). In response to the shortage of qualified teachers within STEM content areas, President Obama (2009) announced a commitment to bolster the number of mathematics and science teachers and the importance of STEM education in the US (Burke & McNeill, 2011). The America COMPETES Act in 2007 provided funds for training 70,000 teachers in advanced placement and international baccalaureate courses and increasing the training and interest of college- and university-level students to pursue STEM degrees. Further demonstrating the need for STEM education, Burke & McNeill (2011) reported that private and nonprofit enterprises had provided donations of approximately $500 million. The federal government affords another $250 million for various STEM-related programs.

Theme 2, Subtheme 3: Master Schedule Preparation

Each participant believed that moving from a traditional to a STEM-focused school required a master schedule organized to enable full STEM or STEAM integration in all classes at all levels every day with weekly common planning. Participants suggested that a master schedule should include a common STEM planning block for content teacher integration while they teach elective classes. The schedule should focus on a project-based learning approach, which is a vital way of engaging students to learn STEM (Honey et al., 2014). Dr. Myrtle discussed the school's STEM blocks, saying, We have manipulated our schedule this year to have actual STEM blocks. Each grade level will have an hour and a half of STEM block. So, as much as possible, we try to integrate [STEM] throughout ELA and math and to pivot and have a STEM block. Dr.
Rose explained the process at her school. She said:

> They do explicit reading and math in the mornings, and after that, they do STEAM integration. When they go to the labs to see the upper- and lower-grade STEAM teachers, it's not considered a connection, where you take the kids and drop them off. It's co-teaching. I don't see how you can do it without having another adult in the room. It especially benefits the kids.

Theme 2, Subtheme 4: Curricular Development

One key feature of STEM-focused elementary schools that differentiates them from traditional public schools is the saturation of STEM into every school function. STEM saturation occurs in every classroom and receives support via community involvement, especially business partnerships. STEM saturation is a major requirement of the evaluation for certification as a STEM school which also accounts for the success of STEM schools in urban settings. Principal Rose said described the STEM curriculum. She said, “It’s standards-based, and it’s safe, and it’s relevant. I think teachers know that that’s what undergirds what we’re doing.” Each school in this study had systems in place to provide teachers and leaders with opportunities to meet regularly for planning to ensure that STEM curriculum was the focal point of each lesson every day. Lily described established teacher and leader involvement in STEM education. She stated her belief that the coaches do an amazing job of providing professional learning opportunities for educators to increase the rigor of their lessons.

Theme 2, Subtheme 5: Regular School Day

Across the US, school-aged children attend a form of school every day. The principal has the primary authority for making decisions about conducting school within each school building (Evans, 2003). Although each state has different regulations, many similarities have emerged in the best education practices over the history of public education (LaForce, 2017). STEM-focused schools have an emphasis on STEM throughout the regular school day. Both schools in this study were part of the same school district. They had governing criteria provided by the two agencies of STEM certification (GADOE and Cognia). Each agency provides a rubric of the non-negotiable activities for the working structure of the school (see Appendix F). A focus on the strategies and practices utilized in each school indicated several similarities and differences.

All six participants described a typical school day as smooth, organized, and laden with STEM-focused lessons. Although the educators worked at different schools, their days appeared similar, from arrival time to release time. The students at both schools wore uniforms each day and received a free breakfast and lunch. The study includes a detailed description of the typical school schedule at School 1, which resembles the schedule of School 2.

Dr. Myrtle described a typical school day. She told me the students have breakfast, then go to their designated reading room at 8:00. There is social emotional learning time that helps the students set an intention for the day, then they move into the instructional day. Enrichment is provided for students as co-teachers push in and out of classrooms with students. After school, the teachers have grade-level planning sessions or meetings discussing data that is used to plan for the following week. Dr. Myrtle's perception was that it is a family-oriented, organized school.

Willow noted:

> You will see lots of student-led learning. You see teachers taking a back seat and just facilitating the learning. You see lots of hands-on activities and group assignments. You will see students working outside, whether they're just sitting, whether they're observing, [or] whether they're exploring.

A few qualities unique to School 2 were the practice of daily hugs in the mornings during student arrival and the robotic school mascot that regularly roamed the halls. The remainder of the daily activities were nearly identical to school #1. A regular school day at a STEM school looks remarkably different from traditional schools due to the constant cross-curricular and problem/project-based pedagogy being utilized (LaForce, 2017).

Theme 2, Subtheme 5: Parent Connection

As a follow-up to *The Coleman Report* (1966), Harris and Robinson (2016) researched the role of parental involvement in setting the stage for academic achievement. *The Coleman Report* suggested that the home and immediate surroundings contribute to the inequality of educational opportunities, presenting minorities with disadvantages. Harris and Robinson found community and family support significant and that there was the least overall family support upon school entry that increased as students moved up in grades. They recommended "education and school personnel take more active roles in providing parents with effective strategies to help their children academically" (p. 199).

In the present study, the STEM leaders perceived parental involvement as significant. The participants prioritized including parents as much as possible. Each participant shared some examples of parent engagement within the schools. Willow and Aster discussed the various opportunities for parental involvement at their school, beginning with Parent University and the principal's tea at the beginning of the school year. The events provided the parents with oversight of the school year in a relatable and understandable way. Parents received information about how students receive support in STEM, with refreshers provided throughout the school year.

Willow and Aster also described the PBL unit showcases that occurred four times each year, to which they invited parents, as well as staff members from other schools and districts. Each school incorporated this practice. During the PBL, the students showcased and presented their work and projects. Many parents loved and attended PBL showcase nights. The participants reported PBL as the biggest parent engagement component related to STEM. Additionally, if the students harvested something from the garden, they had cooking demonstrations for parents to taste the food. Dr. Rose stressed the importance of connecting STEM to parent interaction, saying, “We do the STEM nights [and] math nights. Every time we have a PTA meeting or something, we’re talking about STEM and STEAM. We use social media. We use parent nights.” Lily also described parent inclusion, saying:

> Our parents are part of our stakeholder meetings… throughout the year. We have a parent liaison who is amazing. We also have a social media parent who collaborates with the adults in the building and pushes information out. And if we’re not getting enough engagement, she finds another platform. She and our parent liaison have been like the tag-team duo.

Lily continued, sharing details of the teacher–parent meetings that are regularly conducted. She shared that the grade levels pick a topic that they want to educate the parents on or for which there is an area of concern. The grade level teachers conduct a meeting with the parents so they can share what is being worked on in class.

Iris explained new styles of engaging parents in the learning process such as children learning about healthy options and taking that information home to their parents. She told me, “They learned the difference between buying organic produce and non-organic produce, what it looked like in the store, what numbers to look for on the little tag that they put on the food. And they started sharing that information with their parents". One of the parents quoted their first grader describing a fast-food restaurant menu, saying, "The only healthy thing on that menu is orange juice and apple slices."

Theme 2, Subtheme 6: Community Stakeholders

The involvement of community stakeholders in STEM-focused schools was a criterion for certification for both the certifying agencies (GADOE and Cognia) of the schools in this study. Community stakeholder involvement is one of the most important characteristics of a STEM school because it supports authentic, project-based learning. The ongoing recruitment of community partners at each school included an effort to incorporate some national policies, such as Educate to Innovate, a nationwide campaign for excellence in STEM education. The campaign's purpose was to improve STEM education through partnerships with nonprofit organizations and companies in the private sector to increase STEM literacy, enhance teaching quality, and expand educational strategies and practices. Companies, such as Time Warner Cable and Discovery Communications, and television programs, such as *Sesame Street*, included STEM on a large scale as part of the Educate to Innovate initiative (Burke & McNeill, 2011). Private and nonprofit enterprises and the federal government have provided millions of dollars annually for STEM education initiatives such as this one.

The community stakeholders who partnered with the schools in this study provided lifelines to real-world, relevant content that motivated the students to learn about the problems they aimed to solve. The two largest partners were businesses and postsecondary organizations, the former being the largest. The businesses ranged from small local businesses to large Fortune 500 companies with branches worldwide. The business partners provided expertise to support the STEM units taught throughout the year, and they participated in the planning of units at the building level. Partnerships are a requirement for STEM certification; however, it is a challenge to maintain those partnerships over time. Dr. Myrtle proudly described the school's more solid partnerships, saying:

> The ones who are really there, they attend some of the professional learning meetings with the teachers. They hear what they're learning and then provide support that way. They have to come in and hear where we are to see what we need.

Willow discussed some of the topics supported by the school's partners, such as urban gardening, landscape beautification, weather, and electricity. Company representatives came to the school to participate in creating and supporting ideas for PBL activities. Aster shared information about community partners before asked about the topic in the interview, describing how these partners supported STEM education and how she worked hard to keep them engaged. She said that it was important to show community partners that they are appreciate. At the end of the year, they always do a partners' appreciation and invite them to a luncheon. They have a presentation that the students organize, and they give them tokens of appreciation. They display their information on the school website to let them know that they're appreciated. She said, "It's not really money that we want from them; it's more so the time to just come and sit with our students or work with them on a project, and a lot of the partners love to do that."

Dr. Rose, leader of School 2, added that churches in the community helped with tutoring and noted the significance of grants. The school's partners supported STEM education by paying for field trips and sending people from their organizations to talk about how they used STEM in relevant ways in their careers. In-kind donations of goods, services, and free admission to organization-sponsored events were also major contributions.

Theme 2, Subtheme 7: District Support

STEM education is a high priority at the local, state, and national levels (LaForce et al., 2017). Some districts have policies for STEM school clusters and maintaining the STEM pipeline between elementary, middle, and high school education. The elementary schools in this study were integral members of a STEM cohort that received district-level support. Willow described her school as one of the first within the district to focus on STEM, saying, “It was new to everyone.” The leaders at her school had to navigate this new initiative and then assist others in doing so as well. Upon gaining momentum, they began inviting district personnel to the school to support them in their planning sessions.

Dr. Rose described the district’s support for the framework of the STEM program within the cluster of schools to which they are connected. She explained that a district leader supports the schools by recruiting different community/business partners to complement the overall focus of the school and provide additional money and other resources for schools that receive STEM certification. Dr. Rose said:

> [The schools receive] autonomy at the school level to use school funds to support school initiatives. We are encouraged to respond to our individual community’s wants, needs, and directions, which is why it’s a collaborative effort to get there. There is more to be desired at a higher level and in the area of marketing to share the good news on a wider scale than what has currently been done.

