INVESTIGATING THE CRITERIA AND PROCESSES USED IN THE SELECTION, IMPLEMENTATION, AND EVALUATION OF STEM WITHIN K-12 EDUCATION

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INVESTIGATING THE CRITERIA AND PROCESSES USED IN THE SELECTION, IMPLEMENTATION, AND EVALUATION OF STEM WITHIN K-12 EDUCATION

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This study utilized survey research to investigate how school districts within K-12 education select, implement, and evaluate Science, Technology, Engineering, and Mathematics (STEM) programs. Thirty school districts within the Math and Science Collaborative located in Western Pennsylvania participated in this research. In addition to characterizing the STEM programs of the participating school districts, this study also analyzed the alignment of these programs to the components of comprehensive STEM programs and critical approaches to substantiate STEM program implementation as stated in the literature (Augustine, 2005; Bybee, 2010a, 2010b; Carnevale et al., 2011; DeJarnette, 2010; Epstein & Miller, 2011b; Gardner et al., 1983; Hossain & Robinson, 2011, 2012; Kuenzi, 2008).

Findings suggest that the primary goal for school districts, as it relates to STEM program implementation, is to influence students' interest and pursuit of STEM-related careers and degrees. In order to achieve this goal, results of this study indicate the focus of STEM program implementation occurs with the greatest frequency at the middle school (grades seven and eight) level, are developed as an adaptation to the curriculum, and are very diverse from one school

district to the next. In addition, findings suggest that although school districts maintain they aim to promote careers and degrees in STEM, districts rely on traditional methods of evaluating STEM program implementation (i.e. standardized test scores) and do not track the longitudinal impact their STEM programs as they related to degrees and careers in STEM. Furthermore, results indicate district STEM programs are not aligned to the characteristics of comprehensive STEM programs as defined by the literature.

In order to address the misalignment of school district goals and evaluation processes involved in STEM program implementation and the absence of the characteristics commensurate with comprehensive STEM programs, this study has created a framework to guide school districts in STEM program selection, implementation, and evaluation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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1.0   INTRODUCTION

1.1   BACKGROUND

The launch of Sputnik in 1957 prompted the United States to increase its focus on the role of Science, Technology, Engineering, and Mathematics (STEM) education in US school systems (Jolly, 2009). This immediate threat to national security and symbolic battle for technological superiority was further exacerbated by decades of national assessment data measuring students' proficiency in science and mathematics. The 1983 report, *A Nation at Risk*, and standardized assessments, such as the *Trends in the International and Math and Science Study* (*TIMSS)*, *National Assessment of Educational Progress (NAEP)*, and *Program for International Student Assessment* (*PISA),* have painted a picture of student performance that lags behind that of international students (Banning & Folkestad, 2012; Hossain & Robinson, 2011). The United States continues to perform below the levels of many developed and developing nations across the globe; including some key economic and geopolitical competitors. This, in turn, has sparked concern for our economic and national security well-being (Carnevale, Smith, & Melton, 2011; Riccards, 2009).

The United States' ability to compete in global markets is often linked to success within STEM or STEM-related fields (Atkinson & Mayo, 2010; Dickman, Schwabe, Schmidt, & Henken, 2009; Hossain & Robinson, 2012). There is a consistent drive to maintain technological

superiority in the fields of research and development and a push to develop new military technologies so as not to lag behind international competitors. An example of this can be seen in the development of broadband technology. The United States currently ranks 28th among developing countries with respect to Internet speed and service (Hossain & Robinson, 2011). At current rates of technological progress, it will take 15 years to catch up to the Internet speeds of South Korea (Hossain & Robinson, 2011).

In addition to the focus on the development of technology and pursuit of innovation, the need to fill a growing void in the job market as it relates to STEM is another area of growing concern in the United States. The demand for STEM careers continues to increase worldwide yet student interest in entering STEM fields in the United States remains stagnant (Carnevale et al., 2011; Scott, 2012). Alternatively, international students are entering these fields at an increasing rate. While only 15.6 percent of students within the United States are pursuing degrees in math and science, 46.7, 37.8, and 28.1 percent of students in China, South Korea, and Germany are choosing this career path (Beering, 2010; *Increasing the number of STEM graduates : Insights from the U.S. STEM education & modeling project*, 2010). The result is a disproportionate representation of United States students filling vacancies in growing areas of the job market.

In response to this phenomenon, the federal government has launched and funded reform efforts aimed to stimulate student interest and performance within STEM fields (Moore, 2007). The federal budget included $3.7 billion targeted for educational policies that highlighted STEM and another $4.3 billion earmarked for STEM as part of the Race to the Top funding. Despite billions of dollars being funneled into the K-12 school system, the numbers of students pursuing

careers in STEM-related fields and student performance on standardized testing in the areas of science and mathematics has not changed in 30 years (Mervis, 2009; Scott, 2012).

Despite the seemingly ineffective efforts to motivate student interest and performance in STEM-related fields, the importance of pursuing these efforts remains intense from both economic and national security perspectives. As a result, the need to examine the implementation processes of educational reform efforts in this arena remains a high priority (Bybee, 2010a; Johnson, 2011). It is crucial to establish the criteria behind successful implementation of STEM programs that promote both student performance and interest in these fields.

1.2   PURPOSE OF THE STUDY

The purpose of this study is to investigate the process school districts use when selecting and implementing STEM efforts into their school systems. A wide range of approaches to address STEM has emerged in K-12 education. Programs that occur after school, as part of the school curriculum, and as stand-alone educational entities have been developed to serve students at various levels of education. This has resulted in a spectrum of implementation efforts all claiming to satisfy a district's desire to include STEM in their curricula.

The rationale for a school district's pursuit of STEM is also diverse. Increasing student interest in STEM-related careers and degrees, promoting essential job skills for success within a rapidly evolving global economy, addressing the achievement gap between US and international students, and promoting females and underrepresented groups of students to pursue STEM-

related careers and degrees, including minorities and students of low socioeconomic standing, are among the most commonly cited reasons for implementing STEM in K-12 education.

This study utilized survey research to identify the types of STEM efforts occurring within a purposeful sampling of school districts in Western Pennsylvania. The processes used to identify and implement STEM within these school districts were investigated to determine how and why districts select a given approach to address STEM from the aforementioned spectrum of possibilities. This includes an examination of the program they have chosen as well as the grade level or levels they have selected for implementation. Embedded within this selection process lies the limiting factors individual school districts face in providing resources and programs to their student population and the resulting differences in STEM implementation observed between districts of varying socioeconomic status. In addition, this study sought to determine how school districts evaluate the effectiveness of the early stages of implementing STEM within their school districts. Finally, the characteristics of the decided upon STEM efforts were critically evaluated against what the literature has identified to be the key tenants of robust STEM initiatives and programs.

The results and analysis of this survey research may help to shape the identity of STEM programs occurring within this select group of school districts and provide insight into the thought processes used by these districts to select, implement, and evaluate STEM programs. Ultimately, the results of this research will support school districts' efforts to implement STEM by framing the factors and considerations associated with instituting comprehensive STEM programs. In addition, this study promotes the use of STEM-specific criteria when selecting STEM programs for implementation. This established set of criteria may allow a district to effectively frame the needs of its students, select or create a STEM program that adheres to the

research-based fundamentals of an effective STEM initiative, and more prudently invest in resources that will maximize the successful implementation and evaluation of STEM within the educational setting.

1.3   RESEARCH QUESTIONS

The following research questions were developed to generate and analyze data pertaining to the characteristics of STEM efforts for a select group of school districts within western Pennsylvania participating in what is known as the Math & Science Collaborative. These questions shaped a greater understanding of the factors and processes by which school districts identify and implement STEM within their school systems. The 136 school districts within the Math & Science Collaborative were presented with a STEM inventory survey to frame the current STEM efforts that have been implemented within their school districts. The surveys collected information specific to each school district's rationale and processes used to select, implement, and evaluate the implementation of STEM within their school district and identified the factors influencing the decision-making process. The research questions for this study are as follows:

1. What factors influence school districts to implement STEM programs within their respective school systems?

2. How do school districts decide which STEM programs to implement and where that implementation occurs within the existing educational framework (i.e. curriculum, school day, and grade level)?

