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IMPLEMENTING S.T.E.A.M – ONE SCHOOL'S JOURNEY TOWARD IMPLEMENTATION

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IMPLEMENTING S.T.E.A.M –

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ABSTRACT

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The purpose of this multiple case study, grounded theory design is to describe and document the process teachers go through when implementing a STEAM (Science, Technology, Engineering, Arts, and Mathematics) curriculum and program at a K-4 elementary school. Throughout this process, elementary teachers' beliefs and perceptions of effective STEAM instruction will be analyzed to determine how teachers interpret and implement this new initiative. The goal of this investigation will be to gain a deeper understanding of teacher attitudes, beliefs, and mental models surrounding STEAM instruction as well as their comfort with implementing the new Next Generation Science Standards ("NGSS"). Prior studies have shown that elementary school teachers are limited in STEAM content knowledge (CK), pedagogical content knowledge (PCK), and confidence in teaching STEAM concepts, resulting in elementary teachers avoiding teaching STEAM subjects altogether (Epstein & Miller, 2011). The sample for this research will be 5 teachers (n=5), one from each grade level K- 4. These teachers have taught in a Title 1 funded suburban school located in Long Island, New York. Data collection and analysis will consist of a triangulation between lesson observations, lesson plan review, and a focus group interview - which will examine teachers' perspectives regarding the overall effectiveness and implementation of the STEAM initiative. This

study is significant to teacher leaders in understanding the challenges and experiences teachers might face in integrating and implementing new STEAM curriculum in an elementary school setting. The findings of the study seek to assist educators and leaders in identifying strengths and weaknesses with respect to teachers' pedagogical knowledge, CK and PCK with respect to STEAM implementation.

DEDICATION

To my husband, Erik, who believed in me and encouraged me throughout this journey.

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None of this would have been possible without the help of many, many people. It is only natural to extend my heartfelt gratitude and appreciation to all those who were at my side during the long journey that got me where I am today. If today I am a better person, I owe it to many people.

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CHAPTER 1

Introduction

This research seeks to explore and document the process a school and its teachers undergo as they embark on the journey to set up and implement a new Science, Technology, Engineering, Arts, and Mathematics ("STEAM") program and curriculum aligned to the Next Generation Science Standards ("NGSS"). The concepts of STEAM were developed from STEM (Science, Technology, Engineering, and Mathematics) with the addition of the arts: humanities, language arts, dance, drama, music, visual arts, design and new media. The main difference between STEM and STEAM is STEM explicitly focuses on scientific concepts. STEAM investigates the same concepts but does this through inquiry and problem-based learning methods used in the creative process. Chapter two will provide further explanation and research outlining the distinct differences between these concepts.

The NGSS are K–12 science content standards which set the expectations for what students should know and be able to do. The NGSS enable teachers to offer all students interactive science instruction that promotes critical thinking, problem solving, analysis and interpretation of data, and connections across science disciplines—with a high set of expectations for achievement in grades K–12. The *Guide to Implementing the Next Generation Science Standards* (2015) can be utilized as a valuable resource to plan and implement science changes at the elementary level. Students in kindergarten through fourth grade can have educational opportunities strengthened by STEAM. The NGSS have outlined grade level standards and curriculum content. This research seeks to examine how teachers respond to this new curriculum, its effects on their instruction, and teachers' attitudes and perceptions to STEAM. This schoolwide initiative seeks to provide classroom teachers with the tools they need in order to not only achieve the goal but to bring science teaching and learning into the 21st century.

Background of the Problem

Kindergarten through fourth grade elementary school teachers are limited in subject knowledge, pedagogical experiences, and confidence in teaching STEM concepts, resulting in an avoidance by elementary teachers of teaching STEM subjects altogether (Epstein & Miller, 2011). The way elementary teachers are currently trained is not aligned with STEAM innovation. Current policies favor elementary teacher candidates without expertise in STEM areas (Epstein & Miller, 2011). The potential of STEM curricula to advance student learning in key areas cannot be realized if the individuals expected to implement the curriculum do not have an adequate understanding of what STEM is or do not have confidence in their abilities to implement the curriculum (Epstein & Miller, 2011).

To be fully successful, the introduction of STEM should be at the earliest age possible and in process rather than in specific content (Roth & Eijck, 2010). Epstein and Miller (2011) maintained that development of STEM-proficient students begins in elementary schools. According to Sanders (2012), STEM is not a concentration of subject areas but is a learning environment in which students learn to innovate, experience, discover, debate, design, create, and build. STEM content is replete with activities that allow students to experience project-based, experiential learning activities that lead to higher-level thinking and engage them in real-world problems (Morrison & Bartlett, 2009). STEM's differentiated instructional strategies are effective when used to accommodate students' cognitive levels and multiple-learning styles (Sanders, 2009).

Learning in a STEM environment helps students comprehend processes that lead to innovative solutions by understanding issues and solving problems. The overarching goals of STEAM are to increase K–12 students' interest in STEAM fields and to help students become 21st century learners. Previous researchers have addressed the perceptions of teachers at the secondary level, but a literature gap exists in assessing the perceptions of elementary teachers (Brown et al., 2011; Nadelson, Seifert, et al., 2012; Paulson, 2012; Wang, 2012).

In 2016, about 45% of freshmen indicated they planned to major in a science and engineering ("S&E") field (up from about 8% in 2000): about 16% in the biological and agricultural sciences; 11% in engineering; 10% in the social and behavioral sciences; 6% in mathematics, statistics, or computer sciences; and 3% in the physical sciences (National Science Board, 2018). However, few women in the United States are earning degrees in STEM, except in the life sciences (National Science Board, 2015). Students' futures are at stake if schools do not prepare them for a global society (U.S. DOE, 2013). Helping students make connections in STEAM fields while experiencing real-world problems combined with the changing workforce may help spark interest in these fields (Brown, et al., 2011). The general belief is that students will be better prepared for advanced education and careers in STEAM fields with increased math and science requirements and greater infusion of technology and engineering concepts in education (Brown et al., 2011).

A report from the United States Department of Education ("U.S. DOE") set out a federal strategy for the next five years based on a vision for a future where all Americans will have lifelong access to high-quality STEM education and the United States will be the global leader in STEM literacy, innovation, and employment (U.S. DOE, 2018).

Problem Statement

In 2010, STEAM education became a goal for U.S. schools due to goals of global competitiveness in both the public and private sectors. According to the U.S. DOE (2013), the United States was falling behind other industrialized nations as it ranked 17th in science and 25th in math. Current data from the U.S. DOE (2018) shows that the United States is now ranked 25th in science and 39th in math. Inadequate STEAM education affects the entire U.S. educational system, the economy, global stature, homeland security, and the quality of life of students (Department of Defense ["DOD"], 2012). If we want a nation where our future leaders, neighbors, and workers have the ability to understand and solve some of the complex challenges of today and tomorrow, and to meet the demands of the dynamic and evolving workforce, building students' skills, content knowledge, and fluency in STEAM fields is essential (U.S. DOE, 2018).

Prior to May of 2013, no nationally developed standards or assessments existed for STEAM (National Science and Technology Council, 2013). In August of 2013, the new NGSS were released. These new standards were developed through a collaborative, state-led process managed by an independent nonprofit education reform organization, Achieve. They are rich in content and practice and arranged in a coherent manner across disciplines and grades to provide all students an internationally benchmarked science education (NRC, 2013). The NGSS are based on the Framework for K-12 Science Education developed by the National Research Council (NRC, 2013).

Twenty states and the District of Columbia (representing over 36% of U.S. students) have adopted the Next Generation Science Standards (NGSS), and twenty-four states, including New York, (representing 35% of U.S. students) have developed their own standards based on recommendations in the NRC Framework for K-12 Science Education (National Science Teaching Association, 2010). New York State has given schools a deadline of 2021 by which they must fully implement these new science standards.

The specific problem is that STEAM curriculum is new and therefore not currently implemented into the curriculums of elementary schools. New York State DOE has given schools a timeline to implementation before new state assessments are to be in effect. This school has one year to fully implement the science standards and the district is in the beginning phase of this process. The challenge will be to garner buy-in from teachers and develop a unique STEAM curriculum for the target school and have full implementation of the NGSS within the next two years. This research looks to document the process of curriculum implementation and instructional practices during the first year and seeks to be able to make the necessary recommendations and plans for the 2020- 2021 school year and beyond.

Purpose of the Study

The purpose of this multiple case study, grounded theory research is to explore, understand, and describe K-4 teachers' perceptions and experiences with integrating and implementing STEAM curricula. This research will look at elementary teachers' role in the program and will look to identify the qualities of effective STEAM instruction. This research will examine one participant each from grades, kindergarten, first, second, third and fourth grade. Therefore, for this research design each grade level and its participant teacher will be considered a case.

Most K-4 teachers have not been taught disciplinary content using STEAM contexts (Bursal & Paznokas, 2006; Cotabish et al., 2011). As such, teachers may integrate

STEAM in the manner most comfortable to them correlated with their beliefs about the value and purpose of STEAM integration (Wang et al., 2011). Paulson (2012) speculated that teachers' attitudes and perceptions can affect STEAM achievement, therefore, this study is important as it seeks to provide a viewpoint for STEAM implementation in education. Understanding teacher perceptions of STEAM education is critical for each teacher's success and for the success of the program (Nadelson, et al., 2012).

STEAM areas are not generally a part of K-4 education or elementary teacher education programs. The way elementary school teachers are currently being trained does not align with state and federal goals related to STEAM. Currently, there is no New York State certification for an elementary teacher in the area of STEAM. Current policies favor elementary teacher candidates without expertise in STEAM (Epstein & Miller, 2011), and there are few programs designed at preparing teachers to teach STEAM. Instead, those with strengths in reading and math tend to be hired more frequently (Quigley & Hero, 2016).

Throughout this investigation, the goal will be to gain a deeper understanding of teacher perceptions. Teacher mental models consist of conceptions of science subject matter and barriers related to teaching and learning. This study will prove to be extremely useful as it highlights teacher understanding, as well as examines what may support or hinder teachers' adoption of this new STEAM initiative. To date, STEAM areas are not generally a part of K-4 education or elementary teacher education programs.

Theoretical & Conceptual Framework

The theoretical framework for this study will focus on the interrelationship of content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) and how these are essential for effective instruction. CK, PK, and PCK were introduced decades ago by Shulman (1986). CK represents teachers' understanding of the subject matter taught. According to Shulman (1986), "[t]he teacher need not only understand that something is so, the teacher must further understand why it is so" (p. 9). Shulman (1986) defines PK as knowledge about broad pedagogical principals and strategies. This also includes strategies of classroom management as well as organizing learning opportunities. Therefore, PK is the various instructional components or principles used by teachers coming together.

Shulman (1986) defines PCK as an awareness of one's difficulties in a particular subject and the methods of representing and formulating the subject that make it comprehensible to others (e.g., analogies, illustrations, examples, explanations, and demonstrations). Shulman was credited with coining the phrase "pedagogical content knowledge," which he used to emphasize the need for teachers to integrate their knowledge of subject matter with content-specific pedagogical strategies so as to produce successful teaching outcomes. The importance of CK is not exclusive to any one content area. The works by Ball *et al*. (2008) focused on ways to define and improve the CK needed to teach mathematics. This research seeks to use Shulman's theory as a lens through which to examine STEAM instruction.

While having well-developed CK is crucial in teaching a particular subject, PCK is also necessary to effectively address student needs and help them learn (Ball et al., 2008). Learners are not blank slates and come into a course with many preconceptions and varying levels of preparation (Shulman, 1986). Thus, teachers need both the knowledge of student difficulties and effective instructional strategies to help them overcome these difficulties. With respect to this study, the researcher seeks to examine how Shulman's theories of CK, PK and PCK impact an elementary teachers' ability to instruct STEAM, since STEAM is the instruction is the overlapping of multiple domains of learning. This theoretical framework will be discussed in greater detail in the next chapter.

Significance of the Study

The United States has become a global leader in developing STEM fields, however an inadequate number of teachers proficient in teaching these fields are in classrooms (Cotabish, et al., 2013; U.S. DOE, 2018). In an effort to respond to the status of STEAM education in the nation, schools continue to develop and implement programs and strategies that have the potential to improve STEAM education. Conversely, little is known about the challenges that teachers, particularly at the elementary level, face in implementing these STEM programs (Scott, 2012).

As this district looks to act, the leaders must ask themselves how elementary teachers can successfully implement these new science standards. What supports can be put in place to build the passion of teachers and encourage the use of STEAM hands-on methods? How can the school best provide its students with the opportunity to learn STEAM? The goal of this research seeks to document this process of implementation and provide the necessary recommendations should other schools find themselves in a similar situation. This study is significant to understanding the challenges and experiences teachers face when integrating and implementing a new curriculum and program. The findings of the study seek to assist educators in the development of a K-4 NGSS-aligned curriculum and to help guide the development of a STEAM program in order to provide students with access to this content. Previous researchers addressed the parameters of the current study in part for specific areas of math or science education at the secondary level, but a literature gap exists regarding assessing these parameters for elementary teachers (Brown et al., 2011; Paulson, 2005; Wang, 2012). The objective is to ensure teachers are equipped with the necessary skills, knowledge, and experiences which will help their students to compete in a global and multicultural age.

The significance of this study to leadership is that understanding teachers' perceptions about K-4 STEM integration may provide school district leaders insight into developing effective programs for STEAM integration and effective professional development opportunities while supporting the needs of teachers (Stansbury, 2011). Teachers gain a personal sense of self-esteem and professional success when they feel safe, secure, and confident with what they teach (Hoachlander & Yanofsky, 2011; Howell & Costly, 2006; Stansbury, 2011). Learning about teachers' perceptions of STEM and addressing the insecurities and questions are important in order to empower teachers (Harris et al., 2008; Morrison, 2006).

STEAM literacy may help students connect to the global world (NRC, 2007; Tsupros, et al., 2009). Less than 8% of all graduate degrees in the United States are in STEM, rendering moving forward into the 21st century very challenging for students in the United States (Breiner, et al., 2012). Without STEAM, the United States could not compete in a world-based economy, especially because its workforce would be inadequate, and the United States would lose much ground to other nations in which STEAM disciplines are more emphasized (Scott, 2012). Poor STEM preparation for students would not only negatively affect the U.S. educational system, but also the economy, world ranking, homeland security, and quality of life (DOD, 2012). STEM literacy may help students gain creativity in learning and help the United States improve its position in the global marketplace and in the international ratings of school quality. The findings of this study may assist educators in developing a defined description of STEM, help guide the development of STEM programs, and create an interest among students to pursue STEM areas in college and life (Breiner et al., 2012).

Research Questions

This multiple case study and grounded theory design will utilize a combination of teacher observations, lesson plan evaluations, and interview data. Using these data points, the researcher seeks to evaluate and understand the complex dynamic between curriculum and teachers. The advantages of utilizing case study research is that it allows for the exploration and understanding of complex issues (Yin, 2009). Case studies, in their true essence, explore and investigate contemporary real-life phenomenon through detailed contextual analysis of a limited number of events or conditions, and their relationships. The evidence from multiple cases is often considered more compelling and the overall study is therefore regarded as being more robust (Herriott & Firestone, 1983). Yin (2003) defines the case study research method as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used." (p. 13). The systematic design for grounded theory is widely used in educational research, and it is associated with detailed, rigorous procedures that Strauss and Corbin identified in 1990 (Creswell, 2012).

This research will begin with a clear direction and set of questions with anticipation that data will be collected throughout the process. One broad question will drive this research: What is required for elementary teachers to effectively implement a STEAM curriculum within their classrooms? Several sublevel questions will be asked to draw out the answer to this broad question. The sublevel questions include:

1. What are elementary teachers' understandings of what STEAM education is at the elementary level?
2. How do K-4 teachers feel about their ability to teach STEAM education and do those feelings affect their willingness to integrate it into their classrooms?
3. What problems, if any, do teachers perceive in implementing and integrating STEAM at the elementary level?

Definition of Terms

The following operational definitions for terms used in the study are provided to ensure a common knowledge base:

21st century skills: Many skills other than just technology are involved in 21st century learning. Skills include: communications, social, cross-cultural, information, collaboration, creativity and innovation, initiative, problem-solving, self-direction, media and technology, productivity and accountability, leadership and responsibility, and life and career (Grunwald Associates, 2010).

Attribution theory: a theory which focuses on how internal perceptions of people's capabilities caused by an event affect their behavior (Weiner, 2010).

Content knowledge (CK): the knowledge one has for a specific discipline or topic.

Elementary school: schools that contain classroom grades K-4.

Innovators: those who creatively use the concepts and principles of science, mathematics, and technology by applying them to the engineering design process (Dugger, 2012).

Inquiry-based teaching and learning: a standardized, scaffolded, structured, guided, and open-inquiry form of teaching and learning (Dugger, 2012).

Interdisciplinary learning: refers to the integration of STEAM subjects with other traditional subjects that thoroughly blends writing and reading (Morrison, 2006).

Integration: refers to the blending of technology and individual subjects together to build a learning environment (Sanders, 2012).

Pedagogy: the art, science, and profession of teaching (Gredler, 2009).

Pedagogical knowledge (PK): the various instructional components or principles used by teachers coming together (Shulman, 1986).

Pedagogical content knowledge (PCK): a teacher's ability to integrate his or her knowledge of subject matter with content-specific pedagogical strategies so as to produce successful teaching outcomes (Shulman, 1986).

Science: refers to seeing and understanding what is in the natural world using inquiry, discovery, exploration, and scientific methods (Dugger, 2012).

STEAM: an acronym for the integration of science, technology, engineering, arts, and mathematics (Wynn & Harris, 2012).

STEM: an acronym for the integration of science, technology, engineering, and mathematics (Wynn & Harris, 2012).

CHAPTER 2

Introduction

The purpose of this multiple case study design is to explore, understand, and describe K-4 teachers' perceptions and experiences integrating and implementing a new STEAM curriculum and program. The findings of this study seek to assist educational leaders in understanding teacher beliefs and perceptions surrounding the development of a STE(A)M program. Previous research and studies have addressed the perceptions of teachers at the secondary level and pre-service teachers, in part, but a literature gap exists regarding assessing perceptions of elementary teachers (Paulson, 2012; Wang, 2012). This chapter will further explore the theoretical framework of Shulman and review prior studies in STE(A)M beginning with an introduction to the literature, followed by the history of STEM, from STEM to STEAM, elementary STEAM, STEAM and instruction, STEAM education, the NGSS Framework, STEAM and teachers, concluding with teacher professional development (PD).