This second theme of daily focus guiding collaboration was developed as a result of the researcher seeing how important collaboration was to each participant. This theme aligned with RQ #1 and #2 because collaboration was a strategy used on a daily basis throughout the implementation phase to transition each school to a STEM-focused school. The practices that were performed on a daily basis supported the collaboration effort and helped the entire faculty reach full immersion of a schoolwide STEM pedagogy.

Theme 3: Success Becomes Evident

Success is one of the most difficult aspects to describe about a program, as people perceive success in different ways. One of the largest successes, according to participants, was students' increased confidence and excitement about STEM education. As a result of increased confidence, the students themselves changed, the school culture changed, science proficiency increased, the schools became STEM-certified, and academic celebrations became a part of the culture. Having an expectation for these changes may equip new STEM program developers with the need to make room for success from the beginning of the program.

Theme 3, Subtheme 1: Students Change as a Result of STEM

Teachers who receive professional development for teaching STEM-related content are more confident in their teaching ability, which causes increased student confidence in learning (Nadelson et al., 2013). That confidence spilled over into student success. Lily shared an example of the success of her school. She said, "Our kids take ownership." She shared a situation when they were learning about life cycles and gardening. One student shared the observation that worms don't have bodies like other animals and wanted to know how they have babies. Lily said, “That's a really good question. I have no idea. You know what? You should figure that out and teach me.” She said he came to school the next day with a descriptive and thorough explanation.

Willow described her experience with peer tutoring as an indicator of the success of the STEM education program at her school. She said:

> [Peer tutoring is] very beneficial, especially considering the [curricula] they’re crossing, so although first and second grade may only be studying impact to the earth, fifth graders are telling them what those impacts are, the specific names of those impacts, and how they’re caused. They just kind of teach each other, so it’s really helpful.

Willow also described the students’ success in mastering the engineer design process for learning, saying that even though the students may arrive at an incorrect answer, what is most important is that they follow the process and are leading their own thinking and learning.

Theme 3, Subtheme 2: School Culture Changes

Success as a result of STEM education is a variable that is hard to measure since it is often unknown whether a student’s success is school due to other factors (National Research Council, 2011). STEM certification is one event that may occur at a school with leaders that have managed to change from a traditional school to a STEM-focused one. Once certification is achieved, the school faculty considers themselves to be fully immersed in STEM.

Dr. Rose shared that her students had become so entrenched in the STEM culture that it influenced what they did outside as well as inside of the classroom. She shared that they do a lot of competitions with students, such as robotics competitions. Since art was added, making it a STEAM school, the students in Dr. Rose's school won first place at the state competition in drama. She spoke about a play that the students performed about protecting Mother Nature, that contained elements of science and the arts. The staff also brings students on different STEM and STEAM field trips, both in-state and out of state.

Each year, one of the biggest events is taking the fifth graders to Washington, D.C., to the different Smithsonian museums. They had raised the funds and were supposed to leave on the Thursday that the district shut down due to the COVID-19 pandemic.

Willow described the two most effective practices that were permanent parts of the STEM program experience:

> One, students have reflection journals. They just talk about their thinking. A lot of times, you can see if they grasp the concept or not. That's one way that we are assisting the learning of the students. Two, teachers actually allow the students to lead their learning. When we have our PBL night, we have lots of visitors in the building, and students are ready to tell you from beginning to end how the project began and where they ended up.

Iris described the integration of STEM into the fabric of the school. She spoke about the creation of a STEM culture:

> You can feel that it is a STEM school authentically. There are displays that are created around our schoolwide initiative which is, "We are the world conquering hunger through sustainability and creativity." Music is integrated with science and math, and our art teacher integrates art into the science.

Theme 3, Subtheme 3: Academic Proficiency Increases

Several different scored criteria are the means of measuring school success each year in Georgia. EOG scores are the main evaluation tools used to measure student proficiency in core subjects in elementary schools. (See Table 2 for the results of EOG testing in the two schools in this study.) This study's findings align with the claims by Anderson (2017), Becker and Park (2011), and Bencze (2010), who found that students whose teachers exposed them to STEM integration excelled academically on standardized tests compared to students who were not exposed to STEM integration. Each school in this study had received several accolades since the inception of its STEM programs. Increased student proficiency in any core subject is a reason to celebrate. Although the state's major focus was increasing math and ELA proficiency, the goal of STEM schools is to help students become proficient in science, which is an indicator of success for the STEM program. Both schools in this study showed increased science proficiency, as indicated by the fifth grade EOG science scores for the three years since STEM program implementation.

One of the goals of this researcher was to share the strategies and practices that school personnel used to increase science proficiency at their urban Georgia elementary schools. Willow described what she thought was the reason for improving science scores. Her observation was that they led with science. She could see that her students were able to grasp a larger and a more conceptual understanding of the topics, such as following procedural steps, making connections, and having arguments about their academic convictions. They focused largely on the claims, evidence, and reasoning (CER) method.

She shared that the vocabulary is rigorous, therefore, they have to ensure that they center everything around that and continue to allow the students to draw their own conclusions. Then she added, “We just allow the students to take charge.”

Dr. Rose believed that her school had the most success in implementing the STEM program “[because] the data shows [*sic*] that the kids are able to do a better job on that fifth-grade science test [than before we became a STEM-focused school].” She explained the reasons for the rising scores:

> Actually, making time in the schedule to actually teach relevant and authentic science has really helped children and motivated children to want to learn. It has shown tht they want to come to school now. Engagement is high. They want to do projects even though we don’t ask them to. Parents will come in after the weekend sometimes and tell me, “So-and-so and I worked on this. We started a garden.” Those types of things that sometimes you just can’t measure quantitatively. That shows me that it’s successful.

Theme 3, Subtheme 4: Schools Become STEM-Certified

Lily revealed that she used the checklist used for school STEAM certification throughout the year to sustain the program’s success. The rubric was a way to stay on track to gain certification for the STEM planning stages at the elementary schools in this study. Two agencies provide STEM certification in Georgia: GADOE and Cognia. The GADOE-supported STEM Georgia standards directly connect to the GADOE website, and the STEM coordinators hired by GADOE professionals play key roles in the certification process. Cognia (formerly AdvancEd) is a private, nonprofit company based in Georgia that provides STEM certification for schools nationally and internationally.

Cognia partners with schools in the process of certification to assist in the certification process and certification maintenance.

Each school in this study had received Cognia STEM certification. One of the schools received certification through GADOE for STEM and STEAM. The school with both certifications was one of the first elementary schools to receive the new levels of Cognia certifications, resulting in what they called the triple crown of certification.

Due to the amount of energy required to maintain a successful STEM program, a natural culmination of the process is to celebrate the success. Public schools have limited ability to celebrate. Both schools in this study underwent a slow progression from STEM days to STEM weeks and then to STEM units before transformation into year-round, STEM-focused schools. There are many ways to reward the hard work of such a process. The personnel from the schools in this study expressed their appreciation for the participants in the process by:

1. Treating the certification evaluators like guests in their homes.
2. Treating the community partners to a yearly appreciation program at the school with the students taking center stage to share what they have learned.
3. Providing opportunities for parents to come to the school during PBL nights to learn from their children about what they have learned.
4. Rewarding students with the privilege of being the student innovator of the month.
5. Providing students with the opportunities to attend field trips and competitions, both locally and out of state.

Theme 3, Subtheme 5: Academic Celebrations Are Built in

The participants shared the ways that they celebrated success at their schools. Dr. Myrtle said, “We have the science fair at school [and] a technology fair. We’re always acknowledging the efforts that the students are doing. Then, of course, [on] PBL night, [that’s] when we really celebrate the students and acknowledge their work.” Aster stated:

> We have STEM student innovator of the month [to] highlight students who have been very innovative in their thinking, whether they’ve designed something or they’ve had an innovative idea about something. They have their own little video PSA segment that comes on. They’re highlighted in the hallways with QR codes for their interviews out there so anybody who's walking by can just scan the QR code and listen to them.

Dr. Rose said, “We actually let teachers come up with ways that they want to celebrate and showcase. We happen to have an indoor amphitheater where we put on shows. They do a lot of videos showing their projects. It’s done in a lot of ways. Lily stated, “It’s just giving an opportunity for kids to share. …We have kids perform at assemblies. We have some amazing singers [here], which blows my mind. Whatever type of intelligence they have that they want to showcase and show off, we provide a platform for it.”

The third theme that success becomes evident was perhaps the most surprising of all, because success is not always an expected part of a school’s culture. Indicators of success were mentioned by each of the participants. They proudly shared success stories including those about students wanting to come to school, taking the initiative to carry out projects from home and getting their parents involved, asking questions and showing confidence in answering questions. Success was on display throughout the hallways, which showcased student work. Participants also claimed that success was evident based on the nature of the student-centered classrooms, and the peer tutoring taking place within the school. STEM certification and an increase in science proficiency was a required strategy for inclusion for each school. Each of these accomplishments helped make success evident from the beginning of the study, however many of the successful practices helped reveal how each strategy was achieved. An understanding of these strategies and practices helped the researcher answer RQs 2 and 3.

Summary

The STEM/STEAM certification journey of two urban Georgia elementary schools was examined through the lens of participants who provided a plethora of thick, rich data. Other educators, community partners, and policymakers may use this information to help level the playing field of STEM education and certification by incorporating some or all of the strategies and practices in their own settings. STEM program development is a time- and energy-intensive process that requires passionate, committed, STEM-focused teachers. The school leaders expressed their belief that STEM education is the teaching and learning method of choice for students and teachers. This study provided evidence to support the literature that elementary school students in urban settings can become science proficient. This chapter presented the three themes that emerged from the data: intrinsic passion ignites effective leadership, daily focus guides collaboration, and success becomes evident. The researcher explained how the themes aligned with the research questions. Chapter VI provides a discussion of the results and implications of this study.