3. How do school districts evaluate the initial implementation of STEM programs within their school systems?

1.4   SIGNIFICANCE OF STUDY

My interest in researching STEM in K-12 education is based on my role as a high school administrator and former biology teacher. I am presented with the opportunity to work with students, parents, community members and staff to shape and guide the future success of students. Parents and members of the community trust that beyond focusing on the educational experiences that occur in grades K-12 there remains a greater focus for students to be career and college ready. The role STEM education plays in generating that focus is preparing all students for potential career and degree opportunities within STEM-related fields. It is also important to equip students with the critical thinking and problem solving skills inherently found within STEM content areas. These skills have rapidly become ubiquitous throughout the job market and essential to navigate throughout basic everyday life in the 21st century. In addition, the demand for professionals in these fields coupled with salary and compensation packages that often exceed most other occupations presents a great opportunity for students.

With the increasing cost of post-secondary education, it is a responsibility of K-12 educators to inform students of career paths that justify the significant financial investment associated with higher education degrees. In my experience as an educator, the short-term goals for students are to get into the college of their choice to pursue an area of study often determined by the interactions had with family members, family friends, and close community members. It is important for K-12 education to consider a deeper investment in students by identifying and outlining career paths earlier on in their educational experience so that when the time comes to investment in post-secondary education they are doing so in an informed and intentional manner. STEM is one significant measure that exposes students to the marriage between content areas

and prospective careers; thereby supporting the informed decision-making process of college bound students.

This research provides a deeper examination into the STEM efforts currently being implemented within the 136 public school districts of the Math & Science Collaborative and the processes by which these efforts are chosen. The information gathered from this study has allowed me to take a cross sectional view of school districts' attempt at satisfying an identified purpose for implementing a STEM within their school district. Additionally, I have examined the alignment of the selected STEM initiatives, programs, etc. to the characteristics identified by the literature as being essential elements of STEM education.

1.5   CHARACTERISTICS OF STEM PROGRAMS

Throughout this study, references have been made to what the literature has defined to be the essential characteristics of comprehensive STEM efforts within K-12 education. It is first necessary to outline the many definitions of STEM that exist in education. Barakos (2012) categorized STEM education as occurring on a continuum ranging from no integration between the four curricular areas of Science, Technology, Engineering, and Mathematics to the full integration of the content areas up to and often including the infusion of the Arts. Currently, school districts make independent determinations as to where they choose to fit along this continuum of integration. As a result, this lack of a defined expectation for the four content areas to interact with and through one another has resulted in a wide-range of K-12 STEM initiatives. Ideally, STEM initiatives are created with the intention of achieving the full integration of the four content areas thereby establishing a seamless and robust STEM program.

This study investigated where the participants' STEM programs fall along this continuum and how the individual districts define their satisfaction of creating a STEM initiative.

It was also important to consider the equitable representation of each of the four content areas when considering the implementation of a given STEM initiative. Historically, the science and mathematics content areas have been given greater levels of attention than the technology and engineering components of STEM (Bybee, 2010b; Dugger, 2010).

Furthermore, the following characteristics are considered to be essential components of an effective STEM program: Promoting innovation, creativity, and design (Bybee, 2010a; Harrison & Royal, 2011; *K-12 STEM education overview*, 2011; Vilorio, 2014); developing critical thinking, problem solving, application of knowledge, collaboration and communication (DeJarnette, 2010; Saxton et al., 2014); directing students to make sense of the natural world (Bybee, 2010a; *K-12 STEM education overview*, 2011); engaging and inspiring students to pursue careers and degrees in STEM, content is aligned to state standards, and STEM is introduced holistically rather than in individual silos of each respective content area (*K-12 STEM education overview*, 2011; Scott, 2012; Sneider, 2011); and consisting of real-world assessments, internships, and job shadowing experiences (Berry, Reed, Ritz, & Lin, 2005; Breiner, Harkness, Johnson, & Koehler, 2012; DeJarnette, 2010; Harrison & Royal, 2011).

This study utilized survey research to investigate the profiles of STEM programs within the 136 public schools districts involved in the Math & Science Collaborative and determine their alignment to the criteria listed above for comprehensive STEM programs. The data generated from this study has helped to determine the degree to which existing STEM programs meet the criteria established for STEM programs as described in the literature. The survey utilized in this study also provided insight into the processes used by school districts to select,

implement, and evaluation STEM initiatives within their school systems and determine if there is

alignment to the elements of comprehensive STEM programs listed above.

2.0   LITERATURE REVIEW

2.1   THE HISTORY OF STEM EDUCATION IN THE UNITED STATES

Since the 1950s, an emphasis on the fields of science, technology, engineering, and mathematics (STEM) within K-12 education and throughout the geopolitical landscape is a phenomenon that has evolved due to a number of historical events. These events have involved concerns related to national security, the race for technological innovation, competition within an international labor market, and in the comparative performance of American and international students in math and science (Gonzalez & Kuenzi, 2012). Each of these categories has been met with proposed fundamental changes to the American educational system and/or renewed points of emphasis regarding our domestic focus on STEM (Augustine, 2005; Gallant, 2010; Gardner, Larse, & Baker, 1983). Though greatly influenced by the launch of the Russian satellite, Sputnik, the pursuit of improved interest and performance in STEM fields has continued throughout the latter half of the 20th and beginning of the 21st centuries (Augustine, 2005; Gardner et al., 1983). The following section outlines the key events that have impacted our perception of the importance and relevance of STEM as an historical phenomenon.

2.1.1   Sputnik and the emergence of the National Science Foundation

Prior to the launch of the Russian satellite, Sputnik, the focus of the American education system resided in addressing the needs of below-average students and students with special needs (Nelson & Weinbaum, 2009). In the 1950s under the Eisenhower administration, the federal government increased its formalized role in the American educational system, largely in response to the baby boom of the 1940s and 50s. The dramatic influx in students drained resources at the local and state levels. This then necessitated increased intervention from the federal government (Nelson & Weinbaum, 2009). In order to manage the new role the federal government was now playing in public education, Eisenhower formed the Department of Health, Education, and Welfare in 1953 (Nelson & Weinbaum, 2009). The formation of this Department was not without debate. The issues surrounding the funding and oversight of education were then perceived to be state and local matters and not those requiring the involvement of the Federal government (Nelson & Weinbaum, 2009).

Prior to the establishment of the Department of Health, Education, and Welfare, and following several years of Congressional debate, the passing of the National Science Foundation Authorization Act of 1950 established the National Science Foundation (NSF). The NSF was to be an authoritative presence in the fields of scientific research and education and had the primary responsibility of promoting the growth of STEM in the United States (Gonzalez & Kuenzi, 2012). The NSF proved to be a significant participant in the focus on STEM education in the late 1950s and early 1960s, specifically following the sudden emergence of the Russian space program and the inception of the "Space Race" (Gonzalez & Kuenzi, 2012).

The 1957 launch of the Russian satellite Sputnik sparked an extensive investigation into our nation's competency within the fields of mathematics and science. The perceived gap in

technological and scientific innovation between the United States and Russia, as evidenced by this landmark event, sent shockwaves throughout the country and around the world. The United States was quickly forced to assess its relevance within the fields of mathematics and science and how this relevance, or lack thereof, affected national security, potential for innovation, and competency to educate future leaders in these fields (Barrow, 2006; Jolly, 2009).