Theoretical Framework

As stated in chapter 1, the theoretical framework for this study will focus on the interrelationship of CK, PK, and PCK. PCK is an awareness of a student's difficulties in a particular subject and the methods of representing and formulating the subject that make it comprehensible to them (e.g., analogies, illustrations, examples, explanations, and demonstrations). As previously stated, Shulman was credited with coining the phrase "pedagogical content knowledge," (1986) which he used to emphasize the need for teachers to integrate their knowledge of subject matter with content specific pedagogical strategies so as to produce successful teaching outcomes. The various components of PCK tend to interact, overlap, and vary in importance based upon the instructional environment.

Shulman (1986) initially classified teacher CK in three terms: subject matter content knowledge, PCK, and curricular knowledge. Pedagogical knowledge is a component of PCK and is addressed in detail below. CK is discipline specific and is defined as “the amount and organization of knowledge per se in the mind of the teacher” (Shulman, 1986, p. 9). For example, the subject matter CK one needs to teach science would be different then the CK needed to teach math. In the case of STEAM, CK would include the ability for teachers to concurrently teach interconnected disciplines since CK is the knowledge one has for a specific discipline or topic (Shulman, 1986)

The definition of PK can be expressed as the various components or principles coming together, mitigated by the relational qualities of these interactions. Shulman (1986) defined it as “...the ways of representing and formulating the subject that makes it comprehensible to others” (p. 9). Other scholars have similar definitions for PK. Van Manen (1994) proposed that pedagogy is more than the act of teaching; it entails “distinguishing between what is appropriate and inappropriate, good or bad, right or wrong, suitable or less suitable for children” (p. 139). He continues by addressing the many constructs that make up effective instruction.

> Teaching, as a pedagogical interaction with children, requires not only a complex knowledge base but also an improvisational immediacy, a virtuelike normativity, and a pedagogical thoughtfulness that differs from the reflective wisdom (phronesis) of other practitioners. The classroom life

> of teachers is difficult especially because it is virtuelike, improvisational, and pedagogical. (Van Manen, 1994, p. 139)

While Shulman (1987) considered PCK a subcomponent of CK, other researchers provide different concepts of PCK. Grossman (1990) proposed four components of PCK: (1) concepts and purposes for teaching subject matter, (2) knowledge of students' understanding, (3) curricular knowledge, and (4) knowledge of instructional strategies.

While having well-developed CK is crucial in teaching a particular subject, PCK is also necessary to effectively address student needs and help them learn (Ball et al., 2008). Learners are not blank slates and, in reality, come into a course with many preconceptions and varying levels of preparation (Shulman, 1986). Although teacher expertise is not identified as a component of PCK, defining teacher expertise is a challenging concept (Berlinger, 1986). However, the role of experience in developing expertise in teaching has been conservatively estimated as 5-7 years (Berlinger, 2000). Marks (1990) stated that PCK comes from both subject matter knowledge (e.g. CK) and general pedagogical knowledge. Thus, a definition of PCK involves three concepts: knowing what to teach, how to teach, and how students learn in a variety of conditions. The ability to discern student knowledge, learning preferences, and provide accurate assessment with appropriate remediation of task representations would also be represented by teacher PCK.

Researchers have sought to define PCK both in terms of an educationally generic concept (Grossman, 1990; Shulman, 1986) as well as a discipline specific concept (Rovegno, 2008). PCK encompasses many qualities and attributes, including a perception of what makes the learning of certain topics easy or difficult, and an intuitive sense of what background the students bring with them to the various instructional settings. Disciplines such as science have identified that PCK is important. By examining PCK research from the science discipline, Abell (2008) conceptualized PCK with four important principles: (1) separate categories of knowledge utilized synergistically while teaching, (2) PCK is fluid and changes as teachers gain experience, (3) subject matter knowledge is central to PCK, and (4) PCK facilitates the alteration of subject matter knowledge into an understandable form of knowledge for students. Additional research in the field of science education sought to develop models to try and ascertain the PCK of science teachers (van Dijk & Kattmann, 2007).

Teachers gain their knowledge for teaching from various sources (Grossman, 1990); the same can be expected to apply to teacher knowledge of subject matter. Drawing on Grossman's research, Friedrichsen et al. (2009) identified three potential sources of subject-matter knowledge: (a) teachers' own K-12 learning experiences, (b) teacher education and professional development programs, and (c) teaching experiences. Teachers need both the knowledge of student difficulties and effective instructional strategies to help them acquire new information. This research will use the lens of Shulman and his concepts of CK, PK, and PCK as a means to explore STEAM instruction from the teacher's perspective.

Introduction of the Literature

Over the past 25 years, STEM education has been evolving from a convenient clustering of four overlapping disciplines toward a more cohesive knowledge base and skill set critical for the economy of the 21st century (U.S. DOE, 2018). Economic projections suggest the United States will need more than 1 million additional STEM professionals above the current graduation rates during the next decade (NRC, 2015). That includes STEM majors of varying skill levels and knowledge from community to graduate colleges.

Nearly two-thirds of the S&E graduates in the United States in 2015 were from India and China (NSB, 2015). In 2015, 58% of foreign-born individuals in the United States with an S&E degree were from Asia; another 13% were from Europe (NSF, 2018). Among individuals employed in S&E occupations, 17% of foreign-born workers have a doctorate, compared to 10% of U.S. native-born individuals in these occupations (NSF, 2018).

The industrialized nations of the world have long benefitted from the inflow of foreign-born scientists and engineers and the S&E skills and knowledge they bring. S&E skills are more easily transferrable across international borders than many other skills and many countries have made it a national priority to attract international talent in S&E (NSB, 2012). Foreign-born workers employed in S&E occupations tend to have higher levels of education than their U.S. native-born counterparts (NSB, 2015).

Women are underrepresented among STEM degree holders and in STEM jobs even though women make up half of the college-educated workforce and nearly half of the United States workforce (National Science Board, 2015). For the past decade, women held fewer than 25% of STEM jobs. Women with STEM jobs earned 33% more than women in comparable non-STEM jobs but were less likely than men to work in STEM occupations and instead chose to work in education or health care. Contributing factors to the discrepancy of men and women in STEM jobs include gender stereotyping, a lack of female role models, and less family flexibility in the STEM fields (Lacey & Wright, 2009). For the United States to perform competitively in a global society, STEM education at multiple levels is critical (National Science and Technology Council, 2013).

There has been ample focus on addressing the shortage of qualified science and mathematics teachers in the United States. An emerging awareness is growing that technology is a critical component not only in contemporary culture but also in global competitiveness (Sanders, 2012). Technological literacy offers enormous potential for all students throughout K–12 education delivered through STEM education. Technology motivates young learners in STEM subjects and the potential to maintain their interest in these subjects throughout all grade levels, beginning in kindergarten, is critical (Sanders, 2012).

The National Research Center (2007) defined the elements of STEM as: science (the study of the natural world), technology (the entire system of creating and operating technological artifacts), engineering (a process of solving problems and knowledge about the design and creation of products), and mathematics (the study of patterns and relationships (p. 4).

The importance of STEM literacy is an attempt to bridge discrete disciplines and offer a holistic view of the world, enabling rigorous academic concepts of science, technology, engineering, and mathematics that are applied while making connections between the students' world with the ability to eventually compete in a global world (Stansbury, 2011). Traditional barriers between the four disciplines are removed with STEM and are cohesively integrated (Kaufman et al., 2003). The common factors among the four disciplines of STEM – problem-solving, inquiry, and reconciling multiple solutions – are common undertakings of designers and artists too (Bequette & Bequette, 2012; Wynn & Harris, 2012). STEM better links K–12 subject areas to industry while preparing a future high-tech workforce (Bequette & Bequette, 2012). Positive, confident instruction blended with STEM areas is critical to the successful integration of STEM education for all students, beginning in kindergarten (Singer, 2011).

The History of STEM

In 1985, the Triangle Coalition formed and began advocating for improved science, technology, engineering, and mathematics education in the United States. Although the acronym STEM did not refer to the program until later, U.S. organizations that represented business, education, and STEM societies composed the Triangle Coalition in order to improve STEM areas of education. Through communication, advocacy, and programmatic efforts, the Triangle Coalition attempted to unify voices of the stakeholders to advance STEM education for all students (Triangle Coalition for Science and Technology Education, 2012).

Worry that American students were lagging behind others in international rankings prompted a movement toward science standards in 1995 (National Science Education Standards, 2012). The publication *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* brought awareness to the decline of scientists, engineers, and mathematicians in the United States and of the need to keep the United States in the forefront of innovation, technology, and research (Lantz, 2009). A congressionally requested report published in 2006 made four recommendations to focus new science and technology efforts and creating high-quality jobs and meeting the needs in the future. The request was to (a) increase mathematics and science education to improve the U.S. talent pool; (b) commit to and invest in long-term research; (c) recruit, educate, and retain highly qualified students, scientists, and engineers; and (d) work toward ensuring that the United States is number one in the world for innovation (NRC, 2007). Reduced academic STEM performance and concern of global competitors increased interest and investment in STEM education and the development and training of a STEM workforce (Wang et al., 2011).

Initially, the movement of STEM education included specialty charter or magnet schools that focused on STEM, leaving students in public school without the option of STEM education (Dugger, 2010). Only 37,000 students enrolled in schools specializing in science, technology, engineering, and mathematics in 2008 (NRC, 2007). As of 2012, the majority of STEM students had not entered the field after program completion (National Science Board, 2012). Often, communities do not work with schools to attract students to STEM careers (NRC, 2007). Financial challenges and mandated initiatives often prevented districts from having the time or tools to train teachers (Bursal & Paznokas, 2006).

The No Child Left Behind (NCLB) era diminished science education (Bybee, 2010). There had been a significant departure from and de-emphasis on science instruction, especially at the elementary level, as a result of the increased emphasis on English language arts (ELA) and mathematics (Dorph, et al., 2011). As early as 2002, Jorgenson and Vanosdall (2002) stated, “Teachers and school administrators across the U.S. are facing enormous pressure to improve test scores in the basic skills areas; consequently, they have been forced to reduce—or in some cases eliminate—the amount of class time devoted to science” (p. 602).

Teachers were subsequently held less accountable for science content, an area in which teachers already endured intimidation. Under the NCLB, students were not tested for science until 2007, which left a gap in science education for more than seven years

(Bybee, 2010). Some educators speculated that NCLB was the reason student enrollment for science and engineering majors declined (Bybee, 2010).

In January 2010, the U.S. Congress passed a bill allocating $250 million to STEM education for K–12 public, charter, and private schools in an effort to increase the quality of STEM education (NRC, 2007). The belief is that STEM prepares students for the challenges and opportunities of the 21st century. Students exposed to STEM typically participate in advanced studies, learn how to make informed decisions, and work toward solving problems (STEM Education Center, 2012).

Fewer students enter STEM fields in the United States than students in other nations (National Science Board, 2012). Science and mathematics components, which are usually taught as separate subjects, are often inadequately integrated into the technology and engineering components of STEM or other conceptual areas of curricula (STEM Education Center, 2012). A fully developed STEM program may provide a movement of students into the scientific field to meet current and future demands for scientists and engineers (STEM Education Center, 2012).

All STEM disciplines present opportunities for building 21st century skills and may be important to the future of students. Increased recognition of engineering in K–12 education directly involves students in problem-solving, hands-on inquiry learning, and innovation (Bybee, 2010). Classroom teachers need help understanding how to teach lessons because of a lack of background in science (Bursal & Paznokas, 2006).

According to Lantz (2009), the underlying problem with developing STEM education programs was the lack of a clear definition of STEM. Although the U.S. DOE (2013) recommended the implementation of STEM education in American schools, the

DOE failed to provide a working definition of what constitutes STEM curricula and offered little guidance about how to approach such integration strategically or about how to assess the success of a STEM curriculum after implementation (Stansbury, 2011). Educators embraced STEM even though a lack of understanding regarding how it should look in the classroom still existed (Paulson, 2005; Stansbury, 2011). Although a growing consensus that more in-depth science and math education in the American education system is needed, no definite program or implementation has been developed (U.S. DOE, 2013).

From STEM to STEAM

A search for a true definition of STEAM education might prove difficult. Although educators are aware of the role of STEM education as an economic imperative of education (Chesky and Wolfmeyer, 2015) as well as a pedagogical need to enhance learning (Lansiquot 2016), neither educators nor researchers consistently agree on definitions for K-12 STEM education or best practices for integrated STEM instruction (e.g., Breiner et al. 2012). There are few resources that give comprehensive guidance and applicable methods. In fact, the Department of Education utilizes STEM as the prominent acronym for the strategic initiative underscoring the best way to learn 21st century skills (DOE, 2018).

STEAM education is derived from STEM education and focuses on fostering not only the core subject areas of science, technology, engineering, and mathematics, but also the *arts*. This is a key differentiator from STEM, as STEM teaches pragmatic mathematical, coding, and scientific subject matter. When educators think of the arts, they often think of visual arts, but STEAM includes anything from digital design, such as websites, to language arts, to music or performing arts. The idea is that many STEM projects require an element of artistic design, communication, and collaboration, and without these elements, projects may not reach their full potential (TEQ, 2019).

STEAM was initially coined by the Rhode Island School of Design; the university has championed an effort to bring the arts to the national agenda of STEM. RISD's belief was that we cannot have scientists and programmers without artists and writers as these jobs are complementary to one another, should work together, and should understand each other. Before STEAM was acknowledged widely, educators were exploring variations of STEM as a means of attending to more authentic integration of the disciplines, acknowledging the importance of arts and humanities in subject integration (Sanders, 2009). The acronym STEAM is relatively new and typically attributed to Yakman's (2010) early conceptualization of how principles of math and science could be explored through the arts. Yakman's framework (2010) seeks to remove the isolation of STEM disciplines in "silos" and develop an integrative approach that exists authentically with the inclusion of the arts.

Elementary STE(A)M

One of the main goals for K-12 STEM education in America is to increase STEM literacy for all students, and research has indicated that this begins with early and consistent exposure to STEM subjects (DeJarnette, 2012; National Research Council, 2011). Though, efforts to develop integrated STEM curriculum at the elementary level are largely undeveloped (Lantz, 2009). Unfortunately, many STEM education initiatives are rarely designed solely for elementary grade levels (DeJarnette, 2012).

Elementary students are not too young to participate in and understand STEM concepts; many have argued that early exposure to such learning experiences is the optimal time to make positive influences on young students (Nadelson et al., 2013). As noted in the National Research Council's (2012a) *A Framework for K–12 Science Education Practices*, "Before they even enter school, children have developed their ideas about the physical, biological, and social worlds and how they work" (p. 24). Young children, particularly in the elementary grades, are naturally inquisitive and avid investigators. They are eager to explore, invent, and make sense of the world around them in doing so—skills that are critical to succeed in STEM fields (Bosse, et al., 2009; National Research Council, 2013).

Furthermore, effective STEM teaching "capitalizes on students' early interest and skills, identifies and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest" (National Research Council, 2011 p. 18). Lottero-Perdue et al. (2014) found that integrated STEM education utilizing hands-on and inquiry-based strategies improved students' self-management (i.e., autonomy) skills. In a study of elementary-age students attending a 3-day summer STEM camp, Dillivan and Dillivan (2014) found that inquiry-based activities were most successful in stimulating interest in STEM disciplines. Elementary students' interest levels will lead to more proficiency in core concepts that can deepen a student's understanding of complex ideas in STE(A)M. Therefore, the need for STEM instruction at the elementary level is of increasing importance (Epstein & Miller, 2011; Judson, 2014; National Research Council, 2012b).

Efforts to increase the presence of STEAM learning in elementary settings have mainly focused on stand-alone programs implemented in afterschool, summer, or other out-of-school enrichment programs (National Governors Association, 2012). The Bayer

Corporation's (2016) Compendium of Best Practice in K-12 STEAM Education identifies programs that are proven to be highly effective. These programs offer students unique hands-on learning experiences that promote technological literacy and engineering skills. Programs with problem-project-based lessons are designed to engage young learners in building critical thinking and collaboration skills as they explore various STEM-content topics (Brenner, 2009). Similarly, engineering lessons that engage students in solving hands-on problems through the use of storybooks and integrated English, social studies, mathematics, and science skills (Bayer Corporation, 2016; Brenner, 2009) help elementary aged students learn STE(A)M concepts. Nevertheless, there still remains a need for a more comprehensive approach to exposing and engaging young children to integrated STEM/STEAM curriculum. The future generation of STEM innovators and professionals are reliant on our country's educational system to "cultivate, excite, and promote their STEM learning to influence their future career decisions" (Cotabish et al., 2013, p. 215).

STE(A)M and Instruction

STEM education was never intended to be stand-alone subject-area teaching with licensure regulations (Sanders, 2009). According to the literature, the core of STEM is the engineering design process based on the constructivist and cognitive learning theories (Bandura, 2001; Dewey, 1997; DOD, 2012; Sanders, 2009). The concepts of STEM are hands-on, inquiry-based, real-world, and project-based interdisciplinary programs of study that connect STEM-related subjects (Hoachlander & Yanofsky, 2011). STEM was thought to be greater than an interdisciplinary program and meant to be far more than the grafting of technology standards onto science and mathematics curricula (Shaughnessy, 2012). Although school administrators and educators are aware of the importance of STEM education, many K–12 teachers and educators do not understand what STEM education is (Wang, 2012). Thus tomorrow's STEM education leaders must better understand the interdisciplinary connections of STEM subjects and educators' roles in the classroom (Berlin & White, 2012; Cunningham & Cordeiro, 2006; Dugger, 2010; Sanders, 2009). When evaluating or determining the program, consideration for the elements, implementation, and the requirements to implement and teach STEM effectively are important (Nadelson et al., 2012). Finding the most effective method of teaching and learning for STEM education may lead educators toward a more effective form of teaching and learning for students in STEM education (Singer, 2011).

According to Morrison (2006), STEM is an effort toward a holistic, cohesive teaching and learning paradigm, offering a complex, multi-faceted whole with new spheres of understanding. Traditional barriers between the four disciplines are removed with the integration of all disciplines and STEM subjects (Kaufman et al., 2003; Sanders, 2009). Integration in curriculum design and implementation, connecting classroom practices with the real world, and focusing on innovation and application are among the tasks that a STEM teacher is expected to fulfill (Morrison 2006). Tomorrow's STEM education leaders must better understand the interdisciplinary connections of STEM subjects and their role in the classroom (Cunningham & Cordeiro, 2006; Dugger, 2010; Sanders, 2009). Finding the most effective method of teaching and learning for STEM education will lead educators toward a more effective form of teaching and learning for students in STEM education (Singer, 2011). Accelerated proficiency in STEM is imperative for new teachers (Berlin & White, 2012; Brown et al., 2011).