Chapter VI CONCLUSIONS AND IMPLICATIONS

Seniors graduating in Georgia have low proficiency in science (gosa.georgia.gov, 2015–2019) even though the rate of high school graduation is steadily increasing (GADOE, 2021). Minority students in urban elementary schools have struggled to meet standardized test requirements since 1954 (Parker et al., 2015). However, students whose teachers introduced science, technology, engineering, and mathematics integration have excelled on standardized tests compared to those not exposed to STEM integration (Anderson, 2017; Becker & Park, 2011; Bencze, 2010). This parallel has warranted a national strategy for exposing students to STEM topics throughout their educational careers (McClure et al., 2017). I interviewed school personnel to answer the following research questions:

RQ1: What are the lived and career experiences of school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ2: What strategies are used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

RQ3: What practices are used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

The explanatory research approach (Merriam & Tisdell, 2016) was appropriate to better understand STEM education in Georgia's elementary schools. I used a constructivist approach to collect information on STEM program development that was inclusive of the participants' life and career experiences and their strategies for and practices of creating a sustainable STEM culture in elementary school. Some researchers claim that the best place to begin STEM education, with continued exposure throughout a student's educational career to identify potential "STEM innovators," is in elementary schools (CoSTEM Education, 2018). When developed into STEM schools, elementary institutions can provide a productive learning environment for students that also meets the need for increasing exposure to STEM pathways (Erdogan & Stuessy, 2015; Kasza & Slater, 2017). Cotabish et al. (2013) described this early integration as a potential motivator for students to want more STEM. A goal of this researcher was to expand on the existing knowledge base regarding STEM education in elementary schools, in order to help identify methods to better prepare students to eventually embark on STEM careers.

I used purposeful selection (Creswell, 2014) to identify school leaders who could provide the data pursued through this qualitative case study. Snowball sampling (Patton, 2015) was the means used to obtain more participants who could substantiate and validate the information given by each school's leader. In-depth interviews, document reviews, and researcher memos provided the data for this study. Three-part interviews (see Seidman, 2013) were embedded into the interview protocol (see Appendix C), allowing me to answer the three research questions and correlate the findings with the guiding conceptual frameworks.

The conceptual frameworks were the CBAM (Hall & Hord, 2001) and Fullan's (2012) change model. After data analysis, I organized the data into three conceptual themes: (a) intrinsic passion ignites effective leadership, (b) intentional focus guides effective collaboration, and (c) success becomes evident. These themes aligned with the literature on STEM education. The study's exploratory nature may help this researcher and other educators develop a roadmap to STEM certification.

Although the six participants were from two elementary schools, they had similar experiences that resulted in data saturation and confidence in a theoretical model for STEM program development. All participants richly experienced the themes that emerged from this study which provided critical data to answer each of the research questions for this study. Table 4-displays the result of this comparison.

Table 4

Relationship Between Themes of School Personnel and Research Questions

Themes	Evolved From Research Question	Participants					
		Myrtle	Willow	Aster	Rose	Lily	Iris
Intrinsic Passion Ignites Effective Leadership	RQ #1: Life and Career Experiences	●	●	●	●	●	●
Daily Focus Guides Collaboration	RQ #2: Strategies RQ#3:Practices	●	●	●	●	●	●
Success Becomes Evident	RQ #2: Strategies RQ#3:Practices	●	●	●	●	●	●

Research Findings

Each of the educators in this study held leadership positions in the elementary schools where they worked. The principals assumed their leadership role before the development of the STEM program. The STEM coordinators and STEM specialists obtained their leadership roles because of the STEM program development and were all traditional elementary school teachers before STEM program development. In Georgia, the GADOE recommends beginning STEM program development at the elementary level. The goal is to increase the positive pressure for middle and high schools to promote STEM-educated students to higher education levels. This plan was revealed in a conversation by the STEM director for the DeKalb County School District (A. Wright, personal communication, October 19, 2020).

This study's findings enabled the identification of several significant components of a STEM-focused curriculum in urban elementary schools. The components emerged as developmental levels within the STEM implementation process and became this study's themes: (a) intrinsic passion ignites effective leadership, (b) intentional focus guides effective collaboration, and (c) success becomes evident. These development levels correlate with Fullan's (2012) change model, part of the conceptual framework for this study. The change model has five parts: moral purpose, understanding change, relationship-building, knowledge creation and sharing, and coherence-building. The following paragraphs summarize how the findings in this research align with Fullan's model of change.

A moral purpose for this study is to provide an engaging way for students to learn and therefore increase racial, social, and gender equity in STEM education. Moral purpose seemed to fuel the intrinsic passion in the interviewed leaders. The passion of each leader is linked to effective leadership and the first research question: What are the lived and career experiences of school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

My first finding is: STEM education requires dedicated individuals in leadership roles to support STEM leaders. Each STEM leader interviewed expressed a strong belief that STEM education is the best way to educate students and each had significant enjoyable experiences with science early in their lives. Five of the six knew they wanted to become teachers as children but followed a different path before their intrinsic passion led them back to teaching. Fullan (2001) emphasized putting the best person on the problem or in the leadership role as a part of the change process. Each principal in this study was able to identify dedicated individuals with a strong interest in science to serve as teacher leaders. This interest proved to be necessary for the STEM leaders facing pushback from other faculty and enduring intensive planning for integration opportunities. Principal Myrtle shared her experience:

> We started to have the teachers who were science gurus lead that work. Although we're integrating in the other content areas, a lot of times, science would lead the units, and I wanted to make sure there was a strong…someone who's very passionate about science and inquiry-based learning.

Once there was agreement with the curriculum, school leaders almost universally saw the benefits of STEM education for students and teachers. Teachers often grew from novices to experts and then expressed a desire to share STEM education wonders with others. This finding is similar to what Nixon et al. (2019) noted in a study about elementary teachers' science subject matter knowledge. Nixon et al. also found that teachers' knowledge of their subject area was vital for educating students and working together with other teachers. Content knowledge and pedagogy emerged as strong collaborative forces for effective teaching. The intentional selection of teachers with strong science backgrounds or experiences helped provide a strong foundation for the STEM programs studied by bringing in teachers already primed and ready for STEM education. Fullan (2020) considered purposeful selection a key ingredient in finding leaders committed to capacity-building within the organization.

Van Driel et al. (2014) stated that educators must keenly understand the subject matter they are assigned to teach after taking a close look at science teacher knowledge. However, this is not an easy feat for elementary teachers who are often expected to teach all of the content subjects themselves and require PD to stay current (Donna & Hick, 2017; Wheeldon, 2017). When PD is necessary to get teachers current with content, it is most effective to focus on training them just what they are required to teach instead of full-spectrum content (Bullough & Smith, 2016). It appeared that cross-curricular planning and in-house professional development worked well within each STEM school in this study, providing a family atmosphere and a strength-in-numbers effect as they attended to the PBL at hand. Willow explained:

> Every one of our units start[s] by addressing a problem…and allowing them to work backwards in circumstance. We use an engineering design process to actually go through each phase and go through each subject. We make sure that we also include the specials teachers. They play a part in everything. …You get a

music portion, an art portion, Spanish. We try to make sure that it's inclusive of all stakeholders in the school.

It was clear from talking to the STEM leaders that a specialist released from classroom teaching is best to lead the program; however, the seasoned, passionate classroom teachers in this study also seemed to do quite well. Each STEM coordinator or specialist demonstrated a common key component of working together for the staff's and students' benefit. A candid conversation provided insight into the issue. Dr. Myrtle recalled when the STEM specialist suggested she take a more active role in supporting the STEM coordinator. She explained her rationale, "So, [initially], I was kind of like, you do STEM, and I'm going to do everything else." Maybe the third year in, she pulled me in, and she was like, "Dr. Myrtle, I need you to help me." Dr. Myrtle soon realized that the only way to make it happen was if they talked the same talk, so the faculty knew that the ideas were not just coming from the STEM specialist.

Dr. Myrtle began to see improved Georgia milestone assessment scores increase once she fully engaged in the STEM philosophy and started to manipulate the schedules and the curriculum to echo that importance. She also observed decreased rates of suspension and negative behavior, which she attributed to the high level of student engagement. She said, "STEM was not what we did; it was who we are. That made all the difference in the world when I really embodied what STEM is."

STEM leaders who embrace the STEM philosophy can spread the passion to other faculty members. The teachers who demonstrated the most passion for STEM education shared their love with others in the building. This finding aligns with those of

Owens (2014) and Tofel-Grehl and Callahan (2014), who found skilled STEM leadership necessary for influencing curriculum development and teacher preparation to support STEM programs. Some of the ways the STEM coordinators and specialists supported the other teachers were by participating in weekly planning sessions, assisting with PBL nights, recruiting community stakeholders to help with planning, providing activities to support the curriculum, and seeking opportunities for students to showcase their knowledge. When asked about the supports in place to address STEM barriers at her school, Willow, a STEM specialist, responded, "Ms. Aster. She's in place." Such a statement indicated a clear focus on the need for passionate faculty members dedicated to school-wide STEM education. Ms. Aster had written a grant and received $350,000 per year for five years to support implementing a STEM program at her school. The principal later allowed her to come out of the classroom to facilitate the STEM program development process.

STEM education requires dedicated individuals in leadership roles to support STEM teachers throughout the building. There is a national need for more STEM focused teachers (Kelley & Knowles, 2016) to deliver STEM education to more students. This study's findings provide evidence for a need for the intentional selection of STEM teachers and leaders who have an intrinsic passion for science that can ignite effective leadership potential within them.

All chosen STEM teachers were able to acclimate to their roles once selected. They effectively supported their fellow teachers and staff members to obtain STEM certification within three years after the transformation initiation. The intentional selection of the participants by their principals seemed to be effective in this study and led to the collection of thick, rich data during the interview process.

The participants' experiences indicated that STEM exposure and education must become more prevalent in education and daily living experiences to create a culture of inquiry and analytical communication skills. It is necessary to provide a society of individuals who can create products and experiences that will help to meet 21st-century living and working challenges. An increase in STEM teachers on all levels may support this effort. STEM teacher development will increase due to changes in instruction and actions directly linked to achievement (Fullan, 2020) and should be monitored throughout elementary, middle, high, and postsecondary school. The data collected as a result of these assessment elements will build public confidence in the widespread presence of STEM education and help fill the gap in documentation about STEM education progress (Honey et al., 2014; Kasza & Slater, 2017)

My second finding is: collaboration and PD are necessary components of STEM programs. This finding correlates with my second theme emerging from this study: Intentional focus by STEM educators guides effective collaboration that drives the planning process and involves intense PD to prepare teachers for the forthcoming changes. Each STEM-certifying agency has specific criteria required for qualifications. The outline or rubric with this information is useful for each school considering embarking upon the STEM certification journey, serving as a guide throughout the process and beyond certification.