Two prominent members of the scientific community of the 1950s, I. I. Rabi and Edward Teller, captured the magnitude of this event. Rabi was a physicist and chairman of the Science Advisory Committee of the Office of Defense Mobilization. He likened the Russian launch of Sputnik to the United States' leapfrog in technological innovation over Europe just decades earlier. This sudden and significant usurpation in technological prominence had significant geopolitical and economic consequences (Wang & Oreskes, 2008). Teller took a more militaristic stance by comparing the event to a loss of greater significance than that of Pearl Harbor. This analogy came with great weight given Teller was considered to be the "father" of the American hydrogen bomb (Wang & Oreskes, 2008).

Each man's commentary captured the concern regarding Russia's sudden rise to technological superiority and framed the consequences the United States might face by not immediately addressing the matter. The launch of Sputnik demanded timely and significant action aimed at addressing the gap in innovation, concerns over national security, and the necessary fundamental changes to the instruction of mathematics and science within the American educational system (Barrow, 2006; Jolly, 2009; Wang & Oreskes, 2008). The establishment of a pipeline of future mathematicians, engineers, and scientists ultimately would begin in the classroom. The opinion of many was that highly trained teachers within these

content areas could motivate and properly educate students to prepare for careers in these fields (Gallant, 2010; Jolly, 2009).

This sentiment was further emphasized by another powerful and outspoken figure of his time. Navy Admiral Hyman G. Rickover, known as the 'Father of the Nuclear Navy,' held a position of prominence backed by his decades-long success in building and sustaining a safe and dominant fleet of nuclear-powered submarines. His successes gained him a network of political connections to which he shared his positions on the importance of education, specifically focusing on mathematics and science. His books titled, *Education and Freedom* and *Swiss Schools and Ours* highlighted the need to increase the standards we held within the American educational system and the importance of fostering pathways for students to pursue careers in science and technology. This passion for education later translated into his establishment of the Center for Excellence in Education in 1983 and the Research Science Institute in 1984 (Hyman G. Rickover, 2015).

2.1.2 Addressing curricular and instructional gaps in STEM

One of the initial steps taken by the NSF to address the educational component of the technological gap with Russia was to establish the Physical Science Study Committee. This committee aimed to create a new Physics curriculum in K-12 education that emphasized the process scientists used within a laboratory setting to solve problems and engage in meaningful research (Barrow, 2006). Similar programs followed including the CHEMStudy; the Chemical Bond Approach; the Earth Science Curriculum Project Investigating the Earth; and the green (environmental), blue (molecular), and yellow (organism) content areas of the Biological Sciences Curriculum Study (Salinger & Zuga, 2009). These programs provided an authentic and

engaging experience for the students while simultaneously addressing the perceived gap in skills in their respective content areas. Each committee consisted of a diverse collection of classroom teachers and curricular experts from varied backgrounds aimed to improve education in STEM-related classrooms (Nelson & Weinbaum, 2009; Salinger & Zuga, 2009). This methodology could also potentially guide more students towards the pursuit of careers in scientific fields by exposing them earlier on in their educational pathways. This new perspective on how to teach the sciences proved to be the beginning of the inquiry-based education movement (Barrow, 2006). Although the development and integration of these new curricular materials were done through federally funded grants, the success of their implementation could only be measured at the local levels. At this time, the Federal government was prohibited from extending itself into the locally controlled classrooms at the state level and, therefore, the evaluation of this initiative was left to local entities (Nelson & Weinbaum, 2009). As a result, a gap existed between the training of teachers on improvements to STEM curriculum and instructional strategies and the evaluation of strategy implementation within classroom settings. The buy-in for local entities to evaluate these strategies was not established and therefore the effectiveness of their implementation was left to the individual teacher (Nelson & Weinbaum, 2009).

Foster et al. (2010) outlined a number of steps taken by the NSF to conduct outreach efforts into the classroom throughout the 1960's. Each year, the NSF facilitated nearly 1000 teacher institutes aimed to improve instruction in mathematics and science. Approximately 20,000 teachers at the elementary and secondary levels participated in these workshops. The focus of these institutes was on content development and refining pedagogical skills associated with teaching science. At their conclusion, the institutes highlighted the following areas: the need for evaluating the efficacy of these types of professional development opportunities for

teachers, the role of content and pedagogical expertise in measuring the effectiveness of teachers, and the importance of the collaborative process that occurs after training, including the informal exchange of information between and amongst colleagues (Foster et al., 2010).

The National Science Foundation's focus on advancing education within the STEM fields has continued through the latter half of the 20th and into the 21st century. In 2001, the NSF adopted a change to the acronym once used to collectively identify STEM throughout much of the 1990s (Breiner et al., 2012). Former director, Judith A. Ramaley, made the change from SMET to STEM in 2001 in order to avoid the negative connotations associated with the acronym and positively promote the pursuit of STEM initiatives (Banning & Folkestad, 2012; Breiner et al., 2012).

Near the 50th anniversary of the launch of Sputnik, the NSF released "A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System" (Moore, 2007, p. 1). The goal of this initiative was to increase the number of highly qualified STEM teachers and make connections between the STEM fields throughout the learning process (Moore, 2007). In 2009, 85 NSF programs included STEM as a focus within their grant applications. In addition, more than $100 million of the $787 billion federal stimulus package was allocated to the NSF (Kelley, 2010). The launch of Sputnik heightened the awareness and focus on STEM that has continued throughout the latter half of the 20th and beginning of the 21st century.

2.1.3   Funding Resources – The National Defense Act of 1958

The establishment of the NSF, its organizational evolution, and its prescribed impact on STEM education in response to the launch of Sputnik is a key event in the development of STEM as a

historical phenomenon. Directly on the heels of the establishment of the NSF was the National Defense Act, passed in 1958. This Act complimented the work of the NSF by providing $1 billion in funding that included monies for supplies, loans, scholarships, and graduate fellowships for the pursuit of STEM-related degrees (Gonzalez & Kuenzi, 2012; Jenkins & Hill, 2011; Jolly, 2009). Nelson & Weinbaum (2009) addressed many aspects of the funding structure included in the National Defense Act of 1958. President Eisenhower was determined to regain technological superiority from the Russians by "outmatching them in military power, general technological advance, and specialized education and research" (2009, p. 12) and this large procurement of funds was indicative of that determination. These funds purchased many scientific technologies such as microscopes, telescopes, radios, and televisions that were placed into the hands of teachers and students. Nelson & Weinbaum (2009) stated these funds were somewhat controversial because many of the financial needs of the schools regarding construction and teacher salaries were neglected in favor of this promotion of STEM. The need to be competitive in STEM fields was to ensure national security and economic viability and it trumped the local needs of school districts. Hence, the infusion of such a large amount of federal funding to foster STEM while neglecting some of the infrastructural needs of districts further substantiated the position on STEM held by the federal government (Nelson & Weinbaum, 2009).

In addition to regaining technological superiority, this investment was aimed at directly competing with the Russian educational system. Jolly (2009) discussed a number of factors that led the emphasis on STEM education to be placed on the advanced and gifted students within the American educational system. A focus was placed on instruction in STEM-related content areas and on influencing students to pursue careers in those fields. This group of highly talented

students was seen as an untapped resource. As a result, funds were used to accomplish three goals as they relate to STEM: 1. Develop appropriate curricular pathways that could best engage, influence, and prepare students for pursuing careers in STEM, 2. Identify students who might be interested or have the aptitude for these fields through various screening methodologies conducted by school counselors, and 3. Subsequently provide the necessary guidance to pursue those careers (Jolly, 2009).

The use of grants and scholarships to encourage more students, especially gifted students, to pursue careers within the mathematics and science related fields was an incentive to recruit highly talented individuals to bolster the intellectual capital in these areas (Gonzalez & Kuenzi, 2012; Jolly, 2009). Under the general provisions of the Act, the emergent need to respond to the nationally recognized deficiencies in mathematics and science was evident. This section read:

> We must increase our efforts to identify and educate more of the talent of our Nation. This requires programs that will give assurance that no student of ability will be denied an opportunity for higher education because of financial need; will correct as rapidly as possible the existing imbalances in our educational programs which have led to an insufficient proportion of our population educated in science, mathematics, and modern foreign languages and trained in technology (National Defense Education Act of 1958, p. 1581).