With the integration of more technology tools and resources in schools, teachers can benefit greatly from training in STEM education. According to a two-year NSF funded study, STEM teaching is more effective and student achievement increases when teachers work together or in teams to develop strong professional learning communities in their schools (National Commission on Teaching and America's Future, 2011). Today's students are preparing for a future in which they will work collaboratively to develop new knowledge, solve problems, and continuously acquire new skills. In order to succeed, students need educators who know how to create schools that look like the organizations where they will work in the future (Fulton & Britton, 2011).

Many educators perceive STE(A)M education as the focus of instruction on science, technology, engineering, and math as separate entities and diminish the arts (Bequette & Bequette, 2012). Other educators perceive STEM as an integration of STEM subjects with other traditional subjects, or thoroughly blending writing and reading with the use of science and math (Sanders, 2009). Still other educators perceive STEM as a transdisciplinary approach that integrates the concepts of the STEM fields with the arts and other traditional subjects with emphasis on STEM subjects (Morrison, 2006).

Though many sources of information suggest what STEM education should be, no national understanding of STEM education and how it should look in the classroom has developed (Scott, 2012). Additionally, debates continue regarding the specific STEM content expertise that teachers need to be effective (National Science and Technology Council, 2013). Mounting pressure to improve STEM instruction affects education throughout the United States. The lack of a clear definition of STEM education is the underlying problem with developing STEM education programs (Dugger, 2010; National Science and Technology Council, 2013; U.S. DOE, 2013).

Relatedly, teachers' beliefs about learning and instruction influence instructional practice and teacher decision making (Nadelson et al., 2013). Teacher quality and effectiveness affects students' educational experiences more than any other single factor (Bursal & Paznokas, 2006). Therefore, attitudes of both students and teachers affect STEM achievement and are part of the problem with increasing STEM education programs (Paulson, 2012). A teacher's attitude toward science or math may affect teaching methodologies and the amount of time spent teaching science or math content (Paulson, 2012). The attitude that science and math are challenging, difficult subjects, mastered by only a select few is prevalent and seems to permeate achievement for students (Bursal & Paznokas, 2006).

The elementary teaching force, in particular, continues to lack knowledge and confidence in science and math concepts (Bursal & Paznokas, 2006; Paulson, 2012). According to Fulton and Britton (2011), teachers become more positive and engaged in teaching after experiencing STEM education, even if initial perceptions were not positive. Positive reaction because of improved interaction with fellow teachers and students and the reduction of isolation most teachers experience makes teaching exciting and often re-motivates teachers for the profession (Fulton & Britton, 2011). This lack of teacher knowledge and confidence coupled with the absence of an agreed-upon definition and understanding of STEM in this country results in the current situation of under-prepared teachers and students.

STE(A)M Education

Research on successful STEM education indicates that a coherent and rigorous curriculum is essential for any successful STEM school initiative (National Research Council, 2011). An essential component of teaching STEM/STEAM is through the use of integrated approaches which show a cohesive connection made between the subject matter taught in the classroom and its relevance and connection to the real-world. Although the typical structure and organization of most elementary school settings seem to lend itself to integrated instruction because students are primarily with the same teacher, school-level contexts are designed to teach the core subjects of language arts, mathematics, science, and social studies in silos, leaving very little time for integrating instructional technology or engineering concepts. (Wang et al., 2011).

Some consider STEM a transdisciplinary, problem-solving, innovative, inventive, self-reliant, logical thinking, and technologically literate system of learning (Hoachlander & Yanofsky, 2011). The common factors of the four disciplines of STEM are problem-solving, arguing from evidence, and reconciling conflicting views. The intent is to prepare students to study STEM fields in college and to pursue related careers (National Science Foundation [NSF], 2008).

The common factors of the four disciplines of STEM are common undertakings of designers and artists, as well (Bequette & Bequette, 2012; Wynn & Harris, 2012). Integration of STEM throughout the curriculum for all children starting in kindergarten is most effective (Dorph, et al., 2011). By learning this process of problem-solving at an early age, students learn to deal with problems at school, in careers, and in life. Bequette &

Bequette (2012) said STEM better links K–12 sciences to industry while preparing a future high-tech workforce.

STEM literature indicates STEM concepts are those used by engineers when designing and building projects called the Engineering Design Process (EDP) (Cantrell, et al., 2005, ITEA, 2007). All subjects are integrated using hands-on, project-based learning. Students are not only engaged, but they also become problem solvers who develop solutions to real-world problems. The implementation of the engineering design process can successfully improve student achievement and attitudes toward learning (Cantrell et al., 2005). This engineering design process is a multi-step process that includes research, design, production planning, and assessment (ITEA, 2007). The process includes building upon an idea or solving a problem by brainstorming, planning, designing, creating, and evaluation. If the solutions are not accurate or appropriate, the cycle begins again making needed improvements.

The National Research Center (2007) defined the elements of STEM as: science (the study of the natural world), technology (the entire system of creating and operating technological artifacts), engineering (a process of solving problems and knowledge about the design and creation of products), and mathematics (the study of patterns and relationships (p. 4). Classroom constraints and a focus on reading at elementary levels often prevents teaching of STEM content areas for the majority of teachers. Financial challenges and mandated initiatives often prevent districts from acquiring the time or tools to train teachers (Dugger, 2010). Few professionals trained in STEM fields transfer to teaching because of lower income levels or certification requirements (Dugger, 2010; NRC, 2007). The expertise of educators working in classrooms and in after-/out-of- school settings is a key factor – some would say the key factor – in determining whether integrated STEM education can be done in ways that produce positive outcomes for students.

Integrative learning with STEM offers an opportunity for teachers, administrators, and university faculty to become engaged in a learning community that will continue to evolve (Sanders, 2009). Many educators believe that STEM education will transform the typical teacher-centered classroom into a student-centered classroom that requires students to actively engage to find solutions through problem-solving and exploratory learning (Cunningham & Cordeiro, 2006). With the integration of more technology tools and resources in schools, teachers can benefit greatly from training in STEM education.

The NSF advocated for adding an engineering component to comprehensive science education that interfaces with technology and math (Bequette & Bequette, 2012). Some educators have said that STEM education addresses real-world problems using rigorous academic concepts in interdisciplinary or transdisciplinary lessons (Sanders, 2009). "STEM education exemplifies the axiom the whole is more than the sum of the parts" (California Department of Education, 2012, p.1).

Although the NRC and NSF agencies defined STEM concepts within the context of science and engineering, not all educators have the same perception and understanding of STEM education. Consequently, a clear definition for integrating and implementing STEM concepts in school varies (Watt et al., 2007). Many teachers believe certification requirements in STEM subjects are necessary to teach STEM, and many teachers, particularly elementary teachers, are uncomfortable with teaching STEM subjects (Bursal & Paznokas, 2006; Epstein & Miller, 2011). Few educators hold a vision for STEM school reform and believe STEM is just a new acronym for teaching traditional science and mathematics (Watt et al., 2007). Little or no opportunities and incentives are available in most schools for teachers to become proficient in STEM (Atkinson, 2012).

NGSS Framework

The NGSS framework is meant to provide a common perspective and vocabulary for researchers, practitioners, and others to identify, discuss, and investigate specific integrated STEM initiatives within the K–12 education system of the United States (NRC, 2014a). The Common Core State Standards for Mathematics and the NGSS have pushed for deeper connections among the STEM subjects (Honey, et al., 2014). The NGSS explicitly includes practices and core disciplinary ideas from engineering alongside those for science, raising the expectation that science teachers will be expected to teach science and engineering in an integrated fashion (NRC, 2014a).

STEM disciplines are the object of ever-increasing interest and attention to help prepare students for the job demands in today's society. Students not only need to have a strong foundational understanding of the big ideas in science, but they also need to be expert critical thinkers and problem solvers prior to the end of high school (Isabelle, 2017). As stated by the National Research Council (NRC, 2014a),

> by the end of the 12th grade, students should have gained sufficient knowledge of the practices, crosscutting concepts, and core ideas of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to continue to learn about science throughout their lives. They should come to appreciate that science and the current scientific understanding of the world are the result of many hundreds of years of

> creative human endeavor. It is especially important to note that the above goals are for all students, not just those who pursue careers in science, engineering, or technology or those who continue on to higher education. (p. 9)

Compared to previous science standards, the NGSS framework has a unique three-dimensional architecture, with observable performance expectations that are explicitly mapped to three foundation areas: science and engineering practices, disciplinary core ideas (DCIs), and crosscutting concepts (Table 1). As students conduct science investigations to answer questions and solve engineering problems, the performance expectations are meant to serve as assessable or observable outcomes that are a result of active classroom experiences (NRC, 2014a). Furthermore, the new standards specify grade-by-grade expectations for Grades K–5 and make connections to the Common Core State Standards in ELA and mathematics; both of these aspects of the NGSS are unprecedented (Isabelle, 2017).

Table 1

NGSS Framework

THE THREE DIMENSIONS OF THE FRAMEWORK
1 Scientific and Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information
2 Crosscutting Concepts
1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change
3 Disciplinary Core Ideas
Physical Sciences
PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer
Life Sciences
LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy, and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity
Earth and Space Sciences
ESS1: Earth's place in the universe
ESS2: Earth's systems
ESS3: Earth and human activity
Engineering, Technology, and Applications of Science
ETS1: Engineering design
ETS2: Links among engineering, technology, science, and society

The NRC (2012) acknowledged the importance of establishing these early foundations: "Because learning progressions extend over multiple years, they can prompt educators to consider how topics are presented at each grade level so that they build on prior understanding and can support increasingly sophisticated learning" (p. 26). The NGSS emphasize the role of engineering design in facilitating student learning of scientific concepts. Given current low levels of confidence among K–12 educators in the teaching of engineering (Horizon Research 2013), it may be especially important for both new and experienced science teachers to become familiar with the engineering design process and how it can be integrated into science teaching (Honey, et al., 2014). To achieve the goals set forth by the NGSS by Grade 12, thinking and acting like scientists and engineers must begin in the elementary grades (Isabelle, 2017).

STE(A)M and Teachers

Classroom teachers need help understanding how to teach lessons because of a lack of background in STEM subject areas (Berlin & White, 2012). At the middle-and high-school levels, preparing and training teachers with the initial certification in STEM content areas and implementation of STEM units along with hands-on science education programs does not sustain changes in formal science education curricula (Library of Congress, 2008). Only 40% of teachers in grades 7 through 12 majored in math or science (NRC, 2007). At the elementary level, teaching STEM requires a different knowledge and skill base than that held by a majority of teachers (Berlin & White, 2012). Additionally, many K–12 science and mathematics teachers have taken fewer courses in the subject area(s) in which they were trained than are recommended by teacher professional associations, and many have taken few courses in other areas of STE(A)M (Honey, et al., 2014).

Elementary school teachers are considered the beginning of the STEM pipeline (Cotabish et al., 2011). Mathematics and science in the early years of education lay the foundation for future STEM learning, but elementary teachers are often unprepared to teach students in these areas of study (California Department of Education, 2012). Elementary teachers are largely unprepared and uncomfortable with implementing STEM in class curricula for teaching and learning (Cotabish et al., 2011).

Research on STEAM education in K-12 schools has indicated that despite increased funding there has been little improvement (Portz, 2015). This is, in part, due to issues of STEAM being ill conceptualized; teachers are not sure exactly what is and is not considered STEAM, the complexity of changing instructional models (Portz, 2015), and having a narrow focus that typically favors math or science with little attention to engineering and technology, means educators often fail to offer an integrated curriculum (Bybee, 2010; Moore et al., 2014).

CK and quality PK practices play an enormous role in it the effectiveness of integrated STEAM teaching (Caprara, et al., 2006; Stohlmann, et al., 2012). Teachers' beliefs about the efficacy of STEAM instruction improve during STEAM professional development (PD), however these same teachers continue to struggle with STEAM curricula, finding discipline or subject area and technology integration difficult even when collaborating across subjects (Wang, et al., 2011). Another issue plaguing the success of STEAM instruction is the lack of a clear consensus on how STEAM should be taught (Herro, et al., 2019).

Research has identified a number of challenges with STEAM programs including additional preparation time, access to resources, storage space, teacher attitudes toward STEAM, learning new content, and effective assessment (Laboy-Rush, 2011). Teachers also had difficulty with standards alignment (Nadelson et al., 2013), cited a lack of collaboration among colleagues (Zubrowski, 2002), and struggled to have a solid understanding of how to teach subject matter across disciplines (Pang & Good, 2000).

The challenge for teachers lies in aligning STEAM with classroom practices, at times creating a dichotomy between theory and practice. Without strong STEAM teachers who understand how to embody this vision of integrated STE(A)M, STE(A)M could be reduced to a simplistic version of "design cycles" based on hands-on activities absent of strong science and mathematical content (Williams 2011).

Teacher Professional Development

Teaching STE(A)M content at the elementary level is filled with opportunities and challenges (Abrams, et al., 2008). The opportunity to capitalize on the enthusiasm of young learners and their desire to explore STEAM concepts, the development of student foundational STEAM knowledge, and flexibility in the elementary curriculum that can more readily support innovative approaches for teaching STEM content (Nadelson, et al., 2013). The challenges include access to appropriate resources, the overwhelming focus on English language arts and mathematics learning standards, and teacher preparedness to teach STEM curriculum (Nadelson et.al., 2013). Meeting these opportunities and challenges is likely to require teachers to engage in ongoing professional development (Morrison, et al., 2008; Tsai, 2006). Teachers' need for continuing education to enhance their preparation to teach STEM is accompanied by the need to investigate the effectiveness of these continuing education offerings (Nadelson et.al., 2013).

The typical elementary education teacher certification curriculum requires candidates to complete two college-level science courses and two college-level mathematics courses (NRC, 2010), which is arguably inadequate preparation for teaching a STEAM curriculum. To overcome the limitations associated with this minimal preparation in STEAM, it is essential that teachers engage in continuing education (NRC, 2017). Thus, professional development in STEAM is critical for assuring teachers are prepared to effectively meet the STEM education needs of their students. As stated by Sanders (2009):

> Given the amount of CK necessary to be an effective science, mathematics, or technology educator, it's very difficult to imagine a new teaching/ licensure program that would prepare individual pre- and/or in-service teachers with sufficient science, mathematics, and technology content expertise—and the PCK—to teach all three bodies of knowledge effectively (p. 21).

For teachers already in the classroom, a number of curriculum initiatives include professional development (PD) to build CK in more than one STEAM discipline (El Nagdi, et al., 2018). Little is known, however, as to whether these efforts address teacher needs related to integrating STEAM education in their classrooms. Evidence does indicate that educators need opportunities and training to work collaboratively to deliver effective, integrated STEM instruction (El Nagdi, et al., 2018). PD and collaboration should involve staff in the school (e.g., joint lesson planning among STEM teachers) but may extend beyond the classroom to include STEM and education faculty in postsecondary institutions, educators in after-/out-of-school settings, and STEM professionals in industry (Honey, et al., 2014).

Teacher education programs around the country are making efforts to prepare prospective teachers with appropriate CK in more than one STEAM subject and a larger number of programs offer in-service PD related to STEAM education (Honey, et al., 2014). Perhaps obvious, it is worth noting that many of the changes likely to be needed to successfully implement integrated STEM education will require additional financial resources. Money, as well as time and planning, will be required to help educators acquire content and PCK in disciplinary areas beyond their previous education or experience (Honey, et al., 2014).

CHAPTER 3

Introduction

The purpose of this qualitative multiple case study and grounded theory design is to explore, understand, and describe K-4 teachers' perceptions and experiences with integrating and implementing a new STEAM curriculum. This study is important because of the lack of available research with respect to elementary level teachers' abilities and comfort levels of teaching science curricula. Understanding teachers' perceptions with respect to this, particularly during the implementation of a newly aligned STEAM program, will prove to be invaluable as it will help to identify areas of strength and weakness with this new initiative. Additionally, it is important to review and analyze the requirements needed for effective instruction that affects elementary teachers' attitudes, perceptions, and confidence to implement STEAM education in the classroom (Brown, 2012; Wang, 2012). This research study seeks to provide details and potential implications for how elementary teachers' perceptions affect the integration and effectiveness of STEAM education. The themes identified look to provide a greater understanding of how teachers' personal feelings about STEAM, as well as teachers' experiences, affect the quality of student learning.

Chapter 3 includes the description of the research method and design and explanations of the reasons and appropriateness for choosing a qualitative, multiple case study design and grounded theory. Included in this chapter are a list of the research questions and descriptions of the sampling criteria, sampling frame, study participants, informed consent, confidentiality, and geographic location. Also discussed are data-collection procedures, rationale, validity and reliability, and data analysis.

Methods and Procedures

Research methods and designs explain specific procedures used in data collection and data analysis in qualitative or quantitative research methods (Yin, 2009). In this study, the researcher used the multiple case study and grounded theory design to explore and understand the perceptions and experiences of elementary teachers relevant to K-4 STEAM education. There will be three distinct sources of data that will be examined: lesson plans, teacher observations, and interviews. Merriam (2002) described qualitative research as a method research use to uncover the meanings individuals have constructed about an event, a situation, or a specific phenomenon. Stake (2010) posited that qualitative research is a process aimed at understanding one thing well and how something works. A qualitative study is appropriate when little information exists about the topic, the variables are unknown, and a relevant theory basis is inadequate (Yin, 2009).

Given the problem and purpose of this study, the appropriate design model for this research is a multiple case study, grounded theory design. Yin (2009) defined the case study as an empirical inquiry to understand a real-life phenomenon in depth. The evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust (Herriott & Firestone, 1983). In this research the multiple cases will be representative of teachers from multiple grade levels. The systematic design for grounded theory is widely used in educational research, and it is associated with detailed, rigorous procedures that Strauss and Corbin identified in 1990 (Creswell, 2007).

This research will also employ document analysis, document analysis is a form of qualitative research in which the researcher interprets documents to give additional meaning to the participants' views on the topic (Merriam, 2002). Information gathered from teacher lesson plans and field notes from teacher observations will be used to triangulate with the interview data. Patterns and themes of meaning are expected to emerge as the documents and interviews are analyzed from the participants' own words as the study unfolds (Yin, 2009).

Interviews are one of the most common forms of qualitative research methods and involve the construction or reconstruction of knowledge (Mason 2002). The interview is a flexible, interactive, and generative tool to explore meaning and language in depth. Interviews with open-ended questions for collecting data are appropriate to elicit the views and opinions from the participants (Yin, 2009). The advantages of using open-ended questions include increased capability to get in-depth perspectives of the participants, increased interaction between the respondent and questionnaire, and an appealing design to people who would use the research (Patton, 2002).