Each of the STEM leaders in the participating schools visited other schools and attended conferences to learn as much about the STEM education process before educating others in the building. Unfortunately, there were not many examples within their school district, so they had to venture out to other districts and then bring the information back to their building. Principal Myrtle explained:

> We would go anywhere that had a STEM-certified school. The STEM specialist would reach out to them for their permission for them to visit their school and see their implementation strategies and results. Then we just made it our own. So, it has definitely been a long journey." Now, each participating school is a site that others often visit to see what a successful STEM school looks like.

Collaboration and PD are also integral components of relationship-building along with knowledge creation and sharing. The leaders gave specific examples of how they went from teaching in silos to integrating content through daily PBL. Collaborative planning and implementation allowed for inclusion and buy-in from teachers; both groups of leaders described it as a significant part of their STEM education journey. The early aspects of program development included a pivotal point when the schools had to determine the overall theme for their STEM program. School 1 chose "Making a Clean, Green Difference within Ourselves, School, and Community." School 2 selected "We Are the World and Conquering Hunger Through Sustainability," adding Creativity two years later when they decided to add the "A" to become a STEAM school. The school themes served as a framework for knowledge creation and sharing through PBL activities, which are continuously selected and developed to enhance students' understanding of the content. The leaders designed the themes to coordinate PBL experiences with some of the natural phenomena in the community.

When the focus is on transforming a school from traditional to STEM-focused, the need for PD intensifies. Many STEM education scholars have cited a lack of PD (Owens, 2014; Turner, 2013). In the book *Teacher Professional Development: An International Review of the Literature*, Villegas-Reimers (2003) listed various reasons for PD. The chapter for policy implications and recommendations contains the itemized reasons. Four of the 15 recommendations had a direct correlation to this study:

1. PD for teachers must be a long-term process that begins with initial preparation and only ends when they retire from the profession.
2. PD for teachers has a significant impact on the success of educational reforms and student learning. The more opportunities teachers receive to be subjects and objects of education reform, the more significant the reform and the teachers' work.
3. There is a need to recognize that the courses cannot or should not address all aspects of teacher PD. Many models of PD provide support for regular development in the workplace.
4. Teachers must have a variety of PD models and techniques.

Teachers in STEM-focused schools require a unique pedagogy obtained through continuous PD to impart knowledge of content and confidence in teaching methods. The teachers design daily lessons to incorporate processes, meaning, and to emphasize technology's importance across disciplines (Anderson, 2017; Becker & Park, 2011; Cotabish et al., 2013). It can take several years to see consistent evidence of the impact on teaching and learning (El Nagdi et al., 2018). Robinson et al. (2014) and Keeley

(2009) argued that teacher PD and PBL curriculum are vital to cultivating young minds. In this study, the development of the STEM programs took place slowly, and the addition of new features of STEM pedagogy, such as after-school programs and STEM days, occurred based on readiness. Afterward, there was progression into STEM weeks and STEM units. The teachers and leaders had to rewrite the curricula to coordinate with the problem-based units and to connect problems in the community. PBL nights increased in complexity and included workshops and cooking demonstrations with plants from the garden. Career week included business partners, due to growing community partnerships. The participants continued to use the rubric to prepare for certification because it had a built-in blueprint for success.

PD provides teachers with professional habits, such as daily focus, for collaboration with clear plans for the curriculum. Research indicates that there is strength in numbers needed for a team effort for STEM education (Owens, 2014; Turner, 2013). Fullan (2001) also stated that facilitating change is a team effort. Representation from different grade levels and disciplines at the planning stage contributed to the successful creation of unit plans for six weeks in each participating school. The plans are roadmaps to focus on an established outcome that often includes the answer to a question or the solution to a problem.

PD also provides training for facilitating planning sessions so teachers can compare their progress with others and learn how to improve. Additional highlights of dedicated STEM leaders throughout the school include facilitating peer and self-evaluations and cross-grade evaluations to identify areas of distinction and improvement. Several teachers in this study mentioned the effectiveness of evaluations in generating ideas and finding deficiencies in their methods. The cross-grade evaluations resulted in upper-grade students peer tutoring the lower-grade students because the teachers saw the connections between their standards and content, especially when working on similar problems. Willow shared that she considers peer tutoring to be very beneficial. She explained:

> Although first and second grade may only be studying [the] impact to the earth, fifth graders are telling them what those impacts are, the specific names of those impacts, [and] how they're caused. They just teach each other, so it's really helpful.

The cross-grade collaboration included inviting middle school teachers to elementary school planning sessions to continue where the elementary school teachers left off. Cross-grade collaboration has advanced to inviting middle school teachers to elementary school planning sessions. Their involvement helps them learn more about the elementary school curriculum, so that middle school educators can continue where the elementary curriculum ends.

STEM education program development requires time and energy to create, implement, and sustain. Several participants revealed that implementing a STEM program takes at least three years from initiation to implementation. This information is critical for individuals considering embarking on the STEM implementation journey in order to plan realistically. The three-year timeline is necessary because reaching proficiency in science and other content areas requires an abundance of practice by both students and teachers. Built into these three years is a plethora of PD to acclimate teachers to teaching science, technology, engineering, and math in an all-inclusive manner and to continuously incorporate PBL throughout the STEM-focused regular school day. A capstone of the STEM program development is the inclusion of parents and community stakeholders throughout the process. Despite a lack of literature to highlight parental involvement in STEM education, there is frequent mention of community stakeholder involvement and need in STEM education. Fullan (2001) stated that using data and providing mutual support among community partners can sustain an organization's change efforts.

Individuals attracted to STEM education at school and community levels often express a morally influenced desire to provide quality education to young people that intensifies with time. Fullan (2001) suggested combining the community partners' and schools' high expectations as a catalyst for coherence building, which is the final stage in the change process. Fullan recommended that leaders prioritize needs common to internal and external organizations to avoid overwhelming the process. Each participant could identify several stakeholders who had helped them transform their school culture from traditional to STEM.

The participants indicated that some of the same information included in the evaluation rubrics for STEM-focused schools should become a part of all schools' evaluation processes. The current CCRPI presently used as a school's report card should expand to comprise some of the STEM evaluation elements. It could help provide a foundation of positive influences on traditional education and remove all excuses (Fullan, 2012) for the lack of critical thinkers and problem-solvers in society.

The third finding in this study was that STEM education was a preferred learning method for teachers and students. The participants shared their belief that STEM/STEAM education is the best way to teach students. Principal Rose shared that she thinks STEM is good for all students, but, more importantly, for children who may not be able to make that connection with what's going on in the textbook. She stated:

> You can't always align [learning] to a standardized test score. My kids are brilliant. Maybe the test scores don't capture everything that they know. What I do know is that when they are engaged in STEM hands-on project-based, problem-based learning, it makes sense to them because it's relevant and it's authentic.

This study's results contribute to the idea that exposure to science at an early age provides students with an advantage. The findings are also aligned with those of McClure et al. (2017), as each participant expressed that hands-on, authentic learning opportunities were ways to make STEM education more enjoyable. Principal Rose shared: [STEM] has really helped motivate children to want to learn [and] they want to come to school now. Engagement is high, so that's a success for me because they want to come to school. They want to do projects even though we don't ask them to do projects.

Although younger children may want to learn, older students demonstrate less passion for learning (Morgan et al., 2016). Young children exposed to PBL and CER learning models show considerable increases in excitement (McClure et al., 2017). Morgan et al. (2016) correlated early learning experience with later success in science, finding a direct relationship. Unfortunately, Cuban's (2013) national survey of teachers showed that only 19% of K–2 students received daily science content instruction. Knowing that students learn best with science instruction may be the motivation that teachers need to provide daily science instruction. Lily described this as "that full-on growth mindset," continuing:

> I know [that] before STEM, I felt confident once I learned my standards and I knew the process, and I knew what was expected of me. After STEM, you don't know what's coming next, and that's half the fun. You know this is going to be a challenge, and you know that your lesson might fail, and that's okay.

The participants' shared experiences suggest that using PBL to solve real-world problems in the community provides students with a sense of pride and excitement. The participants discussed situations of students going home and sharing what they learned with their parents without being asked. Students educated their parents about the lack of nutrients in fast food restaurants that dominate their neighborhoods, creating food deserts. In their research about the highly engaged classroom, Marzano and Pickering (2011) found that involving students' emotions was a way to increase engagement and retention of the studied concepts. In this study, the students and teachers enjoyed STEM education programs due to their inclusion of after-school programs developed in collaboration with postsecondary schools. As well, many science enrichment activities were blended into classroom teaching experiences throughout the regular school day to reinforce learning and make it fun. STEM education is an ongoing process because challenges for improvement often occur alongside the products created in PBL activities when using the engineering design process.

This study indicates that an increase in STEM education in urban settings can provide equity and give teachers the background and training experiences for STEM through PD. STEM schools are significant assets to communities because they often provide a pipeline for young people to get into postsecondary education. STEM schools also foster STEM career opportunities, including internships and apprenticeships, before high school graduation (Smith et al., 2018).

The fourth finding in this study is: Celebrating success is an important component of STEM education. The participants reported evidence of success in STEM-focused schools, including community partnerships, solutions to systemic and community problems, STEM program certifications, and increased science proficiency scores on standardized assessments. Principal Myrtle noted that one of the most valuable aspects of STEM education for her was that "students are learning without knowing they are learning through planned activities and experiences."

The entire implementation process usually takes about three years, which is the same amount of time that STEM Georgia and Cognia recommend a STEM program be in place before seeking certification; evidence of each step must be apparent and documented. Willow expressed how she felt about the certification process:

> The program has definitely strengthened based on the school's personnel, and that's just simply everybody getting acclimated with the new idea of seeing and planning for STEM, implementing STEM, and just understanding what STEM [is], because the hardest part is getting everyone on board to try to understand and try to implement this new way of learning. So that has helped to improve on implementation and student success because the teachers bought into it.