The focus was to provide these students with more robust educational experiences through concentrated efforts that addressed needs in mathematics and science curricula and instruction. Secondarily, these efforts aimed to infuse newly trained talent into STEM occupations to enhance technological innovation. In addition to recruiting new students to pursue degrees in mathematics and science at the postsecondary level, 1000 fellowships for graduate work in these

content areas were awarded in the first year and an additional 1500 fellowships each of the next three years (National Defense Education Act of 1958). As a result, this newly educated and trained workforce would be charged to eliminate the perceived technological and innovative gap with the Russians and reclaim the United States' desired superiority in STEM (Gonzalez & Kuenzi, 2012; Jenkins & Hill, 2011).

Additional support for focusing on the gifted and talented students within the American educational system came in 1958. Deboer (2000) outlined a paralleled financial structure supporting STEM education by the Rockefeller Brothers Fund. This organization generated a report on the state of American education that echoed the sentiments of the National Defense Education Act. This report also stated that a focus should be directed on "nuclear energy, space exploration, cell biology, and brain physiology" and that the educational system should "be used more effectively to prepare people to work in such a rapidly changing world" (Deboer, 2000, p. 5). The Rockefeller Brothers Fund's recommendation was to focus on the students who had the greatest capability of engaging in these areas of study. However, there was also support for providing a comprehensive literacy to all students due to the importance these fields were having on society as a whole. The advancements in technology, marked by the launch of Sputnik, provided a societal responsibility for all students to have scientific literacy (Deboer, 2000).

The impact of the National Defense Education Act, and supplemental support by other organizations such as the Rockefeller Brothers Fund, may have been more profound than simply becoming the first federally funded STEM initiative. Due to the significant amount of federal funds being provided to school districts, this Act is suggested to have been a framework from which the Elementary and Secondary Education Act of 1965 was forged. The Elementary and Secondary Education Act was later reauthorized to become the No Child Left Behind Act of

2001 which tied federal funding for school districts to assessment, accountability, and student achievement (Gonzalez & Kuenzi, 2012).

2.1.4   A Nation at Risk – Revisiting Concerns for National Security

In the two decades that followed the establishment of the National Defense Education Act, the momentum driven by the launch of the Russian satellite, Sputnik, waned as the Russian space program stalled following this seminal event. Although, as stated earlier, the NSF continued its work in building a robust math and science curriculum throughout the latter half of the 20th century, that work had moved into the background of the American conscious. However, in 1981, Secretary of Education T.H. Bell created a committee of educational leaders that spanned K-16 institutions and their governing bodies. This committee joined politicians and representatives from the world of business to assess the quality of the American educational system (Gardner et al., 1983). The results of this study identified STEM, once again, as a significant national concern. The specific areas assessed by the committee began with a look into the quality of teaching that occurred across the American educational system, K-16, and also within the private school setting (Gardner et al., 1983). The committee determined many individuals entering the field of education are from the bottom 25% of their high school and college graduating classes (Gardner et al., 1983). This may have been attributed to the then average salary after twelve years of teaching being only $17,000 (Gardner et al., 1983). Consequently, this may have influenced the shortage in mathematics and science teachers while increasing the number of teachers providing instruction in these content areas without proper certification (Gardner et al., 1983).

The committee also compared the American educational system with other high performing nations. TFor example, they found that the length of school day and year were vastly different. When compared to England and other industrialized countries, the length of the typical high school year was approximately two hours longer each day and forty days longer each year (Gardner et al., 1983). The committee also looked at the expectations set forth for college admissions and the achievement levels of high school students. In spite of declines in the amount of homework being completed, fewer students took advanced level coursework, and the dilution of course curricula were evident. Fifty percent of required credits for graduation were in non-content related areas. In addition, there was a decline in performance on standardized assessments while student grades actually increased (Gardner et al., 1983). This translated in colleges and universities reducing the criteria for acceptance into their institutions (Gardner et al., 1983).

Additionally, the committee examined the factors that promoted student success in post-secondary institutions, social and educational changes over the last twenty five years that may have contributed to adverse student achievement, and identifying the factors that were hurdles to student achievement within the current educational system (Gardner et al., 1983).

The results of this assessment of the American educational system aroused the same concerns for national security that were created by the launch of Sputnik. However, unlike the response to Sputnik that included the federal government's financial and programmatic support of the American educational system, specifically in STEM, this committee attacked the integrity of the system as a whole (Gardner et al., 1983). The educational system that supplies the talent to what has in the past been our "unchallenged preeminence in commerce, industry, science, and technological innovation" was determined to be faltering (Gardner et al., 1983, p. 9). References

to the strides and momentum gathered during our nation's response to the launch of Sputnik were being found to be insignificant and minimal in comparison to the advancements of our international competitors (Gardner et al., 1983).

The degree of this failure was equivocated to an "act of war" against our ability to remain leaders in the global economy had it been instigated by one of our geopolitical foes (Adams & Ginsberg, 2007; Gardner et al., 1983). In addition, our decline in technological innovations risked our superiority both economically and in terms of maintaining our national security (Gardner et al., 1983). The results of this study supported the committee's claim that our nation was, in fact, 'at risk.'

The risk to our nation was further evidenced in the performance of American students on standardized tests in comparison to international students. The results indicated that American students were being severely outperformed. In spite of the motivation to increase student achievement in a post-Sputnik era, scores revealed a level of performance below those observed at the time of the Russian satellite's launch (Gardner et al., 1983). On nineteen assessments, American students scored at the bottom seven times when measured against students from other industrialized nations (Gardner et al., 1983). Scores on the College Board's Scholastic Aptitude Test (SAT) had a general downward trend between the years 1963 and 1980 and the number of students scoring at the advanced levels of the assessment, above 650, declined significantly (Gardner et al., 1983).

Along with the observed underperformance on standardized assessments stated above, gifted students were shown to be severely underachieving given their potential, illiteracy rates were increasing, and student performance in mathematics and science was steadily declining. Science assessments given in 1969, 1973, and 1977 reported a continual decline in student

performance and reports made by four-year colleges indicated a 72 percent increase in students needing remedial mathematics classes (Gardner et al., 1983). A similar level of remediation in basic mathematics and reading competencies was found necessary for new military recruits (Gardner et al., 1983).

The results of this study placed a renewed focus on the functioning of the American educational system and, more specifically, on the instruction of mathematics and science (Gardner et al., 1983). It was determined that for the first time in our nation's history this measured generation of students would not reach, let alone surpass, the performance of the generation before it (Gardner et al., 1983). The country had reached a point of stagnation that threatened the very well being of the democracy and its hegemonic position in the world.

Evidence to support the decline of the American educational system was found when examining key areas within the system's infrastructure. The depth of content, rigor, qualifications of classroom teachers, and instructional time being spent within American mathematics and science classrooms fell well behind the established norms of their international peers (Gardner et al., 1983). Many teachers were not certified in their areas of instruction and classroom expectations, including the amount of time spent outside of the classroom on homework, were drastically below the international norms (Gardner et al., 1983). As a result, there became a renewed focus on STEM as part of an effort to create a scientifically literate citizenry in a world growing in complexity and spurned by technological advancement (Gardner et al., 1983).

2.1.5 Changes made in response to "A Nation at Risk"

The response to *A Nation at Risk* was predominantly found in the approach to curriculum and instruction within STEM-related content areas (Breiner et al., 2012). In 1985, the American Association for the Advancement of Science (AAAS) was among the first to address the Commission's report to promote a scientifically literate citizenry through its creation of Project 2061 (Breiner et al., 2012; Salinger & Zuga, 2009). This project aimed "to help all Americans become literate in science, mathematics, and technology" (Breiner et al., 2012, p. 2). Their publication of *Science for All Americans* in 1991 addressed scientific literacy while *Benchmarks for Scientific Literacy* in 1993 compartmentalized various scientific competencies by grade level (Barrow, 2006; Salinger & Zuga, 2009). In addition, this piece of writing helped to shape inquiry as the pedagogical approach to engage students in scientific practice (Barrow, 2006; Salinger & Zuga, 2009).