A multiple case study design may introduce new and unexpected results during its course, leading research into a new direction. Problems with internal and external validity and with reliability may exist in this type of study. However, the disadvantages are balanced by contributions to theory development and understanding of issues the rich detail and themes provide (Yin, 2009). The benefits of this method of research can be enhanced by the use of multiple sources and multiple methods.

Grounded Theory

Grounded theory is a systematic, qualitative procedure used to generate a theory that explains, at a broad conceptual level, a process, an action, or n interaction about a substantive topic (Creswell, 2012). Grounded theory involves theoretical sampling, constant comparison analysis, data coding (open, axial, selective), and memos. It is a method for building theory inductively, through a process of systematic coding and analysis. The theory is "grounded" in data, is integrated, consistent, and close to data (Strauss & Corbin, 1998).

Using grounded theory enables the researcher to allow a theory to emerge from the data rather than by using specific preset categories, allowing the researcher to explain a basic social process (Glasser, 1993). This researcher used grounded theory to incorporate a systematic approach to analyze participant data and develop a theory for STEAM as it currently relates to teachers. This research used grounded theory practices in an effort to capture the experience of the participants in analyzing teacher perceptions of STEAM.

A good grounded theory is applicable to the substantive area of research; it provides an understanding that makes sense within the context of the study; it is abstract enough yet it includes sufficient variation so that it is applicable to other contexts related to the phenomenon; and, it aims at providing a degree of control over the phenomenon studied. Grounded theory is useful and appropriate for creating substantive, mid-range theory that has explanatory utility (Strauss & Corbin, 1998).

In grounded theory research, data collection and analysis take place simultaneously. Data are coded into categories in a systematic, rigorous yet flexible approach. The researcher interprets the categories and evolves them into broader concepts. Through constant comparison, the concepts and categories are continually revised against the data. Characteristics of the data, category dimensions and relationships are (re)evaluated until no new meaning can be derived from the data. It is at that point that the study ends. The theory emerges from the research, at each of the steps (Denzin & Lincoln, 2000).

Research Questions

This multiple case study, grounded theory design will utilize qualitative research analysis in seeking to evaluate and understand the complex dynamic between teacher and instruction. One broad question will drive this research: What is required for elementary teachers to effectively implement a STEAM curriculum within their classrooms?

Several sublevel questions will be asked to draw out the answer to this broad question. The sublevel questions included:

1. What are elementary teachers' understandings of what STEAM education is at the elementary level?
2. How do K-4 teachers' feel about their abilities to teach STEAM education affect their willingness to integrate it into their classrooms?
3. What problems, if any, do teachers perceive in implementing and integrating STEAM at the elementary level?

Setting

This research seeks to explore K-4 elementary teachers' perceptions and experiences after participating in the new STEAM initiative for one year. The target school for this research is a suburban elementary located in Long Island, New York. This research seeks to explore teachers' beliefs and perceptions surrounding this new initiative and document their experiences with integrating STEAM education into their classrooms. Research questions will focus on two main components of the STEAM initiative: curriculum and instructional practices.

Over the last ten years, there has been a decrease in the amount of time spent on elementary science instruction at this school due to an increased need to focus on developing and revamping core ELA instructional practices. In the last fifteen years, this district has seen an increase in its Hispanic population, current enrollment with this district is 57% Hispanic, 41% White, and 2% Multiracial. During this time, the district was adapting its programs to meet its students' needs.

In 2008, this school was cited by New York State for underperformance on the English Language Arts exams, which resulted in a programmatic review and the requirement to develop a Local Assistance Plan (LAP). As per Commissioner's regulations, LAP schools must develop a plan which focuses on closing identified gaps in student achievement. In order to help improve the performance of second language learners on the ELA exam, a plan was developed as well as a timeline for implementation.

As a means to address academic and instructional areas of weakness, building and district leveled leaders researched new reading programs to support the diverse needs of the community and developed a newly revised daily schedule which provided students reading practice and interventions for three hours per day. The goal of these changes was to close achievement gaps and boost performance scores. As a consequence of this initiative, there was little time devoted to hands-on science instruction.

With achievement scores now above the previous levels on the third and fourth grade ELA exams, leadership has shifted its focus to reinstate science by funding a new school-wide STEAM initiative and is currently focused and committed to developing a unique and innovative program for this school.

Participants

The participants of a study are composed of a group of individuals with similar or same characteristics (Creswell, 2012). The participants for this study consisted of five, K-4 teachers who work in one suburban New York elementary public school. During the 2019-2020 school year, the school involved in this study had a total of 23 K-4 teachers participating in the STEAM initiative. From this population, one teacher per grade level will be recruited to participate in this study.

The total sample for this study will be five, K-4 teachers, one per grade level, selected from the target school. The researcher has identified one teacher per grade level to participate in this study, and for purposes of anonymity, the names of these individuals have been changed: Janice (kindergarten), Kristie (Grade 1), Lori (Grade 2), Heather (Grade 3) and Victoria (Grade 4). Sample size in qualitative research varies with the nature of the study (Patton, 2002). McNamara (2009) stated that no set sample size for qualitative studies existed because of the large amount of data generated and the complexity of analyzing qualitative data, but a researcher can continue to gather data until saturation occurs or no new information is obtained. Similarly, Patton (2002) stated that credibility of qualitative research depends more on the richness of the information gathered and less on sample size. To minimize bias, the researcher plans to conduct a culminative focus group interview until data saturation or until no different ideas are expressed and no new information can be gained. Teachers involved in the study all began the STEAM initiative at the same time. Upon completion of this study they will all have had the same level of exposure to this new program.

Table 2

Description of Participants

Participants	Grade Level	Gender	Years of Teaching Experience	Education Level
Janice	K	Female	20	Masters +45
Kristie	1	Female	15	Masters + 40
Lori	2	Female	25	Masters + 45
Heather	3	Female	17	Masters +45
Victoria	4	Female	11	Masters + 30

Data Collection Procedures

Data analysis is the process of organizing interpreting the data searching for recurring patterns to determine the importance of relevant information (Bogdan & Biklen, 2007). In qualitative research, the collecting of data and analysis takes place simultaneously to build a coherent interpretation of the data (McMillan & Schumacher, 2001).

In this research, data will be collected from three sources: lesson observations, lesson plan review, and a focus group interview. The researcher plans to observe one science lesson per grade level during which data will be collected using evaluator observations and field notes. The researcher will additionally analyze the lesson plan from participant teachers and finally, the researcher will hold a focus group interview and collect data through field notes. These three data sources will then be analyzed.

The data analysis for this study will proceed through the methodology Merriam (2002) and Yin (2009) suggested. Guided by Yin's method of inquiry, data analysis will include transcribing recorded interviews, coding data, categorizing the coded data, and identifying the primary patterns and themes in the data. Merriam (2002) described *coding* as the process of interacting with the data, raising questions about the data, comparing data, and reaching conclusions from knowledge generated from the data. The purpose of coding is not only to describe the data, but also to acquire new understanding of the phenomenon of interest or events central to the study (Yin, 2003). Based on the suggestion of Creswell (2007), the researcher plans to complete preliminary analysis after the focus group interview. The researcher will then code and record data according to the constant comparative method until themes began to emerge. The constant comparative method involves breaking down the data into meaning units and coding them to categories (Glaser, 1965). The researcher will use documentation and field notes to further endorse themes where applicable.

Document Analysis

Document analysis included a review of teachers' STEAM lesson plans and observation field notes. Document analysis is a form of qualitative research in which the researcher interprets documents to give additional meaning to the participants' views on the topic (Merriam, 2002). The researcher used information from documents to triangulate the data with the interview responses. Patterns and themes of meaning will begin to emerge as the researcher analyzes the documents and interview from the participants' own words as the study unfolds (Yin, 2009).

Focus Group Interview

The researcher plans to meet with participants and take interview notes pertaining to the dialogue concerning the teachers' opinions, feelings, thoughts, and suggestions. The researcher will make every effort to help the teachers become comfortable and at ease. The interview will begin with informal conversation about the current school year and other low-stakes topics to assist each teacher with relaxation and comfort with the focus group scenario. The participants will be given the option to opt out of answering an interview question should they not wish to answer. The researcher will review the teachers' answers with the teachers before moving to the next question, allowing for confirmation and accuracy.

Field Notes

Field notes provide an additional opportunity to collect data and allowed the researcher to record and comment on his or her thoughts about the setting and activities during research. The researcher's observations will be recorded by hand during lesson observations as well as during the focus group to ensure recollection of behaviors, mannerisms, tone, or observations of verbal and nonverbal nature that may bring additional clarity to the conducting of the research (Merriam, 2002). Yin (2009) recommended field notes as tools to assist the researcher to carry out the case study and to increase reliability of the research.

Data Analysis

Data analysis is the process of organizing and interpreting the data, searching for recurring patterns to determine the importance of relevant information (Bogdan & Biklen, 2007). In qualitative research, the collecting of data and analysis takes place simultaneously to build a coherent interpretation of the data (McMillan & Schumacher, 2001). The data analysis for this study will proceed through the methodology Merriam (2002) and Yin (2009) have suggested. Guided by Yin's method of inquiry, data analysis included transcribing interviews, coding data, categorizing the coded data, and identifying the primary patterns and themes in the data.

Merriam (2002) described *coding* as the process of interacting with the data, raising questions about the data, comparing data, and reaching conclusions from knowledge generated from the data. The purpose of coding is not only to describe the data, but also to acquire new understanding of the phenomenon of interest or events central to the study (Yin, 2003). The researcher will code data according to the constant comparative method until themes began to emerge. The constant comparative method involves breaking down the data into meaning units and coding them to categories (Glaser, 1965). The researcher will use the lesson plan documents, field notes, and interview transcripts to further endorse themes where applicable.

Bracketing

To begin the process, the researcher will set aside all prejudgments, a process called *bracketing* (Merriam, 2002). The researcher independently analyzed the transcripts, which requires reading and rereading field notes and transcripts for accuracy, significant statements, and meanings. Using the qualitative software, the researcher plans to highlight and grouped code words around significant thoughts or ideas in the data, a step called *categorizing*. The researcher seeks to identify patterns, themes, and meanings using interviewees' statements and phrases.

Coding

Aside from the document analysis, guided interview questions, and field notes, the researcher will use coding to help validate the research (Merriam, 2002). The use of these sources supports triangulation, data collection, analysis, and interpretation of the data (Yin, 2009). The researcher will read through the focus group interview transcripts and code the highlighted terms or phrases into broad themes. The researcher will then assess these themes for commonalities with lesson plan documents and observational data, looking for any commonalities that provide evidence and support the theme.

Interview and Field Notes Analysis

To begin the process, the researcher set aside all prejudgments, a process called *bracketing* (Merriam, 2002). The transcribed interview data and field notes will be highlighted and grouped by code words around significant phrases or ideas in the data, a step called *categorizing*. This will allow the researcher to see the relationships between the coded data and identify categories and emerging themes.

Validity and Reliability

Validity and reliability are central issues in data collection, analyzing results, and in judging the quality of the study (Shank, 2006). According to Miller (2000), validity is the strength of qualitative study based on whether the findings are accurate from the standpoint of the researcher, the participants, or the readers of an account. Validity is the degree of confidence that a researcher draws from the results of a study. Yin (2009) noted that the level of rigor in qualitative research would help determine whether the findings are trustworthy.

Internal Validity

Internal validity in a qualitative study refers to the creditability of the data collected (Shank, 2006). Stake (2010) described triangulation as a process where evidence is collected from different individuals, types of data, or variety of data collection methods for corroborating evidence. Patton (2009) said the purpose of triangulation was to show that different kinds of data or approaches might yield different results because they are sensitive to different real-world nuances, not necessarily to show that the same result is derived from different sources of data or approaches. Credibility of results is not weakened by inconsistencies in findings across different kinds of data but offers opportunities for deeper insight into the relationship between inquiry approach and the phenomenon under study (Patton, 2009). In a qualitative case study, data triangulation can be achieved with the responses and answers of participants in open-ended interviews and by asking participants to review and verify the accuracy of their answers – a process called member checking (Bogdan & Biklen, 2007).

External Validity

External validity is the degree to which the conclusions reached from the study are applicable to other contexts (Stake, 2010). External validity is not commonly used in qualitative studies because qualitative research mainly focuses on exploring or describing a specific phenomenon, not on generalizing the results (Christensen, et al., 2011). A qualitative study may enable naturalistic generalizations, which involves comparing individuals and contexts to those in the study for any similarities (Christensen et al., 2011). This study will contain descriptive data, including anonymous participant details and context, collected from elementary K-4 teachers selected from a target school in New York. The study's results may enable external validity via naturalistic generalization and shed light on successful integration of STEAM education in elementary schools.

Reliability

Reliability for qualitative studies refers to the consistency and dependability of the data collected (Yin, 2009). Within reliability are the elements of trustworthiness, authenticity, and credibility (Creswell & Miller, 2000). Interviews, member checking, and triangulation reduce the risk of bias and increase the reliability of the data (Bogdan & Biklen, 2007). Reliability means that other researchers could use the same method of study and reproduce the same results (Merriam, 2002).

Trustworthiness and Credibility

To ensure trustworthiness, the researcher considered three criteria: credibility, dependability, and transferability. *Credibility* refers to the believability of the findings enhanced by evidence such as confirming the evaluation of conclusions with research participants and theoretical fit (Merriam, 2002). To ensure credibility, the researcher will engage in prolonged analysis with data sources in an effort to describe and present the reader with a thick and rich description of the data.

The researcher will attempt to build rapport with the participants to obtain honest and open responses. During the focus group interview, the researcher plans to restate, or summarize, information given and question the participants to determine accuracy. This will allow the participants to analyze the information and comment. The participants will confirm that the summaries accurately reflected their views, feelings, and experiences. The study is said to have credibility if the participants affirm the accuracy and completeness of the summary (Merriam, 2002).

Triangulation

Triangulation is a process that is often used to investigate results using two or more data sources. Cohen and Manion (2000) defined *triangulation* as an attempt to map out and explain the richness and complexities of human behavior by studying it from more than one standpoint. Stake (2010) described triangulation as a process where evidence is collected from different individuals, types of data, or variety of data collection methods for corroborating evidence. Triangulation is a strategy to increase validity of the study by examining a situation from two or more perspectives (Stake, 2010). Patton (2009) stated that the purpose of triangulation was to show that different kinds of data or approaches may yield different results because they are sensitive to different real-world nuances, not necessarily to show that the same result are derived from different sources of data or approaches.

In a qualitative case study, data triangulation can be achieved using the responses and answers of participants in open-ended interviews and by asking participants to review and verify the accuracy of the data, a process called member checking (Bogdan & Biklen, 2007). Triangulation, using multiple sources, and member checking reduce the risk of bias and increase the reliability of the data (Bogdan & Biklen, 2007). Inconsistencies in findings across different kinds of data does not weaken the credibility of results but rather offers opportunities for deeper insight into the relationship between inquiry approach and the phenomenon under study (Patton, 2009).

Triangulation will be achieved in this study by using multiple data sources including focus group interview, document analysis, and field notes. The semi structured interview will consist of asking demographic questions and open-ended questions about topics related to K–5 teachers' perceptions of the implementation and integration of the new STEAM curriculum program and curriculum. Document analysis will include a review of lesson plans and lesson observation field notes. This researcher seeks to give voice and meaning to the present STEAM curriculum and program.

Researcher Role

As an educator, the researcher is able to relate to the lived experiences of the participants and capture the relevance of the perceptions shared, which will assist in adding depth and significance to the themes (Shank, 2006). The researcher of this study plans to take the position of an "insider." Insider researchers are often able to engage research participants more easily and use their shared experiences to gather a richer set of data (Dwyer and Buckle 2009). Banks (1998) identified four categories of a researcher's positionality: indigenous-insider, indigenous-outsider, external-insider, and externaloutsider. that represent differences in researchers' knowledge and values based on their socialization within different ethnic, racial, and cultural communities. It is this researcher's intent to take on the role of "indigenous-insider." This researcher endorses the unique values, perspectives, behaviors, beliefs, and knowledge of his or her indigenous community and culture and is perceived by people within the community as a legitimate community member who can speak with authority about it (Banks, 1998). Attention will be given to ensure that bias will be minimized, and past experiences and knowledge do not interfere with data collection or analysis.

CHAPTER 4

Introduction

The purpose of this multiple case, grounded theory research was to explore, understand, and describe K-4 teachers' perceptions and experiences with integrating and implementing a new STEAM initiative. As an educator, the researcher sought to gain a better understanding of how STEAM education is being implemented at the elementary level from a case study perspective. The focus of Chapter 4 is a detailed discussion of the research process, which includes: a description of the demographic characteristics of participants, an explanation of the data collection and analysis procedures used to discover common themes, the findings in terms of the emerging themes identified by the study participants, and a summary of the results. The researcher presented the key findings obtained from lesson observations, lesson plan review, and a focus group interview consisting of five teachers, one from each grade level K-4.

The researcher began by conducting STEAM lesson observations, taught by each participant. The researcher collected field notes during each lesson observation. The researcher also requested that the participants share lesson plans for each STEAM lesson. Lesson plans were also evaluated. Finally, a focus group interview was conducted to give voice and perspective to the data collected through lesson observations and lesson plan review. The researcher used the data collected from the lesson observations, as well as the lesson plan review, in developing targeted questions. The culminating focus group interview presented an opportunity for the researcher to clarify the ideas for the study, to modify the interview questions as necessary, and to increase the quality of data for the study (Merriam, 2002). Additionally, the researcher corroborated and triangulated interview data with secondary information, obtained from field notes taken during the lesson observation and lesson plan review in order to support the research findings.

Results

This research utilized a final sample of five female teachers. These teachers all worked in a suburban public elementary school (K-4) in New York. Each participant was directly involved in the new STEAM initiative. The participants' demographic characteristics indicated that the sampled teachers had a broad range of teaching experiences, however all of the teachers had less than one year of STEAM teaching experience (see Table 2).

This research triangulated data from three primary sources: two lesson plan observations per teacher, lesson plan review, and a culminating focus group interview. The researcher then utilized the lesson observations and lesson plan data to identify questions for the focus group interview. The focus group interview was transcribed by the researcher and then analyzed against the other two data sets to identify patterns and themes until data saturation had been reached.

Saturation has attained widespread acceptance as a methodological principle in qualitative research and is commonly taken to indicate that, on the basis of the data that have been collected or analyzed, further data collection and/or analysis are unnecessary (Saunders, et al., 2018). The focus group interview provided depth to the data collection and to gather more recommendations from the sample (Creswell, 2012).