Coherence-building is the final stage of Fullan's (2012) change model that signals that the intended change has been successful and in line with the overall organizational culture. Throughout the implementation process, culminating activities, such as celebrating the successful completion of a project, occur to reward the students' and teachers' hard work.

The participants' experiences indicate that coupling success with celebrations reinforces the importance of occurred actions. People remember the celebration first and what it was about second. There is a lack of literature about the role of celebration in education. The schools involved in this study made culminating events and celebrations of success a regular part of their school culture. An increase in celebratory activities in education could require a restructuring of priorities and more data that show the celebration's positive impact on academic accomplishments. When asked about how they celebrate success, each participant had something to share. Dr. Myrtle revealed, "It's showcased throughout the hallways." Willow said that success is evident by having "an innovator of the month."

The STEM coordinator, Aster, shared a plan for celebrating success within the school. She related plans for next year, which incorporated:

> Teacher ambassadors where we have a trophy…[for] teachers who are showing dedication to STEM and STEM learning. [The] trophy would travel each month to that highlighted classroom or teacher, just to keep up the momentum and the motivation.

Lily disclosed some of the things she believed promote success within their school. She said, "We have kids perform at assemblies. We have some amazing singers, which blows my mind. Whatever type of intelligence they have that they want to showcase and show off, we provide a platform for it." She added, "Our kids take ownership, and they take ownership in a way that is not connected to academia. They take it to the community."

Finally, parent advocacy and raised expectations are evidence of success. Some parents return to the elementary school to get help for their middle-school child who they feel is not getting the same rigor and relevance at home. Iris saw this happening so much that she took on the responsibility of helping some of the parents of her former students identify schools equipped to maintain the same level of rigor and engagement to which they had become accustomed. However, she said, it was not easy.

The ultimate evidence of success for each of the participating schools is STEM and STEAM certification. School 1 obtained STEM certification from Cognia; School 2 obtained STEM certification from Cognia and STEM and STEAM certification from the GADOE. All six participants spoke about the certification process in detail. Although the process was challenging to everyone, invested educators at the school, district, and state levels considered it well worth the effort.

In this section, STEM leaders shared their experiences of direct contact with students during the implementation process. These experiences led to four major findings that were explained in relation to the conceptual frameworks used to guide the study. Several recommendations emerged in support of STEM programs and future program development. This small beginning can serve as a blueprint for the expansion of STEM programs on the elementary, middle, and high school levels in school districts throughout the US.

Research Questions: Summary Discussion

This study provided the opportunity to examine the participants' lived experiences and the strategies and practices that they used at their schools during the STEM implementation process. This section presents a discussion of the research questions and the findings.

RQ1. What are the lived and career experiences of school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

The first research question addressed the participants' lived and career experiences to better understand why they chose careers in education that caused them to serve as leaders in STEM-focused schools. I examined the participants' experiences before their teaching careers through the CBAM (Hall & Hord, 2001) lens to attempt to make connections to how their attitudes and feelings about teaching and STEM education enabled them to become STEM leaders in their schools. Five of the six participants knew they would become educators at some point; all had early experiences with science that produced an interest that caused them to become STEM leaders. The three parts of CBAM are:

1. Stages of concern (attitude and feelings);
2. Levels of use (nonuse to advanced use); and
3. Innovation configuration (levels of implementation with full implementation as the goal).

The participants in this study reported significant concerns and negative feelings about the newly adopted policies and procedures that were necessary to change from traditional to STEM elementary schools. This finding correlates with the typical reaction to change indicated in the CBAM, which indicates that different people Will react to change differently. The CBAM also includes intervention strategies to help individuals who are having difficulty with the changes. Fullan's (2012) change model incorporates strategies to take corrective actions for managing challenges during the change. The school leaders promoted passionate teachers to leadership positions to diminish concerns and increase confidence in the new ways of teaching and learning. The leaders visited other schools and researched best practices in STEM education to provide their teachers with the most helpful training possible.

Early in the implementation phase, the incorporation of collaborative planning and progress monitoring provided constant feedback and indicated the areas in need of remediation. This practice helps fill the literature gap (Owens, 2014), showing the need for increasing collaboration in STEM education to help build teacher efficacy. The arrangement of the master schedule incorporated 90-minute planning sessions each week to provide time for team members, including community stakeholders, to meet and strategize the organization of the curriculum to complement the project- and problem-based learning of the unit. Not commonly found in the literature, these interventions contributed to increased school-wide use of STEM-focused strategies and practices. Within three years of each program's development, there was evidence of innovation configuration, the third state of CBAM, which enabled the schools to obtain STEM certification. STEM certification was the reward for full implementation.

RQ2: What strategies were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

The purpose of the second research question was to reveal the strategies the STEM educators used to develop a school-wide program within their schools for increased student science proficiency. Lily, who was the school's reading specialist before she became a STEM specialist, revealed a strategy that resulted in success in merging science and reading. She exuded excitement as she said:

> We have been using Success for All for three years. We are completing our third year, and in this year alone, by our third quarter, we had 82% of first grade on or above reading level based on their ability to read, use clarifying strategies, and use predictions and questioning.

She also told me that she believes if you take the teachers' excitement, the kids' excitement, and then you give these kids the keys [to] unlock information on their own—that, she thinks, is why the numbers are going up.

The participants' experiences of using strategies underwent analysis through the lens of the change model (Fullan, 2012), which has five stages of transformational change. The change model was the second conceptual framework chosen for this study. The first stage is a moral reason for change. Each of the participants in this study believed STEM to be the most effective way to teach children. A strategy they used was to incorporate STEM in as many ways as possible into the daily lessons.

Much of the first year of planning and implementation consisted of helping everyone understand the changes needed for STEM program development, which is the second part of Fullan's (2012) change model. A think tank consisting of teachers, students, administrators, parents, and community stakeholders met to determine the focus of STEM at each school and the process of understanding change. They carried out the strategy at the onset of the STEM program, implementing it on a smaller scale to establish a four- to six-week unit focused on problems affecting the school community. This strategy correlates with findings from Hernandez (2014).

Both relationship-building and knowledge creation and sharing occurred together, with regular collaboration during the specified planning period built into the master schedule. These two processes are Stages 3 and 4 of Fullan's (2012) change model. During these stages, members of the same departments and grade levels strengthened their traditional relationships and gained strength and consistency. STEM education planning was the means of bringing forth the strategy of planning across different grade levels. The inclusion of community stakeholders was an added value to the influence of STEM lessons. Aster emphasized the importance of collaborative planning with the teachers to enhance the rigor and effectiveness of their lessons.

The final stage in Fullan's (2012) change model is coherence-building, with the goal of full integration. Each school was in the coherence-building stage before receiving STEM certification. The goal was to use strategies to maintain what the staff members and students started, helping everyone continue focusing on STEM-filled lessons and celebrating what the students learned. Creating an overall STEM culture is another strategy that results in the reward of coherence. Fullan stated that successful implementation enables an organization to continue with the modifications even if the founding members leave. The students who participated in the STEM program at School 2 during implementation transitioned to middle school but left a legacy of the STEM program's success: a robot. Iris proudly revealed:

> [The robot] walks and talks. And he comes to all of our assemblies. He meets many very important people who come in our building. And our students built him. They promoted out [long ago], but it was built by fourth and fifth graders about 5 years ago. He's [about] 5 feet [tall]. He wears a shirt [with the school logo]. If it's a special occasion, he'll wear a tuxedo shirt.

RQ3: What practices were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban area in Georgia?

The third research question enabled identifying the actions and practices in which the STEM educators engaged to create STEM-focused in their schools. This section presents some particular practices for each of the strategies used to address RQ2. A practice guiding each school's moral purpose (the first stage of Fullan's change model) was to identify a specific theme to guide instruction at the schools. The school-wide theme was developed to provide each student with STEM education every day and help them understand the change (the second stage of Fullan's change model) from a traditional school to a STEM school. The themes chosen by School 1 and School 2 were, respectively, "Making a clean, green difference within ourselves, school, and community" and "We are the world, conquering hunger through sustainability." The think tank was a vehicle through which the school leaders continuously sought community stakeholders who had business or interest in the STEM standards and activities to foster the sought-after learning.

The practices used that correlate with relationship-building (the third stage of Fullan's change model) were (a) establishing a collaborative planning period into the master schedule to provide at least 90 min per week for teachers from each grade level and team to jointly work with teachers, STEM specialists, and community stakeholders; (b) celebrating student-centered achievement and community stakeholder appreciation; and (c) creating an overall STEM culture with the engineering design process for learning so students could become comfortable with troubleshooting and redesigning their steps to meet the intended goal.

The practices that correlate with knowledge creation (the fourth stage of Fullan's change model) were (a) merging science and reading through the Success for All reading program; (b) providing exciting ways for students to learn, including student-centered classrooms to promote questions from students and remove judgment of correct or incorrect answers; (c) planning for culminating activities, such as PBL nights and Parent University activities, for the students to showcase and teach their parents what they had learned; and (d) including PBL activities to enable students to seek answers to questions about the phenomenon familiar to them and improve the condition of their community.

Dr. Myrtle described when her team chose to focus on butterflies to address learning standards. She shared:

> The [students] planted a garden to attract butterflies and present to their parents, community members, and district leaders what they [had] learned in 6 weeks [to] address standards. From the top to the bottom of the halls, you would see student work. You could see the butterflies hanging from the ceiling, and that's what they did in art.

This study found that long-term problems provided many relevant topics for project learning and PBL. The participants reported that the students felt more excited when they worked to solve community problems, such as flooding or erosion. The students engaged in step-by-step planning to incorporate the curriculum's content into the problem. The participants reported that the first year of implementation was a challenge, but that continued planning and building on previous units was worth the trouble.

The practices conducive to supporting and moving a STEM program into complete coherence (the fifth stage of Fullan's change model) were (a) rewarding leaders with titles and duties for leadership development; (b) providing total buy-in and support from the principal; (c) implementing hiring practices, including interview questions, relevant to science interest and competency; (d) developing culminating activities for each unit for authentic student assessment; (e) providing competitions and events for students; and (f) engaging in gallery walks to enable teachers to observe their progress and the progress of other grade levels and classes.