The National Science Education Standards were then created in 1995. This resulted in measurable benchmarks by which the instruction of science could be evaluated (Barrow, 2006; Salinger & Zuga, 2009). Teaching science was to be about having students perform the work of scientists. Students were to ask scientifically relevant questions, use various technologies to conduct experimentation and discuss the results of their study using both experimental results and deductive reasoning (Barrow, 2006). The focus on establishing standards for the instruction and assessment of science had been established.

Other national organizations and interest groups were also involved in addressing the content being delivered by teachers within STEM. These groups were interested in developing STEM content areas and engaging students in the pursuit of STEM-related careers (Breiner et al., 2012). The National Science Teachers Association (NSTA), the National Council of Teachers of

Mathematics, and a variety of other stakeholders (professors, administrators, and researchers) within higher education were also promoting changes to STEM curriculum and instruction (Breiner et al., 2012).

2.1.6 The 20-plus year focus on STEM education

Throughout the 1980s, 1990s, and early 2000s the focus on STEM primarily resided in the establishment of curriculum and instruction occurring within K-12 education as indicated above. The impact of this emphasis came into question in the early 2000s. In 2005, a committee assembled to assess the ability of the United States to compete globally in the 21st century and sustain its position in the world (Augustine, 2005). The National Academies' Committee on Prospering in the Global Economy of the 21st Century concluded that the United States was not keeping up with the competitive demands created by the ever-flattening world as defined by Thomas Friedman (Augustine, 2005; Friedman, 2005). Specifically, the United States was losing significant ground to its global competitors within STEM-related education, innovation, and job markets (Augustine, 2005; Friedman, 2005). Technological advances and the ease with which goods, services, and human capital traverse the world had leveled the playing field when competing for what were once markets inaccessible to some countries due to geography or resources (Friedman, 2005). What was defined as "high end jobs" were not being pursued or filled by American citizens (Augustine, 2005, p. 2). Fields that demanded expertise in STEM-related competencies, i.e. software design, technological innovation, engineering, and medicine, were being outsourced to countries around the world (Augustine, 2005). Augustine (2005) concluded that an important underlying factor contributing to the widening competitive gap within the global marketplace was the inadequacies of the American educational system.

In spite of the intense efforts to improve the curriculum and instruction of STEM content areas following the launch of Sputnik and the critical analysis reported in *A Nation at Risk*, this committee found student engagement and performance in these fields to be unaffected (Augustine, 2005). Consequently, in a flattening global economy, this stagnant performance was equated to falling behind given the advancements being made educationally and technologically in comparison to our global competitors (Augustine, 2005). Augustine (2005) stated:

> Human capital – the quality of our work force – is a particularly important factor in our competitiveness. Our public school system comprises the foundation of this asset. But as it exists today, that system compares, in the aggregate, abysmally with those of other developed – and even developing – nations . . . particularly in the fields which underpin most innovation: science, mathematics and technology (p. 5).

Although the committee recognized other pertinent factors that contributed to the observed competitive gap such as "tax policy and overhead costs – such as healthcare, regulation and litigation," the focus on STEM remained the priority (Augustine, 2005, p. 6).

A number of factors were cited within Augustine's report that involved the United States' regression in STEM related fields. Concerns over the cost and supply of laborers within STEM fields were noted. The cost to fill engineering positions in countries such as India was significantly cheaper than those in the United States. One engineer in the United States was equivalent to the cost of eleven engineers in India (Augustine, 2005).

Despite this dramatic difference in wages, U.S.-born engineers were not being attracted to the labor market. The proportion of foreign-born engineers working within the United States holding doctorates had reached thirty-eight percent. In 2003, fifty-nine percent of the engineering degrees were awarded to foreign-born students (Augustine, 2005). Even though the

majority of engineering degrees were being awarded to foreign-born students, many of these students were forced to return to their home countries after obtaining that degree. Foreign-born students were only being granted visas to study in the U.S. if they agreed to return to their home countries upon completion of their schooling (Augustine, 2005). In addition, the number of work visas being offered to foreign-born engineers was cut from 195,000 per year to just 65,000 (Augustine, 2005). Therefore, the vast majority of students earning engineering degrees were not able to remain in the U.S. to seek employment.

Due to the number of foreign-born students earning STEM-related degrees and the change in policy regarding the constraints of being forced to return to their home country after schooling, the supply of labor had shifted to foreign countries. This change in the labor market combined with the aforementioned cheaper costs of labor forced the closure of seventy chemical companies within the United States in 2004 with an additional forty more slated to be closed thereafter (Augustine, 2005). New chemical plants were now being built where the supply of labor existed. This was evidenced by only one of the 120 new chemical plants costing at least $1 billion to construct occurring within the US. Of those 120, fifty were being built in China (Augustine, 2005).

A movement was also being made regarding the source of technological innovation and manufacturing. In just seven years, the number of research facilities within China increased from less than fifty to over six-hundred (Augustine, 2005). This study revealed that the United States was becoming increasingly more dependent on foreign manufacturing of technology. The U.S. experienced a thirteen percent decline in their share of global high tech exports while simultaneously experiencing a shift in the trade balance of high tech manufactured goods. By

2004, the U.S. trade balance in this area of commerce went from $33 billion (1990) to negative $24 billion (Augustine, 2005).

The risk to America's sustainability within a global economy and competitiveness within STEM fields was further examined through the lens of the American educational system. The findings perpetuated the negative perspective of our current standing in comparison to global competitors. The proportion of students seeking out degrees in science and engineering were significantly fewer than countries such as Germany, China, and Japan (Augustine, 2005). "In Germany, 36% of undergraduates receive their degrees in science and engineering. In China, the corresponding figure is 59%, and in Japan it is 66%. In the U.S., the share is 32%. In the case of engineering, the U.S. share is 5%, as compared with 50% in China" (Augustine, 2005, p. 8).

Augustine (2005) also cited concerns at the classroom level for STEM-related courses. It was determined that as many as two-thirds of students who were taking a chemistry and/or physics course in U.S. high schools were being provided instruction by teachers who did not have a certification or major in either of those content areas (Augustine, 2005). The same could often be said of teachers within the mathematics classrooms of grades five through twelve. As many as half of the teachers providing instruction in mathematics were not certified to do so (Augustine, 2005).

The Hart-Rudman Commission on National Security, cited within Augustine's research, suggested that such a precipitous decline in performance within STEM-related fields were of greater threat to the nation than that of any "conventional" war (Augustine, 2005, p. 8). This statement is of interest given the reiterative tone shared throughout history when a decline in STEM was identified. Similar statements that suggested the United States' decline in STEM could be equated to war-related rhetoric were cited previously in this paper as it pertained to the

United States' generalized response to Sputnik as well as within the conclusions drawn in *A Nation at Risk* (Gardner et al., 1983; Wang & Oreskes, 2008). In nearly 50 years, the threat to our nation's position within the global economy and national security as a result of underperforming in STEM remained a significant concern.

Throughout history there have been significant events that have resulted in a focus on STEM education. The launch of Sputnik served as the seminal event that triggered the need to focus on STEM and STEM education. The reports *A Nation at Risk* and *Rising Above the Gathering Storm* further substantiated and generated conclusions that the United States was behind the world in STEM education and innovation. This, in turn, placed the United States in jeopardy of maintaining national security and ensuring economic superiority entering the 21st century. As a result, the latter half of the 20th and into the 21st centuries marked a renewed interest in STEM focused on accountability and measurable outcomes in order to satisfy the pressures exerted by a global economy and mobile workforce.