Data Sources

In order to facilitate the triangulation process for conducting this multiple case study and identify grounded theory, the sources of data included: (a) STEAM lesson observation, (b) teachers' lesson plan review, and (c) a semi-structured focus group interview about teachers' perceptions of STEAM integration, (Yin, 2010). The researcher conducted interviews after completing lesson observations and reviewing lesson plans. This information proved to be valuable in corroborating the information obtained from the participants.

Data Collection Procedures

The researcher began by collecting data from five, K-4 elementary teachers who willingly allowed the researcher to observe them instructing a STEAM lesson and provided permission for the researcher to review their lesson plans. The researcher then developed a set of guiding interview questions to utilize as a framework in an effort to garner reflective responses from the participants (Appendix D). The interview format was a semi-structured focus group interview. The focus group interview process allowed the participants to answer freely and allowed for exploration of topics as they presented themselves (Merriam, 2002).

The data collection process was as follows:

1. The researcher requested (Appendix A) and was granted permission (Appendix B) to collect data from Superintendent of Curriculum and instruction for the school district.
2. After permission was granted, the researcher contacted the principal to gain permission to interview teachers and collect data. The principal recommended one teacher per grade level to participate.
3. The researcher provided each participant with a letter of consent (Appendix C).
4. The researcher began by scheduling opportunities for lesson observations.
5. At the conclusion of these observations, the researcher requested copies of participants' lesson plans for review.

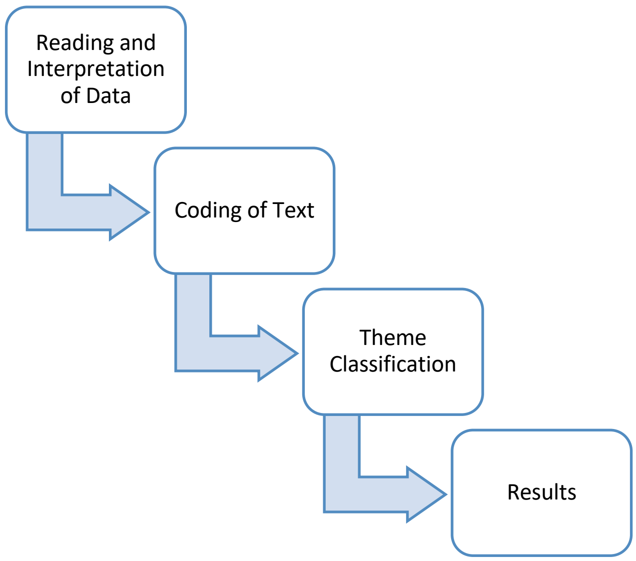
6. Prior to the focus group interview, the researcher developed a set of guiding questions for the interview.
7. The participants met together at an agreed time and location for the focus group interview. The participants signed the informed consent in the presence of the researcher prior to the interview.
8. The researcher took detailed notes throughout the interview process.
9. The researcher also took reflective notes at the conclusion of each guiding question with respect to participants' responses ensuring collection of behaviors, mannerisms, tone, or observations of verbal and nonverbal nature that brought additional clarity to the conducting of the research (Merriam, 2002).

Data Analysis Procedures

The data analysis process for this multiple case study design was guided by Yin's (2009) method of inquiry. To begin the process, the researcher purported to set aside all prejudgments, which is a process called *bracketing* (Merriam, 2002). The data analysis process consisted of coding the data, categorizing the coded data, identifying the primary patterns' themes, and discussing the results of the data. First, the researcher prepared the data. The researcher transcribed the interview data field notes into a textural format (rich text format, or *.rtf*) using. The researcher examined the transcribed data for redundancies, repetitions, inconsistencies, and errors. The researcher then saved the digitally transcribed data in .rtf, and uploaded it to NVivo, qualitative software for storage and management of large volumes of textural data. In addition, the researcher used the software to assist in highlighting expressions, phrases, and other meaning units within the transcripts. *Meaning units* identified in the transcripts and text included strings of words and sentences that convey ideas, thoughts, and expressions in the words of the participants (Merriam, 2002). The researcher compared these for similarities and patterns. Figure 1 depicts the process of utilizing qualitative analysis conducted using NVivo software; a qualitative software analysis developed by QSR international. The analysis followed a 4-step process as depicted in the diagram below.

Figure 1

Four-Step Analysis



After the initial reading and interpretation of the text, the researcher then coded the data according to the constant comparative method until themes emerged (Merriam, 2002). The constant comparative method involved breaking down the data into meaning units and systematically comparing sections of the text (Glaser, 1965). The researcher used the NVivo software to record similarities and differences between these sections as they were discovered. To make the data more understandable, the researcher transformed the text into major themes.

Document Analysis

The researcher examined teacher lesson plans and engaged in qualitative document analysis as part of the triangulation of data. Each participant was asked to provide the researcher with access to STEAM lesson plans so that they could be evaluated. Through the examination of lesson plans the researcher was able to examine how teachers are planning STEAM lessons. The researcher examined these documents against lesson observation data and what teachers discussed in the focus group interview in an effort to look at patterns. These patterns were then examined against one another to identify prevalent themes.

In the examination of ten lesson plans, two from each of the five participant teachers, the researcher looked to see if what was observed during lesson observations matched with what was planned for in the development of STEAM lessons. In other words, did the real-life lesson match the written plan? The lesson plans as a whole demonstrated lessons geared more toward traditional science lessons than the incorporation of STEAM domains. The participants lesson plans did not expressly indicate or use the term *hands-on*, even though many teachers expressed during the interview that this was essential in STEAM lessons. Out of the ten lessons reviewed, there were zero which provided opportunities for *inquiry-based* STEAM learning despite this term also being used by teachers in interviews. Further, although most teachers used a form of technology within the lesson, engineering, math, and art were not seen through either observation or lesson planning documents.

Fieldnotes

Throughout this investigation, the researcher took field notes. This research collected both descriptive and reflective fieldnotes. Descriptive fieldnotes record a description of events, activities, and people, while reflective fieldnotes record personal thoughts that researchers believe relate to their insights, or broad themes that emerge during the observation (Creswell, 2012). Fieldnote data was collected during each lesson observation as well as during the culminating focus group interview.

Overview of Participants

The following descriptions highlight each participant and include selected excerpts from the focus group interview.

Janice

Janice is a female teacher who currently teaches kindergarten. She has been teaching for 20 years and has taught at multiple grade levels. Janice stated that she enjoys teaching but that STEAM is very new concept for her. Janice stated: "Before we had STEAM introduced in our district, I don't think I thought enough about science and math and how they should be integrated into the classroom. I know that critical thinking skills are crucial for students and the earlier they are engaged in this type of learning, the more successful they will be. However, figuring out how to bring all of these subjects together in the classroom is overwhelming." Janice reflected that STEAM was more hands-on and project based. She stated: "I believe STEAM at this level should spark an interest in how things work, how to ask questions, how to get involved in the creative process." While Janice initially felt uncomfortable teaching STEAM, she subsequently admitted that she feels a bit more confident and comfortable with the program.

Janice feels that the main challenges and obstacles she experienced while teaching STEAM were mainly time constraints and the lack of proper training regarding expectations of her as an educator. Janice stated that she lacked sufficient time to do lessons. Janice added, "More time for preparation would be nice." Continuing, she said: "I'm not even 100% sure what STEAM is. When you look online, there are so many different ideas of what STEAM is." Janice also indicated that she felt unsure whether teachers at her school were doing STEAM correctly, but that she and her students enjoyed what they were doing so far with this new program.

Kristie

The second participant, Kristie was a female teacher who holds a Master's degree plus 40 credits and has 15 years of teaching experience. She currently teaches first grade. Kristie described STEAM teaching as teaching critical-thinking skills. She said: "To me, STEAM education at the elementary level is hands-on learning to solve problems and questions that students wonder about." Kristie also stated: "I feel extremely comfortable and confident in my ability to teach science, art, and math in K-4. However, technology and engineering I am much less comfortable teaching." She envisions a STEAM curriculum for each elementary grade that is developmentally appropriate for each grade, helping her students think critically.

Kristie stated she enjoyed teaching STEAM, and she felt like she understood what was expected of her. Kristie: "I believe STEAM education should be a combination of direct instruction and hands-on application. In my opinion, students should be presented with information, given an opportunity to ask questions, and then apply that knowledge through hands-on labs." The major challenges and obstacles she faced while teaching STEAM were being unprepared, not being trained adequately, and feeling uncomfortable with teaching technology and engineering practices. She acknowledged that teachers need to be better prepared and trained to be more comfortable teaching STEAM, and she believed that professional development would help teachers understand the concepts of STEAM.

Lori

Lori is an elementary teacher with more than 20 years of teaching experience. She currently teaches second grade. Lori stated that when she thinks of STEAM she believes that it is teaching all of the disciplines in a very "hands-on" way. She uses the acronym to guide her in teaching STEAM correctly and wished she had more time allotted to experimenting and using different tools to learn. Lori: "When I am teaching STEAM lessons, I try to make sure I am integrating each discipline in the theme." She admits "During STEAM class with the STEAM teacher, I am comfortable assisting in whatever way I can. Teaching STEAM independently is less comfortable because I am not very familiar with the curriculum." Lori also stated that teachers do not have enough time to focus on the curriculum at the elementary level due to a high focus on teaching reading and math.

Lori believes that STEAM education should be collaborative, hands-on, and have teachers facilitating while children explore concepts. Lori stated, "I have read about what STEAM is supposed to be, but I'm not sure I do it correctly." She felt that STEAM would be better if she had more opportunities to learn what other teachers are doing in their classrooms. Lori also expressed that she is more comfortable reviewing topics then introducing them: "Currently, I am only reviewing with my class what they have already learned or doing alternative activities. In order to feel more comfortable with teaching STEAM, especially the new curriculum, I would certainly need training and materials." Her chief complaint was having little guidance with respect to teaching STEAM. She felt that STEAM should be hands-on, project-based learning but didn't quite know how to implement that in her classroom. Lori said, “With more knowledge and training, I would be more comfortable.”

Heather

The fourth participant was a female teacher with 17 years of teaching experience. She has currently been teaching third grade for 8 years. Heather described STEAM as incorporating science, technology, engineering, art, and math into real world topics that students can relate to and then delivering them through lessons. Heather stated: “Lessons should be hands-on, interactive, engaging, and creative. STEAM lessons should reach all students and all different types of learners.” She further explained “STEAM education makes kids think outside of the box. They are able to explore, discover, and know that it is ok to be wrong. STEAM education is interactive, engaging, and fun.” Heather also expanded upon her thinking and added: “I am pretty comfortable with teaching STEAM. Some of the topics may require me to research before presenting the subject matter to the students. I find myself being most comfortable with integrating art and technology into my math and science classes, I am less comfortable with the engineering component of STEAM.”

Heather said if she had access to the more resources as well as the freedom to explore them on her own, it would be easier to integrate STEAM into here grade level curriculum. However, her school currently utilizes a block schedule and she finds that time to be a huge constraint on her ability to incorporate STEAM lessons more frequently. Heather said, “I know how to implement lessons, I just need to learn the resources and have more time dedicated to spend on lessons.” Another complaint of Heather’s was the lack of time for lesson planning. Heather stated: “We don’t have the time because we are always feeling the pressure of the state test. Maybe knowing what is expected and what curriculum should be used would help." Heather admitted that she would benefit from more professional development to fully understand what STEAM is and how to use incorporate it.

Victoria

Victoria is a teacher with eleven years of teaching experience in fourth grade. Victoria believes that STEAM is just 'new' science. Victoria stated: "To me, STEAM is the integration of other subject areas into what we, as educators, have considered 'science' for many years. As time has passed and the world around us adapts and evolves, the education of science is not as simple as we once thought it was. Today scientists are using science in their daily work, but now more than ever before, all other areas of life are dependent on science." She believes that STEAM is important for today's students. In her statement: "STEAM allows students to find out more about the world around them. Elementary aged students should be exposed to STEAM as often as possible." Victoria reflected on the new school-wide STEAM curriculum and said, "STEAM education at the elementary level is all about investigation, experimenting, and hands-on, inquiry-based learning." She acknowledged that the district provided a brief overview of the goals of STEAM with respect to the schools new program and added, "I know there is a great importance for STEAM in an elementary classroom. The jobs that are accessible to our children/students in this day and age are much different in comparison to 30, 15, or even five years ago! The students in our classrooms today will possess jobs that may not even exist in this very moment."

A major complaint from Victoria was not receiving enough training. Victoria stated: "I am particularly interested in having hands-on professional development in which I can fully understand the resources available to us or perhaps even visiting other schools that have successful programs that will/can help us grow our own practices." Victoria believes with more resources and training she will be more comfortable teaching STEAM.

Study Findings

Stage 1: Reading and Interpretation of the Data

The collected data was reviewed and read several times under this phase to get a brief overview of what the data represented. Each data set, lesson observations, lesson plan review, and focus group interview was examined individually. Lesson observation data was compiled and examined for domains of STEAM instruction (Table 3). The data depicts each observation and the elements of STEAM instruction utilized throughout the lesson. In these observations, science was demonstrated in 100% of the lessons, technology utilized in 50% of the lessons, engineering 10%, art 30%, and mathematics 30%. Observations also provided evidence of two key components of STEAM instruction, "hands-on" in 80% of the observed lessons and "problem solving" in 40%. The average amount of time for a STEAM lesson varied by grade level: Kindergarten, 23 minutes; First grade, 31 minutes; Second Grade, 29 minutes; Third grade, 40 minutes; and Fourth Grade, 40 minutes.

Table 3

Lesson Observation

	Observable STEAM Elements							
	Science	Technology	Engineering	Art	Mathematics	Hands-on	Problem Solving	Duration (minutes)
Kindergarten Observation 1	X			X		X	X	22
Kindergarten Observation 2	X	X				X		24
First Grade Observation 1	X					X	X	30
First Grade Observation 2	X	X		X	X	X		32
Second Grade Observation 1	X			X		X		26
Second Grade Observation 2	X	X					X	35
Third Grade Observation 1	X		X		X	X		40
Third Grade Observation 2	X	X				X		40
Fourth Garde Observation 1	X	X					X	40
Fourth Grade Observation 2	X				X	X		40

Next, lesson plans were analyzed. Participant teachers submitted one month of lesson plans for analysis. Currently, teachers are instructing one lesson per week in STEAM and so a total of 20 lesson plans were reviewed and analyzed. Lesson plan documents were submitted in varied forms from participant teachers. This data was first compiled into elements for STEAM instruction comparable to the lesson observation data. This data is displayed in Table 4. Lesson plan data was then compared to the NGSS framework (Table 1) to identify essential elements: practices, core ideas, and crosscutting concepts covered by the lesson plans. This data is displayed in Table 5.

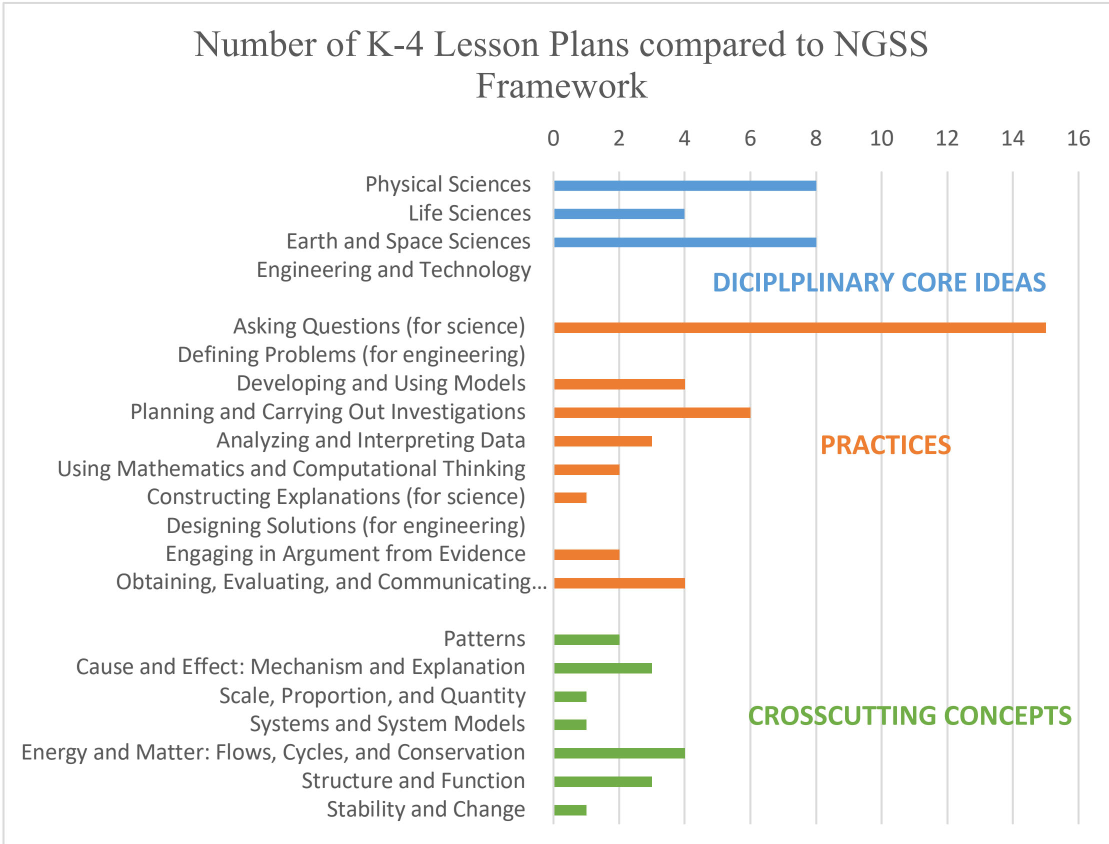
Table 4

Lesson Plan Review

	STEAM Lesson Elements Number of occurrences for each element							
	Science	**Technology**	**Engineering**	**Art**	**Mathematics**	**Hands-on**	**Problem Solving**	**Time Allocated (Per Lesson)**
Kindergarten	4	2	0	2	1	3	1	25 min
First Grade	4	2	0	1	2	2	2	30 min
Second Grade	4	2	0	1	0	2	2	30 min
Third Grade	4	2	0	1	1	3	2	40 min
Fourth Grade	4	2	0	1	1	3	1	40 min

Table 5

Lesson Plan Comparison to NGSS Framework



Data shown in Table 5 revealed that science and technology domains are utilized most often and illustrated that lessons frequently incorporated a "hands-on" component. Data also highlighted that art and mathematics were not frequently being incorporated into STEAM lessons. Less than half of the STEAM lessons can be described as having a problem-solving approach and the engineering component was not utilized in any lessons.