The research questions guided this study on STEM program development in an urban setting. The themes identified in this study aligned with the research questions in the following ways: The lived and career experiences of the personnel referred to in RQ 1 contributed directly to the intrinsic passion that they expressed about STEM education. Many aspects of their experiences were recorded during the participant introductions in Chapter IV. RQs 2 and 3 focused on the strategies and practices used by school personnel. The themes: daily focus guides collaboration and success becomes evident aligned with the strategies identified during the study. The practices identified by participants were directly correlated with successful accomplishment of strategies that contributed to an effective STEM program. The findings from this study had several implications potentially useful for future STEM program development. The findings support the theory that STEM education is an effective way to teach STEM to elementary students in urban settings.

Implications

The participants in this study were teachers and leaders in the same school district in an urban setting in Georgia who had become involved in the planning, implementation, and institutionalization of school-wide STEM programs. School 1 received certification from Cognia during the 2018–2019 school year; School 2 received certification from Cognia during the 2018–2019 school year and GADOE certification in 2019. School 2 had an additional STEAM certification because of the inclusion of the arts in its GADOE certification in the 2019–2020 school year. The STEM leaders' experiences may have implications for future STEM program strategies and practices and may contribute to future policymaking and research. The findings provide practical assistance to the urban STEM education community.

This study contributed to established literature because it found that school leaders can implement STEM/STEAM programs on a school-wide basis and improve science proficiency in urban elementary schools. STEM program development provides students and personnel with a rich STEM culture that can help nurture their educational experience. Improved student confidence, competency, and curiosity about learning were apparent benefits for the teachers, students, and parents represented in this study. This finding aligns with research by Morgan et al. (2016), who reached the same conclusion. Dr. Myrtle shared an example of how STEM is a way to make teaching and learning more meaningful. She said:

> We would manipulate the structure of the scope and sequence. If the scope and sequence said that I was going to teach about measurement, I had to connect it to science. The teachers saw it as easier because I don't just have to teach the standard the way this framework says it. I can teach the standard and connect it to something else that we're doing.

This study indicates the advantages of early exposure to science. Each of the six participants shared memorable experiences with science prior to becoming educators and developing into STEM program leaders, which aligns with the findings of some STEM program development studies (see LaForce et al., 2017; Morgan et al., 2016). This information suggests that the STEM teacher selection process should be based on some evidence of their interest in science, as far back in their lives as possible, to help them push past expected challenges, such as students' lack of confidence, motivation, and skills. When the evidence of intrinsic passion for science is absent, it is necessary to provide thorough science training to help teachers gain confidence in teaching STEM pedagogy. Teachers should also be selected based on their understanding of the importance of providing STEM education or trained accordingly to ensure they can transfer their enthusiasm to students and their families.

Another implication was that the educators' early experiences with educators in their families may provide encouragement for their decisions to pursue teaching careers. Although this finding did not emerge in the literature review, it may be an effective means of recruiting educators. Five of the six participants had family members in education. Although every student had extensive interactions with teachers, the peer tutoring program at one of the participating schools indicated that more students can experience teaching, although they may not have family members in education. This experience may be an incentive for an individual choosing to enter the teaching profession. Teacher cadet and peer tutoring programs in elementary, middle, and high schools can be platforms for effectively building confidence in a student's teaching ability and instilling an interest in education careers.

Having solid postsecondary partners participating in planning, training, and PD, a requirement for certification, often occurred daily or weekly in the two schools in this study. These postsecondary partners provide myriad opportunities for students to learn due to the personal attention they get and the resources that an organization is able to donate. STEM-focused media resources, career exposure, field trips, classroom presentations, and talent searches are needed to attract more future teachers to the STEM education profession. One strategy may be to use improved marketing practices to change the face of education to something desired by successful people. If students' perceptions of scientists and educators are negative, they may not pursue a STEM career. STEM educators must be willing to learn and grow due to the ongoing need to solve real-world problems (Morgan et al., 2016); therefore, individuals who already have the potential for learning science and for teaching likely make the best STEM teacher candidates.

According to the National Center on Education and the Economy (2017), policymakers are responding to the deficiency of STEM educators by calling for STEM focused approaches to teaching. In response to the lack of interest in STEM fields, the federal government has launched and funded reform efforts to stimulate student interest and performance within STEM fields (Moore, 2007). The federal budget included $3.7

billion targeted for educational policies that highlighted STEM and another $4.3 billion earmarked for STEM as part of the Race to the Top initiative in 2011.

Policymakers could use the results of this study to help fill the need for more STEM education because it is easier to adopt education policies when data show that students are excited about this learning experience. Schools and school districts may use these findings in marketing strategies. Most successful educators are already self-motivated, but more recognition for schools that successfully develop STEM programs can add to those teachers' motivation. Recognition will often encourage staff who are involved in STEM program development and may inspire others to get involved.
One strategy could be to include recognition celebrations during the regular school day to motivate students and teachers to continue using STEM curriculum and reward them for their hard work.

Creating more STEM programs in urban settings could help to increase STEM program development nationwide. As STEM-educated young people progress to Stem focused careers, they could influence their friends, children, and other family members to associate with STEM-focused schools. STEM programs may provide students with the necessary exposure to information that can increase their science proficiency. Increased science proficiency may be helpful for any student desiring to pursue a STEM career; however, knowledge about science may not be enough. LaForce et al. (2017) argued that exposure that sparks an interest in STEM is more influential than increased test scores and information retention. This discovery makes sense when considering the amount of time and work required to achieve a STEM degree.

Maltese and Tai (2011) proffered that an interest in science and math was an indicator of STEM career pursuits. The continued cycle of STEM education and exposure may drastically increase equity in STEM careers in the future. The President's Council of Advisors on Science and Technology (Holdren et al., 2010) supported the finding that schools should devote energy and resources to STEM education. Adding self-confidence in students' ability to grasp STEM content to their interest could be an unstoppable combination achieved through continuous exposure to PBL (Tai, 2006; Wang & Degol, 2013). Combined, these efforts may lead students into a lifelong career in STEM by conditioning in them a positive attitude toward STEM education and STEM careers.

This study shows that the number of parent volunteers and their time commitments increases when students participate in STEM education. Over time, the leaders of Schools 1 and 2 saw an increase in parent participation after implementing STEM-focused education. Iris disclosed that the parents of her students are often volunteers. She said:

> They help with spring planting day for the first-grade unit on plants by taking kids out in small groups [during class] so they can plant seeds, volunteer on weekends, and come out to support some of the many competitions the students are involved in.

Parent volunteers can be a synergistic situation because parents can learn life managing and employable STEM skills while helping their students and the school at large. The effort that educators at each of the participating schools made in reference to communicating with and inviting parents into their school should be replicated at more schools. Parents can offer a wide range of support, from participating in planning and assisting with teaching on a regular basis throughout the school year.

There is a long-identified need for better education in America. Despite many reforms and policy changes, little improvement has occurred. Instead, the gap between students who are academically successful and those who are not continues to widen, as the bar for proficiency gets higher (Ravitch, 2016). Ravitch (2016) observed that "high standards and rigorous testing do not provide equity; instead, they produce high rates of failure for many students" (p. xxiii). Ravitch contended that the purpose of American education is to prepare children for the duties of citizenship and democracy, which has nothing to do with students passing standardized tests. Ravitch noted that somewhere along the way, the agendas of many other organizations have entered the curriculum at the academic expense of students. One such agenda is standardized testing, which has become the tool for measuring achievement in American schools. The researcher argued for discontinuing excessive and erroneous emphasis on these scores because all students will not learn the same things at the same rate. Therefore, standardized testing scores should not be the only measurement to compare student progress within schools, states, and nations.

During her interview, Iris mentioned that she would like to see student grades eliminated. Student learning assessment is necessary, but the findings of this study indicate the need for less focus on standardized assessment and more progress monitoring on an authentic, formative level. This would require a major overhaul of education policies at the highest level. Such efforts should be a part of legislation that requires prioritizing science teaching above the math and ELA initiatives that have been in place for several years. This phenomenon is in agreement with recommendations made by the National Research Council (NRC, 2013). The participants each of the participating schools asserted that with science used as the foundation for learning, math, ELA, and technology can be integrated and can support a more realistic approach to learning.

Limitations of the Study

Purposeful sampling is a method used to identify persons who can share thick, rich data on the topic of interest (Merriam, 2002; Percy et al., 2015). In this study, purposeful sampling produced a small sample size of six participants. The individuals who met the selection criteria were all women; five were Black, and one was White; therefore, there was a lack of diversity among the participants. This study may not have had findings representative of men and other ethnicities. The findings provided perceptions limited to STEM-focused elementary school personnel in an urban setting in Georgia, schools that were the focus of this study. The use of semi-structured interview questions may have produced limited information, as the interviewees may have focused on answering the questions directly and not considered other possibly relevant information not requested.

My closeness to the STEM movement influenced the composition of the interview questions. Such an attachment could have made participants reluctant to include negative comments because (a) the questions focused on the strategies with a positive impact on the success of a STEM program and (b) I was mindful that there may be ways to identify the identities of the participants in the study. I did not want to cause anyone to experience negative consequences as a result of shared information.

The data for this study came primarily from conversations perhaps influenced by the participants' emotional states (see Patton, 2015). The fact that STEM-focused elementary schools in Georgia are a relatively new phenomenon may have affected the participants' responses in the absence of other schools for comparison. There are limitations to verifying information collected through the interview, as the analysis process involving categorizing and coding is labor-intensive (Merriam & Tisdell, 2016).

A limitation of the present study came from reliance on participants' voluntary feedback. The participant may choose to withdraw from the study at any time which is explicitly stated in the consent form that was shared with each participant prior to the interview (Seidman, 2013). Voluntary feedback can also be influenced by the participants' mood or life circumstances during the time of the interview. Using data triangulation is a means to address the issues of validity and credibility of information (Merriam & Tisdell, 2016). In the present study, triangulation involved analyzing multiple data sources from the interviews, document reviews, and observations. Three people per school participated in interviews, which enabled constant comparison. Maxwell (2013) regarded member checking as the best way to ensure compatibility between the interviewee's and interviewer's meaning.

The interviews for this study occurred via telephone in May 2020, during the COVID-19 pandemic; face-to-face interviews may have produced different responses. The participants' environments during the interviews may have had an impact on their answers to the questions. In addition, the end of the school year is often a time of increased responsibilities for teachers, which could have limited the intensity of the participants' responses.