2.2   FACTORS DRIVING STEM INITIATIVES IN EDUCATION

The United States' response to the launch of Sputnik and the publications of *A Nation at Risk* and *Rising Above the Gathering Storm* are historical examples of national events that have shaped reform efforts in education. Current STEM initiatives in K-12 education have also been impacted by a variety of factors that influence the policies and mandates that shape the landscape of K-12 STEM education.   The following section explores the educational, economic, and labor market factors influencing the more recent and revived focus on STEM education.

2.2.1 Assessments define gap between U.S. and international students

Student performance on international benchmarks of assessment in mathematics and science such as the Programme for International Student Assessment (PISA), the National Assessment of Educational Progress (NAEP), and the Trends in International Mathematics and Science Studies (TIMSS) have defined the American educational school system as being measurably behind our international competitors (Banning & Folkestad, 2012; Hossain & Robinson, 2011). These results have fueled the need to identify and address the gaps in student achievement, specifically in STEM. In addition, the measures highlight the stagnant longitudinal performance in STEM-related content areas that may directly impact national security and future economic sustainability (Carnevale et al., 2011; Riccards, 2009).

2.2.1.1 The Programme for International Student Assessment

Table 1. United States' world rankings in mathematics and science on the Programme for International Student Assessment (PISA) from 2003 to 2009 (Carnevale et al, 2011; Riccards, 2009).

Year	U.S. Rank in Mathematics	U.S. Rank in Science
2003	28th	24th
2006	28th	27th
2009	18th	13th

The Programme for International Student Assessment (PISA) exam is specific for 15 year-old students from industrialized and developing countries (Dickman et al., 2009; Gonzalez

& Kuenzi, 2012). This exam is designed to quantify a student's ability to translate content knowledge into solving real-world scenarios within the areas of reading, mathematics, and science literacy (Gonzalez & Kuenzi, 2012). In 2003, PISA results placed the United States well behind their international counterparts by ranking 28th in mathematics literacy and 24th in science literacy (Kuenzi, 2008). PISA results in 2006 mirrored the lack of performance in mathematics literacy by ranking 28th. That same year scores on scientific literacy declined, achieving a rank of 27th (Hossain & Robinson, 2011). The United States improved its rankings in mathematics and science literacy in 2009, yet remained behind a significant number of countries with their overall performance in mathematics and science. The United States ranked 18th and 13th in mathematics and science literacy respectively (Epstein & Miller, 2011; Thomasian, 2011). These results placed the United States overall ranking at 17th in these assessed categories (Steele, Brew, & Beatty, 2012).

2.2.1.2 Trends in International Mathematics and Science Studies

In addition to the results of international comparisons made by the PISA exam, the Trends in International Mathematics and Science Studies (TIMSS) exam shows a similar lack of achievement for United States' students. The TIMSS test assesses a student's content knowledge based on international benchmarks for students in 4th and 8th grade (Dickman et al., 2009; Kuenzi, 2008). Results of the 2003 TIMSS assessment for 4th grade U.S. students placed this cohort's performance in about the middle of the countries assessed. These students achieved higher results than 13 of the 24 countries in mathematics and 16 of 24 countries in science. For 8th grade students, the United States scored higher than 25 of the participating 44 countries in mathematics and 32 in science (Kuenzi, 2008).

The results from 2003 showed no change in average test scores of U.S. 4th grade students in mathematics and science in comparison to the same assessed grade levels in 1995. In addition, a number of countries the United States had outperformed in the 1995 assessment had leaped over the United States in the 2003 TIMSS test (Hitz & Robinson, 2007; Kuenzi, 2008). The combination of stagnant performance of U.S. 4th grade students on the TIMSS assessment and subsequent improvement of test scores by their foreign competitors implies a growing gap in performance in the areas of mathematics and science at this grade level.

Eighth grade science results told another story. Scores in both math and science, on average, increased from 1995 to 2003. The number of countries scoring higher than the United States in mathematics declined from 12 to seven and in science from 15 to 10 within this testing window (Kuenzi, 2008). Although scores increased for this grade cohort from 1995 to 2003, a number of countries (China, Japan, Korea, Hong Kong, etc.) continue to outperform United States' students in mathematics and science (Kuenzi, 2008).

This aforementioned group of countries continued to outperform the United States' students on the 2007 TIMSS mathematics and science exams. Taiwan, Singapore, Japan, and Hong Kong scored higher than the U.S. in both 4th and 8th grade mathematics and 4th grade science assessments (Epstein & Miller, 2011; Hossain & Robinson, 2011). Along with those countries already listed, England, Russia, and the Czech Republic also scored higher than the U. S. on the 8th grade science assessment (Epstein & Miller, 2011; Hossain & Robinson, 2011). A deeper dive into the data generates even more cause for concern. Only six percent of 8th grade American students scored advanced on the TIMSS assessment, while 40 percent of the same cohort of students from Korea and Singapore and 45 percent from Taiwan achieved that distinction (Beering, 2010; Hossain & Robinson, 2011; Thomasian, 2011). All told, nine

countries had a higher percentage of 8th grade students achieving advanced scores than the United States in the mathematics assessment and six countries with respect to science (Thomasian, 2011). Hossain and Robinson (2011) summarized these results by stating, "When compared to other industrialized nations, the science and mathematics achievement of US students and the rate of STEM degree attainment seem lower than expected for a nation considered the world leader in scientific innovation (p. 4)."

2.2.1.3 National Assessment of Educational Progress

The National Assessment of Educational Progress (NAEP) exam, also known as the "Nation's Report Card," is the third assessment used to measure student performance in select content areas. This exam is often used as a national barometer for measuring student performance in STEM on a generalized scale (Dugger, 2010; Epstein & Miller, 2011; Sneider, 2011). Proficiency on this assessment may be a window into the students competencies in mathematics and science and, therefore, extrapolated to determine their proficiency in STEM (Epstein & Miller, 2011).

The NAEP samples test takers from urban, suburban, and rural school districts (Kuenzi, 2008; Nelson & Weinbaum, 2009). The data from this assessment was to be originally reported comprehensively so as not to perform a comparative analysis of school districts being tested. However, the reporting of data was later modified to identify the performance of urban districts at the state level (Nelson & Weinbaum, 2009). The test is administered in grades 4, 8, and 12 and spans across 12 subject areas including mathematics and science (Gonzalez & Kuenzi, 2012; Kuenzi, 2008). Student results are categorized into three performance levels: basic, proficient and advanced (Kuenzi, 2008; Thomasian, 2011). The National Assessment Governing Board

has determined that proficiency is where all students should be thereby reflecting competency and understanding of that content area (Kuenzi, 2008).

Table 2. 4th and 8th grade level proficiency in mathematics and science on the National Assessment of Educational Progress (NAEP) in 2005 and 2009 (Thomasian, 2011).

Subject Area	2005		2009	
	4th Grade	8th Grade	4th Grade	8th Grade
Mathematics	36%	30%	39%	34%
Science	29%	29%	34%	30%

The data for this assessment has been scrutinized similarly to the results of the aforementioned TIMSS and PISA examinations, particularly in mathematics and science. Data on the NAEP has shown a small improvement on the mathematics and science assessments for 4th and 8th graders between the years 1990 and 2005 (Hitz & Robinson, 2007; Kuenzi, 2008; Thomasian, 2011). However, student achievement in these grade levels remains representatively low (Hitz & Robinson, 2007; Kuenzi, 2008; Thomasian, 2011). In 2005, only 36% of students in 4th grade reached the proficient level in mathematics and only 30% for 8th grade students (Hitz & Robinson, 2007; Kuenzi, 2008). The performance on the science assessment was even lower. Only 29% of both 4th and 8th grade students scored proficient on the science assessment (Hitz & Robinson, 2007; Kuenzi, 2008).