This data was further analyzed and compared to the NGSS framework (Table 6) in an effort to identify which essential elements; practices, core ideas, and crosscutting concepts would apply to these lessons. This data confirms that of the 20 planned lessons, science concepts were of primary focus as depicted in the table under disciplinary core ideas, and practices. The data also highlights that engineering components described under disciplinary core ideas, and practices were not being utilized. These engineering elements did not appear in any of the participants lesson plans.

As part of the triangulation of data, the focus group interview was also analyzed. From the transcription of the interview, a word cloud diagram was used to depict the most commonly used words and phrases, by participants in response to the guiding questions. This was used to ascertain if the most used words were in alignment with the research objectives. As depicted in the word cloud diagram (Figure 2), the most frequently occurring terms were: STEAM, students, curriculum, comfortable, classroom, teachers, and engineering along with many other sub-level terms. These terms directly relate to this research and its research questions.

Figure 2

Word Cloud Diagram

Stage 2: Coding of Text

Coding of text is a process of categorically marking or referencing units of text, such as words, sentences, paragraphs, and quotations with codes and labels that indicate patterns of meaning in qualitative data (Mills & Gay, 2015). In this phase, the qualitative data was carefully read, and meaning was ascribed to the phrases in the form of codes using NVivo. The initial coding revealed a total of 44 codes which were then reduced to 26, as only 26 of the codes were relevant to the research questions of this study.

Stage 3: Theme Classification

The 26 relevant codes were then grouped based on the relationship between them to form themes. The analysis reveals a total of 5 themes. The themes and their corresponding codes are depicted in Table 6.

Table 6

Theme Classification

Name	Number of participants	References
1. Meaning of Steam		
Integration of 5 subjects into one	3	3
A practical way of teaching	2	2
Co-curricular way of teaching	1	1
Interactive and engaging	2	2
Inquiry-based learning	1	1
2. Importance of Steam		
Teaches critical thinking	4	6
Independent problem solving	2	4
Improves creativity	2	2
STEAM allows exploration of career opportunities	2	2
Encourages innovation through critical thinking	1	1
Improves Academic Excellence	1	1
Prepares students for future employability	1	1
Encourages collaboration amongst students	1	1
3. K-4 teachers STEAM abilities		
STEAM preparation should be grade based/K-4 training is ineffective	1	2
Integration of all discipline is a challenge	3	3
4. Factors that Affect STEAM Implementation in the Classroom		
Presence of Curriculum template	3	4

STEAM Mentorship	2	2
Availability and accessibility of materials	2	2
Collaboration through meetings amongst teachers is essential	2	2
Discussion with educators	1	2
All students should have access to STEAM lab	1	1
Professional Development on instructional strategies is needed	2	3
5. Challenges of STEAM implementation		
More resources are needed	3	4
Inadequate time to implement STEAM demands	4	4
Classroom language diversity will hinder progress	1	1
Excessive pressure to perform	1	1

Five major themes emerged from an analysis of the data. These themes were the following:

1. Meaning of STEAM
2. Importance of STEAM
3. K-4 teachers STEAM abilities
4. Factors that Affect STEAM implementation in the classroom
5. Challenges of STEAM implementation

CK, PK, and PCK

With respect to the data described above, it is vital that this research identifies how STEAM and its instruction relates to Shulmam's theory. The theoretical framework of CK, PK, and PCK needs to be defined within the parameters of this research and as it corresponds to the data. The CK is the knowledge one has for a specific discipline or topic (Shulman, 1986), in this research, STEAM is the combination of multiple disciplines under one umbrella, thus the CK a teacher must possess encompasses all elements of STEAM instruction.

PK describes teachers' knowledge of the practices, processes, and methods regarding teaching and learning. Most importantly PK is a teachers' experience level working with and understanding how students learn. Berlinger (2000), conservatively estimated teacher experience, PK, as 5-7 years. Thus, a teacher with more than 5 years of experience is deemed to have sufficient experience and or PK. All participants within this study have 11 or more years of experience teaching at the elementary level (as depicted in Table 3), therefore according to prior research the participants in this research are deemed to possess sufficient PK experience.

Lastly, PCK describes teachers' knowledge regarding foundational areas of teaching and learning, including curricula development, student assessment, and reporting results. For the purposes of this research, PCK is the ability for participants to instruct STEAM. This will be explored further in the research analysis below.

Analysis of Research Question

Research Question 1

What is required for elementary teachers to effectively implement a STEAM curriculum within their classrooms?

Theme 4 provides the requirements that are needed to effectively implement STEAM curriculum in the classrooms. The data reveal that the following are needed to effectively implement STEAM in the classroom;

1. Presence of Curriculum template: Participants highlighted that they lack understanding on how to effectively cover all aspects of STEAM within the stipulated time. The belief is that the curriculum will help them overcome this delivery challenge.
   "I know that having a template or an outline to follow would be helpful and I would make sure that the topics were covered in my already existing curriculum."
   "Having a template or an outline is very helpful."

2. STEAM Mentorship: Participants believed that having a STEAM mentor would aid the quality of delivery of STEAM by the teachers.

"Having a STEAM teacher mentor could also be a possibility. The mentor could coach the teachers, implement lessons, and observe lessons and provide feedback."

3. Availability and accessibility of materials: This is one of the most mentioned requirements for quality delivery of STEAM by the teacher. Participants highlighted that STEAM requires materials and the lack of these materials and resources would significantly diminish the effectiveness of the teachers on STEAM.
   "Then, they need to have access to resources to implement STEAM into their classroom."

4. Collaboration through meetings and opportunities to discuss amongst teachers is essential: STEAM teachers must collaborate and share knowledge on how to effectively conduct teaching lessons using STEAM. This can be achieved through daily, weekly, and monthly meetings.
   "Having a weekly meeting time to plan for the following week would be beneficial. Working together and brainstorming with the team of teachers would allow for many new ideas."

5. Discussion with educators: Engaging in discussions with other educators who have been successful in synthesizing STEAM in their classrooms. This is mainly to acquire knowledge on how to integrate all parts of STEAM.
   "Talking with other educators and how they have synthesized their program would be great."

6. All students should have access to the STEAM lab: Participants highlighted that access to the lab is a key component required for the successful implementation of STEAM.

7. PD on instructional strategies is needed: Participants highlighted that Professional Development on how to synthesize STEAM is needed for its successful

implementation. The PD should also incorporate training on instructional strategies in implementing STEAM.

"Professional development would be beneficial to help understand the concepts and implementation of STEAM within the classroom."

"Maybe some training is needed on how to use it and how to incorporate it into the lessons in our classroom."

Research Question 2

What are elementary teachers' understandings of what STEAM education is at the elementary level?

Meaning of STEAM. The analysis of the focus group data reveals that participants have a thorough understanding of the meaning of STEAM. They highlighted that STEAM is the integration of science, technology, engineering, arts, and mathematics for instruction. It is a practical, engaging, and interactive way of teaching as it involves experimentation. It is also an inquiry-based model of learning; students learn through solving real-world problems.

"STEAM means having the ability to incorporate science, technology, engineering, art, and mathematics more consistently into our curriculum."

"STEAM to me means incorporating science, technology, engineering, art, and math into real-world topics that students can relate to and then delivering them through lessons."

It would appear that participants have adequate CK with respect to the defining elements of STEAM. They have accurately described the elements necessary for STEAM instruction. However, the data from the lesson observations and lesson plan review depict a different story with respect to participants CK. The lesson observation and lesson plan review identify areas of weakness with respect to participants CK.

Importance of STEAM. The importance of STEAM cannot be overemphasized. Participants highlighted that STEAM prepares the students for future employability. The ever-changing world dictates it is imperative that the traditional way of education should be adjusted to embrace a system that focuses on equipping students with: critical thinking skills, independent problem-solving skills, and creativity. These are the key components needed for innovation. STEAM's goal is to equip students with the necessary skills for innovation.

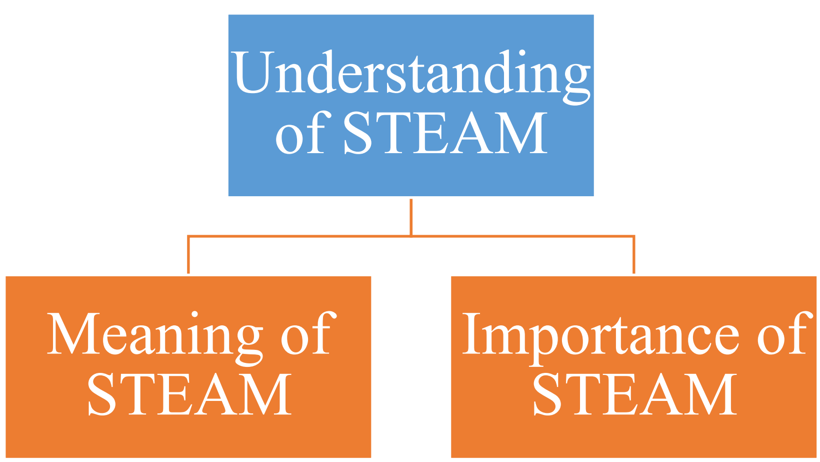
STEAM encourages collaboration amongst the students as students are often grouped into teams to handle tasks during STEAM classes. Also, STEAM increases the level of academic excellence of the students, this is mainly because they learn in an interactive and fun way.

"Also, STEAM provides time for children to collaborate. They work in teams with many different children to problem solve and create."

"We need to prepare our students to be future innovators in this ever-changing world. For this to happen students need to develop critical thinking skills."

Figure 3

Understanding STEAM



Research Question 3

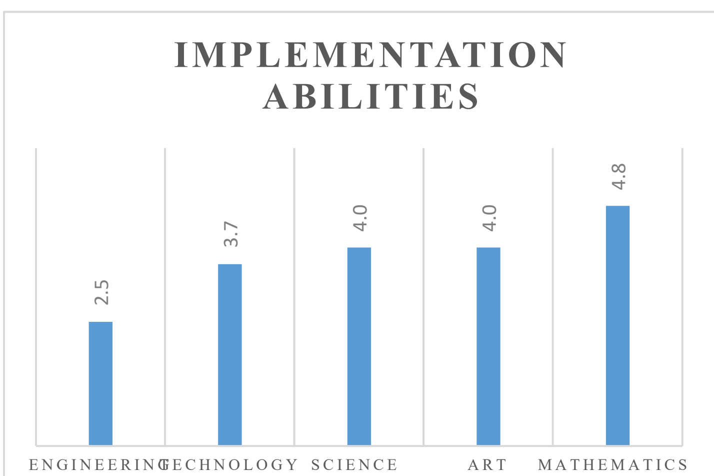
How do K-4 teachers feel about their abilities to teach STEAM education and do those feelings affect their willingness to integrate it into their classrooms?

Participants highlighted that they experience difficulty in implementing all the aspects of STEAM. The majority of the participants experience difficulty in implementing the engineering and technology elements of STEAM. Participants are most comfortable with mathematics; this is followed by art and science. The participants are least comfortable with technology and engineering (Table 7).

Additionally, participants highlighted that the existing K-4 training is ineffective in preparing them for STEAM education. They suggested that the training should be grade based. Teachers in first grade should be trained on delivering STEAM at the grade 1 level alone as they believe this exclusive concentration of efforts based on grade will be more effective than focusing on K-4 training. Teachers feel this broader grade-level training does not help them at this time, since they are uncomfortable with what they should be doing for their specific students now.

Table 7

Implementation Abilities



Research Question 4

What problems, if any, do teachers perceive in implementing and integrating STEAM at the elementary level?

The participants highlighted that excessive pressure to perform is mounted on the teachers and this often overwhelms and impedes the effectiveness of lessons. Additionally, participants highlighted that the time allocated for STEAM lessons is inadequate and that there are a series of scheduling challenges. STEAM lessons need more time allocated to them. Participants also highlighted that some of the materials needed for the STEAM lessons are insufficient. During the course of the focus group**,** the participants expressed several challenges they faced for successfully integrating STEAM subjects. Among them were time, inadequate preparation, not knowing what to expect, and a lack of proper guidance and leadership. The leading complaint expressed by participants was not having enough time to learn and implement STEAM.

Triangulation of these findings, along with the lesson observations and lesson plan review, suggested that teachers are only allotting one, 20-40 minute lesson per week in STEAM. Participants reported that there is no set amount of time expected, nor is there a block of time allocated on teacher schedules for STEAM instruction. Lesson plan documentation revealed on average two hours daily for ELA lessons, and 45 minutes daily for isolated math instruction. Triangulation of these concepts led to the conclusion that teachers may not be planning appropriately for or allotting enough time to be immersed in the STEAM curriculum so as to become more familiar with and/or to become comfortable with this learning initiative.

Conclusion

To gain a better understanding of elementary teachers' perceptions of STEAM integration in K-4, the researcher conducted a multiple case study with five purposefully selected teachers from a suburban school district in New York. Findings from the case study gave rise to five themes: (1) meaning of STEAM, (2) importance of STEAM, (3) K-4 teachers' abilities, (4) factors that affect STEAM implementation in the classroom, and (5) challenges of STEAM implementation. The findings indicated that teachers had different perceptions about STEAM integration and how it should be implemented in K-4. Although, many agreed that it was hands-on and project-based, these skills were not observable in lessons at this time. The majority of teachers felt uncomfortable teaching engineering and felt inadequately prepared and trained to teach STEAM; overall, they were unsure how STEAM integration should be implemented in K-4. The biggest challenge uncovered is the lack of time teachers are allotting for STEAM instruction and the inability of teachers to develop lessons which include all the domains of STEAM. Chapter 5 will conclude this study with a restatement of the research process, literature-based interpretation of results, recommendations, and conclusions.

CHAPTER 5

Introduction

In chapter five, the researcher concludes this study with a restatement of the research process, provides implications of the findings and literature-based interpretation of the results, and offers recommendations and conclusions. This chapter is organized by the following major headings: (a) interpretations of findings, (b) relationship to prior research, (c) limitations of the study, (d) recommendations for future practice, (e) recommendations for future research, and (f) conclusion. The interpretations section begins with a discussion of the results of the analysis, as presented in Chapter 4. The limitations section describes the limitations of the study. The implications section is related to the significance and leadership in the organization. The recommendations section focuses on recommendations for future research, as well as recommended actions for administrators, teachers, and STEAM educators. Last, the conclusion section summarizes the research.

This research set out to understand the process teachers go through when they are faced with implementing a new and unfamiliar STEAM curriculum. With the adoption of the NGSS Framework in New York State, and the small timeline for implementation teachers are currently facing, this investigation was timely. While the new framework is rich in content and practice and is arranged in a coherent manner across disciplines and grades to provide all students an internationally benchmarked science education (Achieve, 2013), elementary teachers may lack the necessary training to properly implement these recommendations.

More specifically, the present STEAM curricula for many K-4 elementary schools were not well understood by teachers. Consequently, they were not properly integrated and taught in many cases. Additionally, STEAM state standards and assessments are required to be implemented by 2021, with an unclear understanding on how to implement STEAM as a new curriculum and program. As most, K-4 teachers have not learned or been taught disciplinary content using STEAM contexts (Bursal & Paznokas, 2006; Cotabish et al., 2011). Teachers' integration of STEAM may then be guided not by the intended curricula, but by the manner most comfortable to them, correlated with their beliefs about the value and purpose of STEAM integration (Wang et al., 2011). Paulson (2012) speculated that teachers' attitudes and perceptions can affect STEAM achievement and, therefore, this study is important as it seeks to provide a viewpoint for STEAM implementation in elementary education.

The researcher's purpose for this multiple case study design in grounded theory was to explore, understand, and describe K-4 teachers' perceptions and experiences with the integration and implementation of a new STEAM program. The researcher chose this focus because teachers' comfort levels directly relate to levels of pedagogical contentment or discontentment (Sowell, et al., 2006). Prior research has shown that these negative, affective responses cause teachers to avoid teaching topics or to teach those topics superficially; therefore, feelings of discomfort can decrease teacher efficacy (Nadelson et al., 2010). The link between teachers' comfort, motivation to teach, and student learning in STEAM provides important reason for enhancing teachers' capacities to teach STEAM (Nadelson et al., 2012; Watt et al., 2007).

The focus of this research was to explore K-4 elementary teachers' perceptions of a newly implemented STEAM program and their abilities to integrate STEAM education into their classrooms. One broad question drove this research: What is required for elementary teachers to effectively implement a STEAM curriculum within their classrooms? The research also sought to provide answers to these sublevel questions:

1. What are elementary teachers' understandings of what STEAM education is at the elementary level?
2. How do K-4 teachers feel about their abilities to teach STEAM education and do those feelings affect their willingness to integrate it into their classrooms?
3. What problems, if any, do teachers perceive in implementing and integrating STEAM at the elementary level?

The multiple case study approach allowed for a rigorous exploration of STEAM education, as experienced and described by the participants in the study (Yin, 2009). The multiple cases, one at each grade level K-4, allowed for a full spectrum perspective of elementary education. Merriam (2002) described qualitative research as a method used by researchers to uncover the meanings individuals have constructed about an event, a situation, or a specific phenomenon. A qualitative study was appropriate because little information exists surrounding this topic, the variables are unknown, and a relevant theory basis is inadequate (Yin, 2009). The sample for this study was five K-4 elementary teachers, purposefully selected from a suburban elementary school in New York.

Data was collected from five, K-4 teachers including lesson plan documents. A focus group interview allowed the participants to gather and discuss their attitudes and perceptions freely and allowed the researcher to explore topics as they occurred (Merriam, 2002). The researcher recorded transcription of responses as well as collected fieldnote data during the focus group interview.

In order to triangulate the interview data, the researcher retrieved data from lesson observations as well as through examination of lesson plans submitted by participant teachers. These three data sources were utilized by the researcher to triangulate field notes.

The researcher conducted an extensive analysis of the data to understand and describe the meaning of the participants' perceptions and experiences about STEAM education. This in-depth process of analysis required the researcher to organize, scrutinize, describe, and interpret the data.

Interpretations and Conclusions

This research study focused primarily on four research questions. The following section presents the researcher's interpretation of the findings and conclusions consistent with the literature review based on the four research questions along with the theoretical framework.

Research Question 1

What is required for elementary teachers to effectively implement a STEAM curriculum within their classrooms?

The first research question focuses on the elementary teachers' perceptions of what they require in order to effectively implement the new STEAM program. Based upon the focus group interview, participant teachers revealed that teachers believe they require seven essential things in order to effectively implement STEAM: (1) a curriculum template, (2) a STEAM mentor or coach, (3) more materials, (4) collaboration time with each other, (5) ongoing discussions with administration and STEAM mentor, (6) access to the STEAM Lab or classroom, and (7) professional development and ongoing training.