Recommendation for Further Research

The purpose of this study was to determine the strategies and practices used by the school personnel responsible for increasing student science proficiency at certified STEM schools in urban settings in Georgia. The case study method of qualitative research was the approach used to gather data on STEM program implementation in a specific setting. An explanatory lens allowed me to describe the essential components of the STEM program of each school. These results may contribute to planning future STEM program implementations and increasing the number of programs for various audiences.

For saturation of STEM-focused teaching to occur in America, there needs to be a better understanding of what it takes to implement and maintain a successful program. Success criteria of a STEM program are varied but often include students' academic achievement and motivation to pursue STEM in future educational pursuits and/or careers.

Recommendations for further research in the STEM community include a thorough in-house study from the beginning of STEM program implementation using an evaluation tool, such as the CBAM (2001), and throughout the process. This tool can provide insight into phases of the implementation process and some of the intervention strategies necessary. It may also provide data to influence the process directly in real time, with information indicating the type of support needed by teachers at the time it is needed. This information can better prepare future STEM program developers for managing support for personnel to avoid possible barriers.

Another recommendation is for a qualitative case study of the professional development of teachers in STEM settings. This type of study will add to the literature by assessing how PD helps teachers' performance, pedagogy, and efficacy. Pre- and post-assessments could include self-reflection surveys for teachers, common assessment data, and student perceptions of teaching to determine how instructors utilized their PD. This type of study could provide indicators about the impact of the overall school culture on the usefulness of different methods and could lead to a differentiation of models used for different types of schools.

Another approach could be a mixed methods study for a constant comparison of attendance and discipline rates between STEM and traditional schools, along with qualitative data, such as teacher and student perceptions of the program. If such a study leads to increased attendance and decreased discipline problems, the justification for more STEM-focused schools could be strengthened.

A longitudinal study of schools within STEM clusters would show the progression of students from elementary school into their careers. This type of study would take several years and require collaboration between and among schools, school systems, postsecondary institutions, and the business community. Morgan et al. (2016) correlated early learning experience with later success in science, finding a direct relationship. A longitudinal study could justify funding from many sources and provide possible information about the effectiveness of inclusion of different types of external community stakeholders unique to certain areas.

In addition, studies of the funding of STEM program development (Drutman, 2012) could provide helpful information for future STEM program developers. A database of funding opportunities may indicate support for more programs, especially in a collaborative setting that includes primary, secondary, and postsecondary educational organizations and their connection to career pathways, community stakeholders, and businesses.

Conclusion

All the participants in this study expressed their belief that STEM education is the best way to educate young people. STEM program development, implementation, and sustainment have qualities and characteristics in common with traditional programs; however, they also have specific, unique qualities that contribute to educational success, such as cross-curricular and problem/project-based learning, parent and community stakeholder involvement in activities during the regular school day, and a focus on schoolwide incorporation of STEM in every facet of the school culture.

This qualitative case study enabled a comparison between the STEM program development of two schools and revealed that there was much they had in common. This may have been a result of both schools' location within the same school district. School personnel's lived experiences and personalities accounted for the most variety between the two schools. Constant comparison was used to identify the common methods. The findings provided information that may be helpful for increasing and maintaining certified STEM programs. Three themes emerged after the data analysis: (a) intrinsic passion ignites effective leadership, (b) daily focus guides collaboration, and (c) success becomes evident.

In line with the research questions, the goal of this study was to examine the role of the participants to include who they are, what they did (strategies) to promote STEM education in their schools, and how they did it (practices). The participants in this study were six female educators who entered the teaching profession before becoming STEM educators. The participants became involved in the STEM program development process because they worked at schools in the process of receiving STEM certification. This study revealed several strategies and practices used in certified STEM-focused elementary schools that resulted in student gains in science proficiency. The strategies and practices were products of teacher and leader collaboration efforts. Each school's overall theme was a guide to focus PBL experiences on issues affecting their community. The participants reported including students in identifying problems and developing ideas with community stakeholders to address them. PBL occurred while learning math, science, English, social studies, and the arts. The students' continuous focus on real-world, relevant issues that impact the community cultivated a sense of ownership and care, boosting their desire to learn.

Maintaining an effective STEM program requires a few components. In this study, collaboration and PD were consistent elements of STEM teaching and learning at each school. These elements were significant factors in the success of the STEM programs because they contributed to the confidence of the teachers, who then passed it on to their students. Community partnership recruitment and sustainment are challenging but necessary for leaders of STEM programs, especially since partners can fluctuate. Partners who actively plan and work directly with students and teachers are critical stakeholders in STEM programs. The evaluation process with rubrics from the certifying organizations is a cornerstone of a STEM program; it is a constant factor at the beginning of the planning process that remains useful daily.

As teachers, policymakers, parents, and administrators learn more about STEM education and how to provide it for students, they could make the desire for STEM education for all a reality (Committee on STEM Education, 2018; Gonzalez & Kuenzi, 2012). Shifts in STEM education funding could lead young people to change their trajectories to STEM majors in postsecondary education and pursue STEM careers. Knowledge about how students learn and develop provides a realistic view of the importance of exposing children to STEM early in their lives. A close look at this phenomenon suggests that young people find science exciting, which could lead them to develop many of the skills needed to navigate a technologically enhanced society. Individuals of all genders, nationalities, cultures, socioeconomic levels, and races can benefit from STEM education experiences.

The need to understand and utilize technology continues to grow as advances in technology continue to be developed. As we advance further into the new Technology Revolution, leaving behind the Industrial Revolution, our school systems that once prepared students for the industrial revolution must now prepare our students for the technology revolution. Most people already benefit from STEM knowledge by utilizing household items that have become a part of daily living, such as cell phones, internet, and telemedicine. STEM curriculum integration in all schools is necessary for young people to be prepared for future careers. The information collected during this study can be used to make this possible through the creation of STEM program development models equipped with a standard operation of procedures. Practices that cater to urban youth can be emphasized and paralleled with practices that non-urban youth may benefit from in school. To reach a wide range of youth, many forms of delivery and experiences need to be developed and shared through school systems, post-secondary schools, media outlets, and other community organizations. Funding from many organizations need to be directed to enhancing STEM program development and maintenance throughout the US to put Americans back on track of being leaders of the world.

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Appendix A

SCHOOL SYSTEM APPROVAL

Appendix A SCHOOL SYSTEM APPROVAL

March 12, 2020

Researcher/Principal Investigator: Candice W. Little

Institution: Valdosta State University

Study Title: Case Study of the Strategies and Practices Used by School Personnel in a STEM-Focused Elementary School in an Urban Setting

Greetings,

Your request to conduct research in Atlanta Public Schools has been **approved** by the Atlanta Public Schools Research Screening Committee. This letter grants you permission to seek approval from the Principals of [redacted] to recruit teachers to participate in interviews for the purposes of this study **from March 12, 2020, to May 20, 2020.**

Study description: "The purpose of this study is to determine the strategies and practices used by school personnel responsible for increasing student's science proficiency at a certified STEM school in an urban setting in Georgia." A few things to consider as you begin your research:

1. The principals of the proposed school must give approval for you to conduct the planned research study prior to recruiting teachers to participate in this study. This letter of permission does not in any way guarantee approval from the principal.

2. Interference with school instruction and operations must be kept to a minimum. Researchers should work closely with school administrators to collect data (i.e., teacher interviews) before or after school hours.

3. No research activities may be conducted in schools during the administration of standardized tests. See the 2019–2020 Assessment Calendar for a list of assessment dates.
4. If you make changes in the implementation of your study, please notify the Office of Research and Evaluation prior to the beginning of your study.

5. Your assurance of maintaining confidentiality of the participants and the selected schools must strictly be followed. Pseudonyms for individuals and schools, as well as references to APS as "a large urban school system," are required in the title and text of your study before publication or presentation.

6. Please submit a completed copy of the final research study to the Office of Research and Evaluation.

[redacted] Research and Evaluation staff are available to answer questions regarding research policies and practices across the District. However, R&E staff will not be able to support recruitment and communication with school staff. Please contact [redacted] if you need any further assistance.

Sincerely,

[redacted]
Executive Director – Data and Information Group
[redacted]

Appendix B

CONSENT FORM

Valdosta State University Research Participation

You are being asked to participate in an interview as part of a research study entitled ***A Case Study of the Strategies and Practices Used by School Personnel in STEM-Focused Elementary Schools in an Urban Setting****,* which is being conducted by **Candice Little***,* a **student** at Valdosta State University. The purpose of this study is to determine the strategies and practices used by school personnel responsible for increasing student science proficiency at a certified STEM school in an Urban area in Georgia. You will receive no direct benefits from participating in this research study. However, your responses may help us fill a void in research addressing strategies school personnel use to increase science proficiency in elementary schools in urban settings as well as providing them with a toolbox of best practices. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life. Participation should take approximately 60 min. The interviews will be audiotaped in order to accurately capture your concerns, opinions, and ideas. Once the recordings have been transcribed, the tapes will be destroyed. No one, including the researcher, will be able to associate your responses with your identity. Your school will be assigned a pseudonym (School 1-2/Participant 1, 2, or 3) to conceal the school's identity. Your participation is voluntary. You may choose not to participate, to stop responding at any time, or to skip any questions that you do not want to answer. You must be at least 18 years of age to participate in this study. Your participation in the interview will serve as your voluntary agreement to participate in this research project and your certification that you are 18 years of age or older.

Questions regarding the purpose or procedures of the research should be directed to Candice Little at cwlittle@valdosta.edu. This study has been exempted from Institutional Review Board (IRB) review in accordance with Federal regulations. The IRB, a university committee established by Federal law, is responsible for protecting the rights and welfare of research participants. If you have concerns or questions about your rights as a research participant, you may contact the IRB Administrator at 229-253-2947 or irb@valdosta.edu.