The NAEP assessment was given again in 2009. Mathematics and science scores marginally improved for the 4th grade cohort. Students in this grade level achieved 39% proficiency in mathematics while science increased to 34% (Epstein & Miller, 2011; Sneider, 2011). The same minimal increase was observed within the 8th grade cohort with performance reaching 34% proficiency in mathematics and 30% in science (Epstein & Miller, 2011; Sneider,

2011). Epstein & Miller (2011, p. 5) concluded from these results that, "far too few U.S. students are at or above the proficient level in mathematics and science."

2.2.2   K-12 instruction of STEM content areas

The combination of student performance on international benchmarks and the reports generated by the committees who authored *A Nation at Risk* and *Rising Above the Gathering Storm* has generated questions regarding the competencies of teachers providing instruction in STEM content areas (Augustine, 2005; Gardner et al., 1983; Hossain & Robinson, 2011; Kuenzi, 2008). Findings made by a study on STEM education in 1999-2000 suggested that as many as half of the teachers providing instruction in mathematics and science at the middle school level (51.5%) lacked the certification in that area (Hossain & Robinson, 2011; Kuenzi, 2008). For teachers at the high school level, the percentage of those not having a major or minor in mathematics or science for their primary teaching responsibilities was 14.5% and 11.2% respectively (Hossain & Robinson, 2011).

The Council of Chief State School Officers in 2007 reported that only 61% of teachers providing instruction in mathematics in grades 7 through 12 had a major in that content area (Hossain & Robinson, 2011). In addition, only 60% of teachers providing instruction in physics and/or chemistry in high school have majors in these content areas (Hossain & Robinson, 2011). The concern is that these percentages may be on the rise. Approximately 50% of teachers in mathematics and science are leaving the field within five years of employment (Hossain & Robinson, 2011). The annual turnover rate is 16% and is the highest for any content area in education (Hitz & Robinson, 2007). This number increases in areas of low socioeconomic status, thereby further depriving these students of the opportunity to be properly exposed to

STEM-related content areas (Hitz & Robinson, 2007). The absence of qualified teachers remaining in the field combined with the stagnant numbers of students pursuing majors in STEM-related fields has generated great concern for the future of STEM in the United States (Hossain & Robinson, 2011).

2.2.3   Federal response to the decline in STEM educators

In response to the shortage of qualified teachers within STEM content areas outlined above, President Obama announced a commitment to bolster the number of teachers in mathematics and science and address the importance of STEM education in the United States (Burke & Mcneill, 2011). In 2009, Obama announced his new plan titled, *Educate to Innovate Campaign for Excellence in Science, Technology, Engineering, and Math (STEM) Education.* This plan aimed to improve STEM education by creating partnerships with non-profit organizations and companies within the private sector to "increase STEM literacy, enhance teaching quality, and expand educational and career opportunities for America's youth" (Burke & Mcneill, 2011, p.2). Partnerships were formed with companies that were easily recognized by the general public. Time Warner Cable, Discovery Communications, and Sesame Street infused a STEM focus into the projects they were promoting as part of the *Educate to Innovate* initiative (Burke & Mcneill, 2011). Private and non-profit enterprises donated approximately $500 million dollars and the federal government added another $250 million towards various STEM-related programs (Burke & Mcneill, 2011).

A focus on teaching was also embedded in this initiative. In addition to the involvement of the previously mentioned institutions providing shadowing and internship opportunities for students, 10,000 new teachers were to be trained in STEM content areas by large public

institutions and organizations such as Intel and PBS (Burke & Mcneill, 2011). This push to train more teachers came directly on the heels of the America COMPETES Act in 2007. This Act allotted funds to train 70,000 new teachers in Advanced Placement and International Baccalaureate courses and increase the training and interest of students at the college and university levels to pursue STEM degrees (Burke & Mcneill, 2011).

The push for STEM was not only to improve the American educational system by addressing the way STEM was being delivered to students, it was also intended to dramatically enhance the overall pipeline of students pursuing careers in STEM. This pipeline was and is crucial in order to address the growing concerns regarding innovation and America's economic viability in the 21st century (Johnson, 2011).

2.2.4 The narrowing pipeline of students pursuing careers in STEM

The need to focus on STEM in K-12 education is due, in large part, to the potential economic consequences that extend beyond the classroom. Ever since the launch of Sputnik in 1957, the number of students pursuing careers in STEM fields has been a topic of discussion (Burke & Mcneill, 2011; Gallant, 2010). The growing gap between American and international students pursuing and obtaining careers in STEM is an escalating concern for the economic viability of the country (Atkinson & Mayo, 2010; Dodson, 2013; Riccards, 2009). It is estimated that "over 80% of the fastest growing occupations in the United States are dependent on mastery of mathematics and science knowledge and skills" (Johnson, 2011, p. 45). The small number of students in the US pursuing careers in STEM coupled with the current and predicted rates of job growth in this sector creates a significant advantage for international competitors within the labor market (Johnson, 2011; Salinger & Zuga, 2009).

It was reported in 2007 that only 15.6 percent of students obtaining a bachelor's degree were in the fields of engineering and the natural sciences (*Increasing the number of STEM graduates : Insights from the U.S. STEM education & modeling project*, 2010). This is in comparison to our international competitors of China, South Korea, and Germany who graduated 46.7, 37.8, and 28.1 percent of their students obtaining bachelor's degrees in those same fields, respectively (Beering, 2010; *Increasing the number of STEM graduates : Insights from the U.S. STEM education & modeling project*, 2010). The Engineering Workforce Commission in 2005 indicated that over the past 20 years, the U.S. has observed a 19.8 percent decline in the number of students receiving bachelor's degrees in engineering and within a five year span found a 50 percent decline in the number of students acquiring a bachelor's degree in computer science (Hossain & Robinson, 2012). Hossain and Robinson (2012, p.444) state, "too many American students conclude early in their education that STEM subjects are boring, too difficult or unwelcoming leaving them ill-prepared to meet the challenges that will face their generation, their country and the world." As a result, American students are avoiding degrees in STEM fields while their international counterparts are taking advantage of this existing opportunity within the labor market.

The disproportionate graduation of students with STEM degrees, in comparison to those observed internationally, has also translated into more international students pursuing graduate degrees and postdoctoral fellows in U.S. universities. Of those students pursuing a doctoral degree in a STEM field, 33 percent are from countries outside of the U.S. (Beering, 2010). In addition, 57 percent of students obtaining postdoctoral fellowships are foreign students (Beering, 2010). Beering (2010, p. 9) noted that "[i]n 2003, foreign-born doctorate holders represented about half of the workforce in engineering and computer science, and 37 percent and 43 percent

of the workers in the physical sciences and mathematics, respectively." In summation, the number of U.S. students pursuing and obtaining degrees in STEM has become stagnant. Concurrently, the number of international students acquiring degrees and jobs in STEM-related fields is on the rise.

Kuenzi (2008) shared a three-tiered approach proposed by the National Academy of Sciences (NAS) to positively support growing the pipeline of students entering STEM fields of study. The first tier addressed expanding the number of middle and high school students who were taking Advanced Placement and International Baccalaureate courses within STEM fields (Kuenzi, 2008). Success on this approach would be measured by the number of students both enrolled in these courses and performing successfully on the AP or IB exams taken at the conclusion of the coursework (Kuenzi, 2008). In addition, this approach may necessitate the establishment of STEM-specific schools where students would be exposed to a wide-variety of content areas pertaining to STEM with an inquiry-based instructional approach to reflect the work of scientists (Kuenzi, 2008).

Second, the NAS proposes the recruitment of 10,000 new STEM teachers by providing grants and monetary stipends to entice individuals to enter the field of teaching (Kuenzi, 2008). These individuals would be provided $10,000 - $20,000 stipends contingent on a five-year commitment to the field and an additional $10,000 annual bonus to teach in a rural or urban setting with a low socioeconomic status (Kuenzi, 2008). The NAS also provided matching funds up to $1 million to post-secondary institutions who would establish programs that foster students to pursue teaching certificates in STEM-related fields (Kuenzi, 2008).