The researcher collected and categorized the responses to this research question under the following theme: factors that affect STEAM implementation in the classroom. This was determined through NVivo analysis. The most frequently requested requirements for quality delivery of STEAM by participant teachers was the need for materials.

Participants frequently stated that STEAM requires materials and the lack of these materials and resources would significantly diminish the effectiveness of teachers' implementation of STEAM. Research identified a number of challenges with integrated STEAM programs including access to resources, storage space for materials, teacher attitudes toward STEAM, learning new content, and effective assessment (Laboy-Rush, 2011).

Participants also requested a curriculum template; a template already exists, however it became clear through use of the focus group interview that this document was either not understood or not being utilized by the teachers. This is consistent with prior research which states classroom teachers need help understanding how to teach lessons because of a lack of background in STEAM subject areas (Berlin & White, 2012). The California Department of Education (2012) found that mathematics and science in the early years of education lay the foundation for future STEAM learning, but elementary teachers are often unprepared to teach students in these areas. More elementary teachers are largely unprepared and uncomfortable with implementing STEAM in class curricula for teaching and learning (Cotabish et al., 2011). This finding may be prevented or avoided with more collaboration and training.

Participant data also highlighted the need for three separate, yet cohesive, ideas surrounding training and professional growth. Participants stated that having a STEAM mentor or coach, opportunities to collaborate, as well as further professional development and ongoing training were essential to the success of this new initiative. Content knowledge and quality pedagogical practices play an enormous role in the effectiveness of integrated STEAM teaching (Caprara, et al., 2012). Cotabish, Dailey, Hughes, and Robinson (2011) supported this and maintained that in order for teachers to lead effective science instruction, they must know how to teach science effectively and know how students learn science. The premise was that when elementary teachers become more knowledgeable of the processes of science, they are more likely to feel confident in their abilities to teach inquiry-based science (Brown et al., 2011; Epstein & Miller, 2011; Gecer & Ozell, 2012; Green 2002; Paulson, 2005). Consequently, Dugger (2010), stated that there are financial challenges and mandated initiatives at the elementary level which often prevent districts from acquiring the time or tools to train teachers. This shift in K–12 STE(A)M curriculum from being organized around specific academic disciplines to an emphasis on themes or big ideas (NRC, 2011) requires teachers to have more of a system perspective and broad CK. It is unlikely that without considerable continuing education K–5 teachers can be prepared to teach effectively STEAM curriculum around themes (NRC, 2007; NSTA, 2002a).

It is evident that these participants have a weak CK and PCK surrounding STEAM. While there is evidence they understand the concepts, their actions indicate an uncertainty surrounding implementation. Baumert et al. (2010) found a significant positive effect for teachers' CK and PCK on instructional quality and on student progress in science and mathematics education. Results even showed that PCK had greater predictive power for student progress and instructional quality than CK. In an effort to build an educator's CK and PCK, ongoing training is necessary. Possession of CK is necessary for the presence of PCK (Kind, 2009, Friedrichsen et. al., 2009).

CK, in this case STEAM, positively influences teachers' decisions about the relative importance of particular subject matter and their selection and use of curriculum materials, that is, their PCK (Grossman, 1990). Participants' requests for collaboration time, "apprenticeship of observation" (Lortie, 1975) or teachers' cooperation with colleagues, has been distinguished as another source for PCK (Haston, and Leon-Guerrero, 2008, Kind, 2009). According to Kind (2009), establishment of a supportive working environment that encourages collaboration may benefit teachers' PCK development.

Notably, research has found that teachers become more positive and engaged in teaching after experiencing STEAM education, even if initial perceptions were not positive (Fulton & Britton, 2011). Teachers' attitudes seemed to change and positive reactions were observed due to an improved interaction with fellow teachers and students surrounding STEAM. The reduction of isolation most teachers experienced through collaboration made teaching exciting and often re-motivated teachers for the profession (Fulton & Britton, 2011).

Participants overwhelmingly emphasized that professional development would help. As stated above, PD is essential in helping teachers develop CK and PCK. A widely accepted framework called Practice-based Professional Development (PBPD; Ball and Cohen, 1999) describes the shift from traditional PD to authentic opportunities to participate in purposeful PD while practicing their skills in context. In PBPD, professional development is teacher-driven, contextualized, and multifaceted; it focuses on teacher development as they acquire and apply new skills, such as STEAM, in the classroom (Harris et al., 2012). In general, effective PD programs are participant-driven, sustained over time, motivating to teachers if they build on existing knowledge, are collaborative, and are contextualized to the teachers' classroom (Zeichner, 2003).

Research Question 2

What are elementary teachers' understandings of STEAM education is at the elementary level?

The analysis revealed that participants have a thorough understanding of the meaning of STEAM. They highlighted that STEAM is the integration of science, technology, engineering, arts, and mathematics for instruction. Participants all agreed that it is a practical, engaging, and interactive way of teaching that frequently involves experimentation. Participants also agreed that lessons should use an inquiry-based model of learning; students learning through solving real-world problems. This thinking is consistent with the literature. Hoachlander & Yanofsky (2011) stated the concepts of STEAM are hands-on, inquiry-based, real-world, and project-based interdisciplinary programs of study that connect STEAM-related subjects. Contrary to the earlier literature of Wang (2012), although school administrators and educators are aware of the importance of STEAM education, many K–12 teachers and educators do not understand what STEAM education is and the research of Berlin & White (2012) called for tomorrow's STEAM education leaders to better understand the interdisciplinary connections of STEAM subjects and educators' roles in the classroom. This research finds that teachers are aware of what STEAM is, and how STEAM should be taught, however there are other obstacles that appear to be preventing full implementation.

Participants further highlighted that STEAM prepares the students for future employability. Consistent with the literature, economic projections suggest the United States will need more than 1 million additional STEAM professionals above the current graduation rates during the next decade (NRC, 2015). Our ever-changing, ever evolving world dictates it is imperative that the traditional way of education should be adjusted to embrace a system that focuses on equipping students with critical thinking skills, independent problem-solving skills, and creativity. STEAM education has been evolving from a convenient clustering of four overlapping disciplines toward a more cohesive knowledge base and skill set critical for the economy of the 21st century (U.S. DOE, 2018).

The literature highlights the need for hands-on, inquiry-based, real-world, and project-based STEAM programs that introduces an interdisciplinary program of study connecting STEAM-related subjects (Nathan et al., 2010) and a transdisciplinary, problem-solving, innovative, inventive, self-reliant, logical-thinking, and technologically-literate system of learning (Lantz, 2009). According to these standards, teachers should provide students with opportunities to explore passionate interests toward learning in a collaborative environment.

STEAM encourages collaboration amongst the students as students are often grouped into teams to handle tasks during STEAM activities. Also, STEAM increases the level of academic excellence of the students; this is mainly because they learn in a "hands-on", interactive, and fun way. Consistent with the literature (Lantz, 2009; Nathan et al., 2010), the most frequent terms participants used to describe STEAM were: project-based, hands-on activities, designing and constructing projects, and interactive lessons and content. For example, participating teacher Kristie described STEAM as a hands-on, technology approach where students work on projects. Lori believed that STEAM was more than just science and should include hands-on activities which allow students to develop, design, and solve problems. In using STEAM at the elementary level, Victoria stated that she wishes she could have her students participate in lessons with manipulatives, technology, and science projects "every day." As evidenced by their responses, teachers seem to understand best practices for STEAM education conceptually.

Despite this conceptual understanding based on the data analysis, the researcher drew the conclusion that teachers' perceptions of implementing STEAM education in the K-4 setting were based solely on their individual experiences – with no collaborative practices or ongoing PD – with teaching STEAM classes. The lack of STEAM training and experience for teachers may help to explain why teachers' perceptions of STEAM education were limited. The literature review supported these findings (Gecer & Ozel, 2012; Haachlander & Yanofsky, 2011; Howell & Costly, 2006; Wang, 2012). In a survey of 172 teachers, administrators, and teaching graduate assistants by Illinois State University it was revealed that fewer than half of secondary school teachers participating in STEAM programs understand the STEAM concept and how STEAM is applied to the classroom (Honey, et al., 2014).

Research Question 3

How do K-4 teachers feel about their abilities to teach STEAM education and how do those feelings affect their willingness to integrate it into their classrooms?

The third research question explores K-4 teachers' feelings about their abilities to engage in STEAM instruction and their willingness to integrate STEAM in their classrooms. The results depict that participants felt ineffectual and unsure about integrating STEAM into their classrooms. The researcher categorized the results connected with this research question under two themes in the NVivo analysis: K-4 teacher abilities and challenges of STEAM implementation.

All participants highlighted that they experience difficulty in implementing all the aspects of STEAM and the majority of participants experience difficulty in implementing the engineering and technology elements of STEAM. Participants reported and data shows that teachers are most comfortable implementing mathematics. This is followed by art and science. The data revealed that participant teachers were least comfortable with technology and engineering. Teachers additionally expressed difficulty with incorporating multiple elements of STEAM within a single lesson. Lesson observations and lesson plan review confirmed that lessons would typically only utilize one or two domains within STEAM. Of the ten lessons observed, all fell solidly in the science domain, only four lessons included math, and only two lessons incorporated technology.

Participants also highlighted that they lack understanding as to how to effectively cover all aspects of STEAM within the stipulated time. The belief is that the curriculum will help them overcome this delivery challenge. Participants also reiterated that having a STEAM mentor would aid the quality of delivery of STEAM by the teachers. Participants further agreed that STEAM teachers must have opportunities to collaborate and share knowledge on how to effectively conduct lessons. Participants highlighted that access to the STEAM lab is a key component required for the successful implementation, suggesting that more opportunities to go to the STEAM Lab classroom would be beneficial. Finally, participants highlighted that professional development on how to synthesize STEAM is needed for its successful implementation.

This researcher's findings were consistent with the literature reviewed. Ledbetter (2012) suggested that high-quality teachers are the key to students achieving STEAM literacy success. The findings of this study are consistent with previous research that discovered that teachers are more effective when teaching content with which they feel familiar and comfortable (Brown et al., 2011; Haachlander & Yanofsky, 2011; Howell & Costly, 2006; Stansbury, 2011). The researcher also aligned these findings with Bandura's (1997) theory, which stated that individuals who possess a strong sense of self-efficacy are better able to succeed in their efforts and are happier when attempting new projects.

There are multiple factors that may be influencing the lack of self-efficacy among teachers. In most school districts across the United States, an absence of opportunity and incentive exists for teachers to become proficient or confident in STEAM curricula (Brown et al., 2011). The National Research Center (2011) stated that two-thirds of educators in K–12 schools are not adequately prepared or confident enough to prepare students to move forward in secondary STEM fields, despite frequent calls to encourage students to engage in STEM education to fit the need for STEM professions (Balmer, 2006; Breiner et al., 2012; Lacey & Wright, 2009; NRC, 2011). Particularly, at the elementary level, teaching STEAM requires a different knowledge and skill base than the majority of teachers have (Epstein & Miller, 2011). The research and the findings of this study indicate there is a great need for education among elementary teachers with respect to STEAM. School districts, colleges, and universities should provide both pre-service and working elementary teachers with content and positive teaching experiences that will improve their interests, attitudes, and self-efficacies toward STEAM teaching (Balmer, 2006; Brown et al., 2011; Caraway, 2003, Nadelson et al., 2012; Stansbury, 2011; Wang, 2012).

Research Question 4

What problems, if any, do teachers perceive in implementing and integrating STEAM at the elementary level?

With research question 4, the researcher focused on teachers' perceptions with the implementation and integration of STEAM in elementary (K-4) classrooms. The researcher included the results under the theme of challenges of STEAM implementation, which included inadequate time for implementation, the need for more resources, language diversity issues, and excessive pressure to perform on behalf of participants. In support of these obstacles, time was a key factor reported by Gecer and Ozel's (2012) study, which identified problems teachers faced during the implementation of the STEAM instructional process. Nearly 66% of the teachers interviewed in that study stated that they did not have adequate time for STEAM activities.

Participants again highlighted the necessity for more resources, however through the focus group interview it became apparent that each participant is doing her best to implement this new STEAM initiative. The lack of resources, however, left them feeling unprepared. Victoria stated: "Sometimes I am not sure where to begin with a topic, or I am not sure what resources to use for teaching certain topics." Another concern of Victoria's was the English Language Learner (ELL) component of her classroom, Victoria expressed difficulty with implementing STEAM with the ELL population in her bilingual classroom. Victoria stated, "It is particularly important for me to try to incorporate any or all aspects of the acronym into my daily teaching practices because of the learners in my classroom and the gaps within their education."

The subtheme of excessive pressure to perform can be attributed to participants' overall lack of comfort with respect to STEAM; this directly relates to the needs expressed through the first research question in regard to more training and experience with STEAM. Ruggirello & Balcerzak (2013) supported the idea that math and science teachers must be exposed to the concept of the application of the subjects in order to create lessons that teach the math and science standards embedded within authentic STEAM problems. Once the teacher understands the content, he or she must then use the pedagogical skills required to plan and enact a comprehensive unit, organized around the STEAM problem (Ruggirello & Balcerzak, 2013).

The need for targeted training is also consistent with the literature, which suggests that teachers who are comfortable with the subjects they teach demonstrate more effectiveness in the classroom (Epstein & Miller, 2011; Gecer & Ozell, 2012; Green, 2002). Berlin and White (2012) and Wang (2012) agreed that training and preparation in STEAM for elementary science teachers will advance science education by promoting science inquiry, project-based, and hands-on learning. STEAM education leaders must better understand the interdisciplinary connections between STEAM subjects and the educators' roles in the classroom (Berlin & White, 2012; Dugger, 2010; Sanders, 2009). When establishing or evaluating a STEAM program, the researcher found that consideration for the elements, implementation, and the requirements to implement and teach STEAM effectively were important (Nadelson et al., 2012).

Vann (2013) expressed that teachers are a critical key to preparing students for the future workforce. For this reason, teachers need practical experience with STEAM in the form of real-world, hands-on experience, so they can better ignite the passion in students and help them develop the skills they need for the industrial jobs of today and the high-tech manufacturing jobs of tomorrow. Vann (2013) also noted that many school systems are strapped for educational funds and find educating youth in an ever-changing environment challenging. For these reasons, it is essential for students to engage in ongoing education and real hands-on experiences in order to understand STEAM application.

A Grounded Theory of Teaching STEAM

The opinions expressed by the participant teachers reflect personal needs related to STEAM instruction. Participant needs ranged in frequency as depicted in Table 5 and were grouped into five themes: (1) meaning of STEAM, (2) importance of STEAM, (3) K-4 Teacher STEAM abilities, (4) factors that affect STEAM implementation in the classroom, and (4) challenges of STEAM implementation. The theory presented here was developed and is consistent with the principles of grounded theory research. Grounded Theory is an approach for developing theory that is "grounded in data systematically gathered and analyzed" (Strauss & Corbin, 1994).

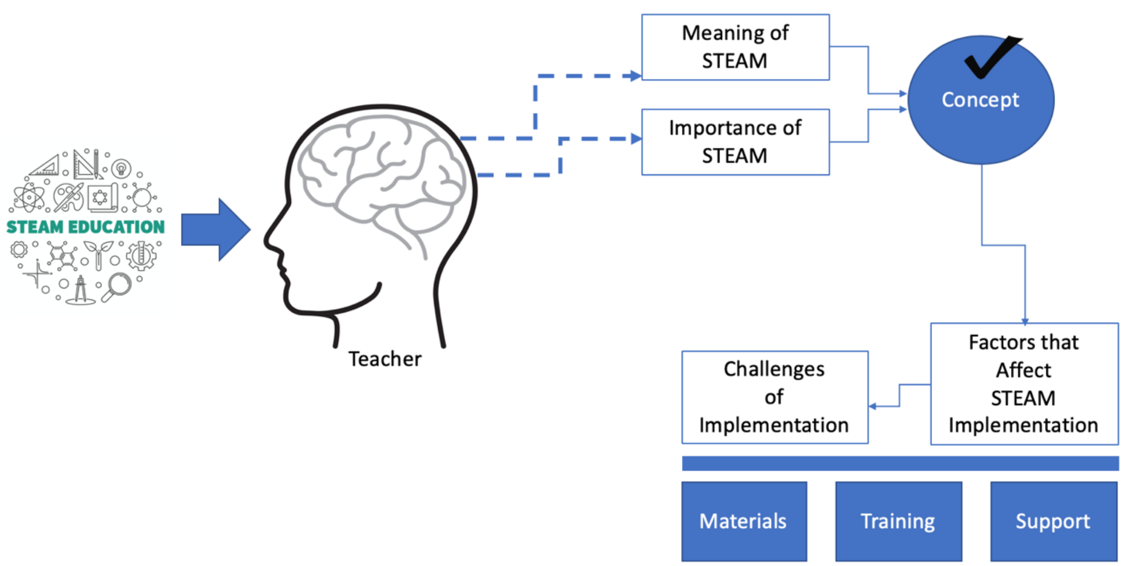
Teachers love to teach. Teaching is a vocation where the real purpose is not merely to transmit information, but to transform people, to help students learn how to use that information as a source and means of self-discovery, self-development, self-transformation, and to improve the world in which they live. In this regard, education is about moral development and character, growth of individuals, and not just preparing students for the real world.

Teachers reflect on their teaching. Participants reflected on their understanding of STEAM and its implications for not only themselves, but for their students and the world that lies before them. Participants expressed being unsure that what they were doing in their classrooms met the requirements and expectations of the STEAM initiative. Participants expressed the need for more assistance in terms of materials, training, and support. Participants gain an increased awareness of how the STEAM initiative affects them and of what it means for their teaching.

The web of categories, interactions, and relationships described above forms the theory of the STEAM teaching experience as perceived by teachers. The theory presented above in narrative form reflects the findings from the study. The constructs and relationships are grounded in data collected from lesson observations, lesson plan review, and a focus group interview conducted with teachers during their first year of STEAM implementation. Although the relatively large number of constructs may seem to lead to an overly complex theory, the diagrammatic representation (Figure 4) should help visualize the constructs and their respective relationships.

Figure 4

Grounded Theory



A good theory is one that organizes the concepts in a theoretical model, allows for prediction of future events, explains past events, offers a sense of understanding about the events and causal processes, and has potential for controlling the events (Reynolds, 1971).

A theory can be expressed as a set of descriptions of causal processes. The statements in the model are presented as a causal process. Causal laws, or statements, state how certain values of the variables in the model are connected (Stinchcombe, 1968).