Appendix C

Interview Protocol

Research Questions	Interview Questions	Conceptual Framework
1. What are the lived and career experiences of school personnel responsible for increasing student science proficiency at a certified STEM school in an urban setting in Georgia?	Interview #1 1. When and how did you know you would become an educator? 2. Describe your journey to becoming an educator. 3. What is your current position? How long have you been in your current position? 4. What are your beliefs about STEM education in urban elementary schools? 5. What do you perceive about the school personnel's beliefs regarding STEM education in urban elementary settings? 6. Describe your attitudes and feelings about STEM implementation at your school. Share how your feelings have changed as the program has progressed. 7. Describe your role in the STEM implementation. 8. Tell me about your school demographics. (enrollment, transportation for students, special programs, school positive and negative attributes, surrounding	**Concerns Based Adoption Model** Stages of Concern (attitudes and feelings)

	community, business partnerships. 9. Describe a normal day at your school? 10. In what ways do you believe your school has been successful in implementing a STEM program? 11. Discuss any current STEM concerns or challenges your school is working to overcome regarding your STEM program. 12. Based on your experiences with STEM program challenges and the national history of STEM education, what do you think should happen at a higher level to improve STEM education?	Levels of Use (nonuse-advanced use) Innovation Configuration (levels of implementation with full implementation being the goal

2. What strategies were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban setting in Georgia?	Interview #2 1. What is your perception about the importance of STEM education programs being developed in elementary schools in urban settings? 2. What are some of the key components that had to change to transition your school from a traditional to a STEM focused elementary school? 3. How do school personnel regularly engage with students in reference to STEM education? 4. How do school personnel regularly engage with parents in reference to STEM education? 5. How do school personnel regularly engage with teachers to provide professional learning opportunities for STEM education? 6. What is the focus of your school's STEM implementation? 7. How is STEM achievement monitored? 8. I see that science proficiency is steadily increasing at your school. What are some of the things	**Fullan's Model of Change** Moral Purpose Understanding Change Relationship Building Knowledge Creation and Sharing

	that you can attribute to that change? 9. How is STEM education achievement showcased or celebrated. 10. How well has STEM education been infused into the overall school culture?	Coherence Building

3. What practices were used by school personnel responsible for increasing student science proficiency at a certified STEM school in an urban setting in Georgia?	**Interview #3** 1. What are your district’s STEM education policies? What are your school’s STEM education policies? 2. How does your school structure and organize the staff to monitor STEM education? 3. How are STEM education decisions made at your school? 4. How does the work around STEM education flow between work roles? 5. What measures are taken to educate parents about STEM education policies and expectations at your school? 6. Share how the master schedule is created to include integrated learning. 7. What measures are taken to engage students about STEM education expectations at your school? 8. What supports are in place to address STEM barriers at your school? 9. How have you created community partnerships? Share how the partners support STEM education.	**Fullan’s Model of Change** Moral Purpose Understanding Change Relationship Building Knowledge Creation and Sharing Coherence Building

Appendix D

VSU INSTITUTIONAL REVIEW BOARD APPROVAL

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

PROTOCOL EXEMPTIONREPORT

Protocol Number: 04016-2020 **Responsible Researcher:** Candice Little

Supervising Faculty: Dr. Bill Truby

Project Title: *A Case Study of the Strategies and Practices of School Personnel at STEM Focused Elementary Schools in an Urban Setting.*

INSTITUTIONAL REVIEW BOARD DETERMINATION:

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

ADDITIONAL COMMENTS:

- *Upon completion of this research study all data (email correspondence, interview transcripts, pseudonym lists, etc.) must be securely maintained (locked file cabinet, password protected computer, etc.) and accessible only by the researcher for a minimum of 3 years.*
- *Participant name lists and the corresponding pseudonym lists must be kept separately to ensure participant anonymity.*
- *The Research Statement is to be read aloud by the researcher - to each participant at the start of the recorded interview session. A copy of the statement is to be provided to each participant.*
- *Exempt protocol guidelines prohibit the collection and/or sharing of audio/video recordings. ○ Recordings are permitted for the purpose of creating an accurate interview transcript. All audio recordings are to be deleted from all devices immediately upon creation of the interview transcript.*

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

Elizabeth Ann Olphie 03.18.2020 ***Thank you for submitting an IRB application.***

Elizabeth Ann Olphie, IRB Administrator

Please direct questions to irb@valdosta.edu or 229-253-2947.

Appendix E

CITI Certification

Completion Date 26-Jan-2019
Expiration Date 25-Jan-2022
Record ID 23983010

This is to certify that:

Candice Little

Has completed the following CITI Program course:

Human Research (Curriculum Group)
IRB Basic (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Valdosta State University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w8d8d1447-6919-4824-8bf7-3dcdefd6b21d-23983010

Appendix F

GADOE AND COGNIA PREASSESSMENT INSTRUMENTS

STEAM Self-Assessment and Reflection

Prior to scheduling a STEAM pre-visit, use this document, along with the STEAM continuum, to reflect on your STEAM journey and implementation. The guiding questions below will help determine areas to focus on prior to scheduling your pre-visit.

1. **Program Sustainability:** How many years has your school or program been working toward certification?

- STEAM certification is awarded to schools or programs with over two years of implementation to encourage program sustainability. Has STEAM been implemented with fidelity for two or more years?

2. **STEAM Vision and Culture:** Insert your school or program's STEAM vision:

- Is your driving purpose for implementing STEAM specific to your local community?
- Does your vision articulate why the arts are essential to your program?
- Are all students and teachers able to articulate why and how STEAM is the school culture?

3. **STEAM Students – *Program Certification Only:*** Insert data regarding STEAM student demographics:

- The Georgia Department of Education believes that STEAM is for and benefits all students. Do the participants in the STEAM program reflect the school's diversity? This includes but is not limited to: gender, race, ethnicity, economic status, etc.

4. **Business and Community Partnerships:** Describe your business, community, and post-secondary partnerships:

- Do you have multiple business, community, or post-secondary partnerships?
- Are the partnerships ongoing in nature? Do some partners support day-today standards-based instruction?
- Do you partner with local arts organizations or individuals? This could include, but is not limited to: professional visual artists, musicians, designbased businesses, radio stations, teaching artists, museums.

5. **Project-Based Learning:** Describe year-long project/problem-based learning units:

- Are PBLs authentic and relevant to your local community?
- Are PBLs student-led and driven by student research and inquiry?
- Do students present findings and ideas to individuals beyond the classroom?

6. **Daily Instruction:** Describe your school's approach to daily instruction.

- Do teachers collaborate weekly to develop unique, locally-drive, interdisciplinary units that connect, at the minimum, Georgia Standards of Excellence for science, arts, and mathematics?
- Are the fine arts educators involved in collaborative planning to promote learning through the arts OUTSIDE of the arts classroom?

- Are educators developing unique and innovative units as opposed to exclusively using online platforms or pre-created lessons?

7. **STEAM Rigor through the Arts:** Describe the role of the arts in your STEAM school or program:

- Do teachers utilize Fine Arts Georgia Standards of Excellence when planning units?
- Have all teachers received arts-based professional development to learn arts vocabulary and strategies?
- Do students create original works of art (dance, theatre, music, visual art, or media art), opposed to copying or following prescribed steps, in conjunction with interdisciplinary math and science units?

8. **Student Documentation:** How are STEAM journals used in your school or program?

- Does your school or program have an established protocol for STEAM Journals?
- Do students collect data, create drawings, and utilize process-based thinking in their STEAM journals?
- Do students use one journal for, at a minimum, interdisciplinary math, science, and the arts?

9. **Process-Based Thinking:** Describe the design process that has been adopted (design thinking or school-created).

- Is the design process used throughout the school? Do teachers embed GSE into the use of the process?
- Have guiding questions been developed for each step of the process?
- Is data collected as a part of the test/ improve sections?
- Are the arts and empathy embedded in the process?

COGNIA RUBRIC

STEM Implementation Readiness Assessment

Use the Rubric below to assess the current level of STEM implementation in your institution. The elements correspond to program areas reflecting in Cognia's STEM Standard framework. Schools or programs that have been implementing STEM for at least two years and have most or all of these elements established should consider STEM Certification. Cognia can also support your institution in implementing effective practices in these areas, as well as areas specified in our STEM Standard framework.

	Description	Not Yet Started	Beginning	Established
Element One: Stakeholder Engagement	School has a STEM leadership team in place that collaborates with representatives from all stakeholder groups.			
	Multiple external partners regularly and strategically engage with students and educators to support STEM learning.			
	School supports parent/family involvement in students' STEM learning opportunities.			
Element Two: STEM Implementation	Classroom instruction focuses on actively engaging students in the learning process.			
	Students have regular opportunities to solve realworld problems throughout the curriculum.			

	Students demonstrate their learning through nontraditional, nonstandardized methods.			

Appendix G

SCHOOLS IN GEORGIA CERTIFIED BY GADOE

Georgia STEM/STEAM Certified Schools

Elementary Schools	
Henderson Mill Elementary (STEAM Certified)	DeKalb County
Dunwoody Elementary School	DeKalb County
Rocky Branch Elementary	Oconee County
Brookwood Elementary	Dalton City Schools
Ford Elementary School	Cobb County
Cowan Road Elementary School	Griffin –Spalding
Clark Creek Elementary School	Cherokee County
Gilbert Elementary	Walker County
River Eves Elementary	Fulton County
Tritt Elementary	Cobb County
Amana Academy-Elementary School	Fulton County
Woodland Elementary	Fulton County
White Oak Elementary	Gwinnett County
Eagle Springs Elementary	Houston County
Northside Elementary	Houston County
Pleasant Grove Elementary School	Henry County
Sagamore Hills Elementary School	DeKalb County
Elm Street Elementary School	Rome City Schools
Marietta Center for Advanced Academics	Marietta City Schools
Martin Technology Academy	Hall County
M.Agnes Jones Elementary (STEAM Certified)	Atlanta Public Schools
Hannan Elementary Magnet Academy	Muscogee County
George W. Whitlow Elementary	Forsyth County
Drew Charter School (STEAM Certified)	Atlanta Public Schools
Colham Ferry Elementary	Oconee County
Heard Elementary School	Savannah Chatham Co. Public Schools
North Heights Elementary	Rome City Schools
Dimon Magnet Academy	Muscogee County
Cave Springs Elementary	Floyd County
Mason Elementary School	Gwinnett County
Mableton Elementary (STEAM Certified)	Cobb County
Eton Elementary School	Murray County
New Mt Hill Elem. (STEAM Certified)	Harris County
Liberty Elementary School	Liberty County
West Fannin Elementary	Fannin County
Samuel E Hubbard	Monroe County