The theory proposed in this research suggests that teachers have a thorough understanding of the meaning and importance of STEAM instruction, however this initiative is affected by several constructs: a need for support, materials, and training. Although tentative, the theoretical model is a valid theory. It does offer an explanation of the phenomenon of interest and it has predictive power. All of the required components described by Dubin (1978) are present in the theoretical model discussed in this theory. In Dubin's view, units have properties and variables (Dubin, 1978). These are equivalent to categories, properties, and dimensions in grounded theory.

The grounded theory presented in this study is a substantive one, applicable to a specific are of interest: implementing a STEAM program in a K-4 elementary school. This sets the boundaries where the theory is expected to hold true. In conclusion, the grounded theory developed in this study, and presented through this research, is consistent with Dubin's views (Dubin, 1978). It meets the requirements for a causal theory, set by Stinchcombe (1968) and Reynolds (1971). While substantive in nature, it is applicable to the phenomenon studied – implementing a STEAM program in a K-4 elementary school. The theory can be tested further in subsequent studies.

Implications

Traditionally, in the U.S., K–12 STEAM education has focused on the individual subjects, particularly science and mathematics. Reform efforts, including development of new learning standards and high stakes assessments, similarly have treated the STEAM subjects mostly in isolation (Honey, et al., 2014). The relatively recent introduction of engineering education into K–12 classrooms and the 2013 publication of the *Next Generation Science Standards*, which explicitly connect science concepts and practices to those of engineering, have elevated the idea of integration as a potential component of STEAM education (Honey, et al., 2014).

Over the past 25 years, STEAM education in the US has been evolving from a convenient clustering of overlapping disciplines toward a more cohesive knowledge base and skill set critical for the economy of the 21st century (DOE, 2018). The NSTC (2018) further illustrates the need for STEAM education for all:

> Even for those not headed for higher education, STEAM skills are increasingly important for all career paths and for all people to succeed throughout their lives. STEAM skills such as computational thinking, problem-finding and solving, and innovation are crucial for people working to manufacture smarter products, improve healthcare, and safeguard the Nation, and these skills are valuable assets across many other fields and job categories. The success of the Nation demands a STEAM-literate modern workforce and Americans adept at navigating an increasingly high-tech, digital, and connected world (NSTC, 2018).

Since 2000, the number of degrees awarded in STEM fields has increased, but labor shortages persist in certain fields requiring STEM degrees, such as computer science, data science, electrical engineering, and software development (DOE, 2018). If teachers are attempting to make all students ‘college and career ready’ and for the U.S. to attempt to stay economically competitive in a global and technological age, there is an overwhelming need for STEAM education.

In the United States, best practice is generally justified by standards-based educational trends, however current STE(A)M standards may be inappropriate as they are relatively vague in their attention to both content and instructional method (Breiner et al., 2012; National Science and Technology Council, 2013; NRC, 2012; Tsupros et al., 2009). Since 2013, the United States has seen limited success with STE(A)M models at attracting diverse populations of today's younger learners, thus an effort to broaden how we think about STE(A)M by incorporating the arts and humanities (the A in STEAM) is seen as a problem-solving approach (Herro, et al., 2018). Since the roll out of the NGSS (2013) and adoption of the standards framework by New York State (2017), schools now have alignments of standards. Prior to that, no standards were aligned with STEAM education; only those in subject areas of science, technology literacy, and mathematics existed separately (ISTE, 2008; National Science and Technology Council, 2013). Research had suggested that soliciting teacher input about these standards can help improve the subsequent efficacy of the programs (Brown et al., 2011; Nadelson et al., 2012; Stansbury, 2011). Teacher input was utilized in the development of the NGSS, and in New York State, schools have until the 2021 school year to implement these new standards of STEAM instruction. In order to maintain the positive benefits and a strong understanding of STEAM principles, it is essential that clear objectives and outcomes are created for STEAM education and that teachers are adequately prepared to fulfill these requirements (National Science and Technology Council, 2013; Tsupros et al., 2009).

The teacher participants in this study expressed the need for more guidance and leadership in order for them to be able to increase their levels of competency and confidence, both of which are important attributes in STEAM implementation. For students to succeed in STEAM programs, they will need competent teachers who know how to create a culture for STEAM learning. Therefore, it is imperative that school leadership secure STEAM training, professional development, and hands-on learning opportunities for teachers.

Implications for Leadership

This research seeks to highlight for leadership the importance of resources, guidance, and support during the adoption of new learning initiatives. Great teachers are important to create great schools. Great schools need powerful learning cultures. Until teachers have the support and leadership they need, this is not possible (Stansbury, 2011). In order to succeed, students need educators who know how to create schools that look like the organizations where they will work in the future (Fulton & Britton, 2011).

Effective leadership and guidance are key components of any STEAM program because school leaders are positioned to influence school policies and practices, student achievement, as well as the teaching profession (Cunningham & Cordeiro, 2006; Stansbury, 2012). In order to promote this type of change, leaders must be able to work productively and collaboratively to achieve the desired STEAM outcomes (Stansbury, 2012). School leaders must understand that teachers may possess a strong PK through experience of five or more years, however maintaining a strong CK and PCK with curriculum changes, the addition of STEAM in particular, it is imperative that they provide opportunities for teachers to expand their craft and understanding. School leaders might be able to utilize the school's available resources for STEAM and use these resources to realize the vision of STEAM programs (Cunningham & Cordeiro, 2006; Stansbury, 2012), or they may need to expand and explore new opportunities to meet the individual needs of their districts.

Limitations

As with all research, there will be some limitations. Certain limitations may exist due to this researcher's limited experience with qualitative research. In an attempt to alleviate this effect, the researcher extensively studied theoretical research through constant review of methodological concepts and study of published works: Creswell (2012), Yin, (2010), Merriam, (2002), Strauss and Corbin (1998), Glaser and Strauss (1967). This study took place in a small school district in New York, and results cannot be generalized to the full population because of the potential regional biases of the schools and specific cultural contexts. Additionally, the teachers' perspectives may vary widely due to educational backgrounds, program designs, and levels of experience. Because the perceptions and experiences of the 5 participants may not be representative of the experiences of all teachers and further other teachers from other schools, further research would be needed to verify these results.

The researcher chose the qualitative method in order to solicit broad themes due to the experimental nature of the study (Creswell, 2012). However, due to this method, the study cannot isolate specific connections – it can only identify general themes (Creswell, 2012). Correlation using a future quantitative study could potentially be an important development that could further affect and clarify the results of this research. In adhering to grounded theory practices, this research is limited in scope due to the small number of participants and cases presented along with the data which they provided. Grounded theory often requires a significant number of interviews, as well as the comprehensive use of memoing, although this research was conducted according to plan, these areas might also be expanded upon in future research.

Due to the nature of the focus group interview process, results may have been biased according to the interviewer's personality or physical characteristics. Measures, such as field notes, transcription of interview sessions, and bracketing, were undertaken in an attempt to remove such bias. However, additional, unanticipated factors may have influenced the responses of the participants or the analysis of the themes.

Recommendations for Future Research

Based upon the findings in the study, the key recommendations are twofold: (a) recommendations for leadership research for administration and STEAM leaders, and (b) recommendations for further study of elementary STEAM. School administrators and the STEAM teachers will be informed of the outcome of this study. While this study primarily focused on teachers' perceptions of STEAM education, other individuals in STEAM elementary positions and state administrative offices are positioned to exert a strong influence on promoting students' future interest in STEAM. The researcher recommends a study of leaderships' perceptions of STEAM in K-4, the current status of STEAM within schools, how best to integrate STEAM into schools, and what leaders believe needs to be done for the overall success of this nationwide initiative**.**

As for recommendations for future research of elementary STEAM, the researcher recommends that this study be replicated in the same location after the appropriate implementation of STEAM professional development and teachers have had an opportunity to become more versed in best practices surrounding STEAM instruction. Survey instruments or interview questions should then be designed to assess changes in teachers' perceptions as a possible result of STEAM training. To clarify the findings of this study, the researcher would recommend multiple qualitative studies from varying regions throughout the country. Subsequently, a metadata analysis could be conducted that would verify the results by using teachers across the nation as samples. These studies would provide a larger perspective from elementary teachers with varying experiences and knowledge of teaching and integrating STEAM in the elementary classroom, and they could be used as guidelines for crafting teacher training for STEAM education.

Meanwhile, districts across New York State and the nation are currently developing or are in the early stages of enacting programs that might be suited toward the needs of their districts and students. The results of this type of research could be used in constructing these programs. Implementing this kind of input from teachers has been determined essential for empowering teachers (Epstein & Miller, 2011; Harris et al., 2008) and could significantly improve STEAM outcomes. The effectiveness of these programs could be measured by developing standards for STEAM education and assessment of STEAM skills based on the literature associated with the changing views of necessary outcomes of STEAM education (Sanders, 2012). These results could be subsequently taken into account as best practices for teaching STEAM over time.

Future research into the area of K-4 STEAM education is suggested due to the essential nature of the elementary years in developing STEAM literacy. Currently little empirical data exists to guide effective instructional practices, and even less is known about the challenges associated with instruction (Herro, et al., 2018). As shown through this research, various themes developed from the interviews which could have value for determining how to successfully implement STEAM education programs. Additionally, these connections could assist in determining conditions which foster teachers' comfort with STEAM programs, as this has been demonstrated to have significant influence on the efficacy of programs (Epstein & Miller, 2011; Gecer & Ozell, 2012; Hoachlander & Yanofsky, 2011; Howell & Costly, 2006).

Future research should also consider the specific way in which schools, districts, and states are implementing the NGSS or its framework, specifically whether teachers feel adequately comfortable with and prepared for these changes (Cunningham & Cordeiro, 2006; Shaughnessy, 2012). Examples of research could include self-reporting surveys filled out by teachers, students, and administrators, and the correlation among their responses. It would also be recommended that STEAM content be flexible, open to revisions over time, this based on teacher feedback through this research.

Conclusion

In summary, the findings of this research have suggested that teachers have had different perceptions of STEAM throughout the implementation of the STEAM initiative. It is apparent that teachers lack experience (PCK) as well as confidence in in their knowledge and abilities to effectively integrate STEAM (CK). Teachers have reported a need for hands-on training and professional development, more time during the day for planning and implementing of STEAM, and better support from leadership. Further training and leadership would provide comfort and knowledge about STEAM principles that can empower teachers and improve efficacy (Cunningham & Cordeiro, 2006; Epstein & Miller, 2011; Harris et al., 2008). Although school administrators and educators are aware of the importance of STEAM education, they do not always fully understand what STEAM education entails (Wang, 2012).

The integration of STEAM at the elementary level has the potential to affect education in a positive and innovative way. Through exposure, K-4 teachers have modified their ways of thinking about teaching STEAM. This multiple case study design provided firsthand evidence that STEAM integration is a complex process for elementary teachers. These educators are currently in the formative stages of learning to implement STEAM in a manner that encourages student learning and exploration. Each of the 5 teachers in the study perceived STEAM education to mean something different, but overall, they had a solid understanding of what it requires. Unfortunately, these teachers felt ineffective as educators of STEAM content. The findings of this study support the idea that some level of professional development and training is needed if the newly-developed STEAM program is to be sustainable for teachers to implement. The researcher recommends that future research focus on the process of teaching STEAM and the process that teachers go through while engaging in active, ongoing professional development.

Further research surrounding the various themes developed throughout this study could hold value for determining how to successfully implement a STEAM program. This research may have significant influence on the efficacy of programs and could determine conditions which foster teachers' comfort with these types of programs (Epstein & Miller, 2011; Gecer & Ozell, 2012; Haachlander & Yanofsky, 2011; Howell & Costly, 2006). Research on teachers' perceptions of STEAM across the nation may provide valuable information that could be used to assess the performance and sustainability of such programs. Future studies may provide a larger perspective from elementary teachers with varying experiences, PK, CK and PCK with respect to integrating STEAM in the classroom, and could be used as guidelines for crafting a teacher-training program for STEAM education as well as the potential need for higher education programs that might better prepare teachers for instructing STEAM.

Appendix A - Request for Permission to Conduct Research

From: DellaSperanza, Jonathan [redacted]

Subject: Request to conduct a study at [redacted] Elementary School

Date: April3,2019at9:47AM
To: Sullivan[redacted]

Dear Mrs. Sullivan,

RE: Request to conduct a study at [redacted] Elementary School

As per our discussion, I am currently working on my dissertation at St. John's University. My dissertation topic is on the newly created STEAM Lab and curriculum initiative taking place at [redacted] Elementary School.

My working title is: Implementing S.T.E.A.M. : One Schools Journey Toward Implementation

Through the use of a multiple case study design, as researcher I will be seeking to examine teachers perceptions surrounding the relationships between leadership, curriculum and instruction. Pending district approval, it is my intent to survey teachers through anonymous online surveys as well as to hold a culminating focus group session in which teachers can reflect on their first year of implementation with the newly created science curriculum.

Abstract:

The purpose of this research is to describe and document the process of creating and implementing a STEAM curriculum and program at a first through fourth grade elementary school. Throughout this process elementary teachers' beliefs and perceptions of effective science instruction will be analyzed to determine how teachers interpret and implement this new science initiative. The goal of this investigation will be to gain a deeper understanding of teacher attitudes, beliefs and mental models surrounding science instruction as well as their comfortability with implementing the new Next Generation Science Standards (NGSS). These mental models consist of conceptions of science subject matter, and barriers related to teaching and learning. The sample for this research will be 5, kindergarten through fourth grade teachers who taught in a title 1 funded suburban school located in suburban, New York. The researcher will utilize a combination of survey data as well as a culminating focus group to gather teacher perspectives and ascertain the effectiveness of the STEAM initiative and curriculum roll out. This study is significant to understanding the challenges and experiences teachers face in integrating and implementing new curriculum, in particular the newly adopted Next Generation Science (NGSS) curriculum in an elementary school setting. The findings of the study seek to assist educators in the development a of K– 4 NGSS aligned curriculum and help guide the development of a STEM/STEAM program in order to improve student learning and academic performance.

Thank you for your time.

Sincerely,

Jonathan DellaSperanza

Appendix B - Approval from District to Conduct Research

From: Sullivan, [redacted]
Subject: Re: Request to conduct a study at [redacted] Elementary School

Date: April9,2019at2:18PM
To: DellaSperanza, Jonathan [redacted]

Dear Jonathan,
Please consider this email confirmation that you have district authorization to conduct your research in [redacted] ES. I spoke with [redacted] and he is in agreement.

Good luck.

[redacted] Sullivan
Assistant Superintendent
Office of Curriculum and Instruction [redacted] Schools [redacted]

Confidentiality Notice: The information contained in this email message may be privileged and/or confidential. Distribution of the material contained in this email message may violate the Family Educational Rights and Privacy Act, the Freedom of Information Law, the Health Insurance Portability and Accountability Act of 1996, and/or other applicable state or federal law. If the reader of this message is not the intended recipient, you are hereby notified that you have received this message and any attached documents in error, and that any review, dissemination, distribution, or copying of the message and documents is strictly prohibited. If you have received this message in error, please notify the sender immediately and delete the message and any accompanying documents.

Appendix C - Consent and Release Form

Division of Administrative
& Instructional Leadership

The School of Education
8000 Utopia Parkway
Sullivan Hall Room 507
Queens, NY 11439
Tel (718) 990-1469

Consent and Release Form

Background: You have been invited to take part in a research study to learn more about implementing Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum and program. This study will be conducted by Jonathan DellaSperanza, as part of his doctoral dissertation. His faculty sponsor is Barbara Cozza, Saint John's University, School of Education, Department of Administrative and Instructional Leadership.

Procedures: If you agree to be in this study, you will be asked to submit a STEAM lesson plan, allow for Jonathan DellaSperanza to observe you teach a STEAM lesson and participate in a focus group interview.

Risks and Benefits: There are no known risks associated with your participation in this research beyond those of everyday life. Although you will receive no direct benefits, this research may help the investigator better understand the process teachers go through with the implementation of this new STEAM program.

Confidentiality: Confidentiality of your research records will be strictly maintained by keeping consent forms separate from data, using a coding system to ensure anonymity, and storing all raw data in a locked cabinet off site from the study.

Participation: Participation in this study is voluntary. You may refuse to participate or withdraw at any time without penalty.

Questions and Contacts: If there is anything about the study or your participation that is unclear or that you do not understand, if you have questions or wish to report a research-related problem, you may contact the faculty sponsor, Barbara Cozza at Sullivan Hall Queens
718-990-1469, cozzab@stjohns.edu, Saint John's University, School of Education, Sullivan Hall, 8000 Utopia Parkway, Queens, NY 11439. For questions about your rights as a research participant, you may contact the Human Subjects Review Board, St. John's University. You can contact Dr. Marie Nitopi, the Board Coordinator, at nitopim@stjohns.edu or by phone at 718-990-1440; or you can contact the Chairperson of the Board, Dr. Raymond DiGiuseppe at digiuser@stjohns.edu .

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Signature of Participant

Appendix D - Focus Group Interview Question Guide

The purpose of this qualitative multiple case study was to explore, understand, and describe K-4 teachers' perceptions and experiences with integrating and implementing a new STEAM initiative. Your involvement is requested in the form of a focus group interview. The interview will take approximately 40 minutes, during the regular scheduled day. The researcher asks for open and honest feelings about the STEAM phenomenon under study. No answer is right or wrong. The researcher will be transcribing your responses to capture the accuracy of your responses to the open-ended questions. During the interview, the researcher will restate or summarize information given and question to determine accuracy. This allows you to analyze the information and comment. You may affirm or deny that the summaries accurately reflect your views, feelings, and experiences.

Demographic Characteristic Questions (asked of each participant)

1. What is your level of teacher education?

2. How many years have you been teaching?

3. What is the current grade level you teach?

4. How many years have you taught at this level and subject area?

5. Gender

Open-ended Questions

1. The acronym STEAM stands for Science, Technology, Engineering, Art and Mathematics. Based on your experience, knowledge, and training, how do you describe STEAM education in elementary K–5?

2. What importance, if any, does STEAM have in the elementary classroom?

3. Based on your experience, how do you envision what a STEAM education for elementary grades curriculum should look like?

4. How would you describe your level of comfort with teaching STEAM in K-4?

5. In what way does your level of knowledge and comfort for teaching K-4 STEAM influence your willingness to integrate it in your lessons?

6. What kind of preparation for teachers would help you integrate STEAM into your curriculum?

7. In your opinion, what are the challenges and obstacles teachers may experience while teaching K-4 STEAM?

8. What would better help you understand the concepts of STEM, and the implementation of K-4 STEAM in the classroom?

9. Is there anything that you feel is important to add?

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