The third recommendation by NAS addressed professional development programs for approximately 250,000 teachers providing instruction in STEM-related courses of study.

Summer institutes, grants to post-secondary degrees in STEM content areas, and training to teach AP and IB courses were points of emphasis to improve the STEM pipeline (Kuenzi, 2008).

The three-tiered system recommended above would reach the classroom level of STEM engagement and foster the interest of students who may pursue degrees and careers in STEM. To support that sparked interest, the NAS also recommended providing as many as 25,000 annual scholarships to students pursuing degrees in STEM (Kuenzi, 2008). Advanced degree attainment in STEM content areas was supported by the proposal to provide 5,000 annual fellowships that would consist of an annual $30,000 stipend and $20,000 tuition voucher to U.S. citizens wishing to attain a doctoral degree (Kuenzi, 2008).

The numbers of students pursuing degrees and careers in STEM as compared to international competitors may also be attributed to a series of factors outside of the American educational system. One of those factors affecting the United States may be the shift from a manufacturing to a service based economy in which careers in business, banking, and communication related industries dominate the job market (Varma & Frehill, 2010). This is in stark contrast to our international competitors that have vastly different foci within their economies. Countries like India and China are large developing economies that have focused on STEM related fields such as technology and manufacturing as their key industries. As a result, their countries stress the importance of STEM-related careers and the importance of pursuing degrees in STEM throughout their educational systems. This translates directly into the number of students who attend colleges and universities to pursue STEM-related content areas (Varma & Frehill, 2010). Although careers in STEM only account for 5% of the labor market, the growth of these fields within the American economy is far greater than the growth of the labor market as a whole (Varma & Frehill, 2010). Between 1950 and 2000, the labor market expanded by 139

percent while within that same period the growth of STEM-related jobs expanded by 669 percent (Varma & Frehill, 2010). It is estimated that between 2008 and 2018, STEM-related jobs will nearly double the growth rate of jobs in non-STEM fields (17.0 percent compared to 9.8 percent) (Langdon, McKittrick, Beede, Khan, & Doms, 2011). Due to this significant and disproportionate demand found within the STEM workforce in comparison to the non-STEM workforce, the question of how to generate the appropriate supply of STEM workers within the United States in order to maintain global competitiveness with countries like China and India remains.

Recent research, however, suggests the trends observed over the past twenty years may be shifting to meet the demands of the workforce. The National Science Foundation (2015) has presented data that suggests a recent uptick in the number of students pursuing degrees in science and engineering. Although data collected up to and including 2005 illustrated a decline, or, at best, a period of stagnation in students pursuing degrees in various science and engineering fields, since then the numbers of students entering these fields has been on the rise. Notably, between 2006 and 2009 there has been an aggregate increase of nearly 60,000 students enrolled in engineering programs (National Science Foundation, 2015).

Furthermore, the number of female students pursuing undergraduate degrees in science and engineering is now nearly equal to the number of male students. Although the data shows variation in the subgroups within both science and engineering degrees, the total number of male and female students pursuing degrees in these fields is nearly equal. In addition, the rate at which female students are pursuing master's degrees is now occurring at a rate greater than their male counterparts (National Science Foundation, 2015).

Although recent data suggests students, specifically female students, are pursuing and obtaining undergraduate and graduate degrees in science and engineering at a greater pace than observed over the previous twenty years, the demand for workers within these fields continues to surpass the supply of graduates.

2.2.5   Promoting STEM through additional legislative action

The lack of interest and performance in STEM–related careers and content areas has stimulated the interest of local, state, and federal levels of government (Johnson, 2011; Stine & Matthews, 2009). The federal government's investment in STEM-related programs was significant in the early parts of the 21st century. The Government Accountability Office (GAO) determined that $2.8 billion was allocated to 207 federal programs pertaining to STEM in 2005. In 2007, the Academic Competitiveness Council (ACC) discovered that approximately $3.1 billion was allotted to 105 STEM programs. The number of STEM-related programs in 2011 and 2012, as observed via studies by National Science and Technology Council (NSTC) and GAO, increased to 252 and 209 respectively. The amount of monetary investment also increased in 2011 and 2012 with an observed $3.4 and $3.1 billion invested in STEM-related programs (Gonzalez & Kuenzi, 2012).

Along with funding, the federal government took legislative action to address the focus on STEM. In 2007, Congress developed policy to address stimulating the pipeline of students pursuing degrees and careers in STEM (Gonzalez & Kuenzi, 2012; Kuenzi, 2008). The America COMPETES (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science) Act was a collective effort of the Department of Energy (DOE), Department of Education (ED) and the NSF that aimed to promote STEM and STEM-related

careers (Kuenzi, 2008; Stine & Matthews, 2009). Each of these institutions influenced the opportunities afforded by the America COMPETES Act. The DOE aimed to promote the establishment of schools whose primary focus resided in mathematics and science, engage students through internships within a variety of STEM fields, and conduct professional development opportunities for teachers to deepen their content knowledge and understanding (Kuenzi, 2008).

The ED concentrated primarily on pre-service teachers and those seeking advanced degrees in STEM content areas. Grants were used to encourage those pursuing degrees in STEM content to concurrently acquire teaching certification (Kuenzi, 2008). In addition, professionals already working in STEM fields were provided opportunities to acquire degrees through flexible part-time graduate programs in order to acquire teaching certifications while maintaining full time jobs (Kuenzi, 2008).

The most substantial economic investment resided in the work of the NSF. Kuenzi (Kuenzi, 2008) addressed a number of factors of the American COMPETES Act that illustrate that investment. The America COMPETES Act aimed to double the spending on educational programs sponsored by the NSF over a seven-year period. Scholarships were established to increase students pursuing associate or bachelor's degrees in STEM content areas through a Math and Science Education Partnership program called STEM Talent Expansion. Increased work in teacher professional development and the pursuit of advanced degrees in STEM proliferated through the work of such programs as: Teacher Institutes for the 21st Century, Advanced Technological Education, Graduate Research Fellowship, and the Integrative Graduate Education and Research Traineeship. Congress reauthorized the America COMPETES

Act in 2010 (Gonzalez & Kuenzi, 2012). At that time, more funds were allocated to STEM and to further promote STEM initiatives (Gonzalez & Kuenzi, 2012; Kline & Hunter, 2012).

In 2011, the focus on STEM became tied to large amounts of federal funding given to states that qualified. The federal government allocated $3.7 billion specifically for STEM in the federal budget and another $4.3 billion in the form of the Race to the Top monies that required successful recipients to focus on STEM (Johnson, 2011). The federal government's financial response was to combat the continued lack of student success in STEM in regards to their performance on standardized tests and to promote the pursuit of careers in STEM. These funds forced states to focus on STEM and change the way STEM was being delivered to their students (Johnson, 2011). Successful states that received funding created "statewide STEM education networks, regional STEM hubs, STEM high schools, K-8 student programs, and STEM teacher professional development" (Johnson, 2011, p. 45).

2.2.6   Beyond the pipeline: Competing in a global economy

The focus on STEM and STEM-education has the utility of encouraging students to pursue degrees and careers that will fill an increasing void in the job market. However, the need to concentrate on STEM extends beyond the occupations that focus specifically on science, technology, engineering and/or mathematics. The nature of job markets is evolving. The competencies necessary to successfully navigate the evolving landscape are supported through a rich focus on STEM education. This focus would develop the skills students' need as they enter any field of employment. The uses of technology, critical thinking, or higher-order problem solving, though prevalent in STEM-related careers, are becoming essential competencies for many areas of employment.

2.3 CURRENT INITIATIVES WITHIN K-12 EDUCATION

In an effort to satisfy the desire to promote STEM within K-12 education, a wide range of strategies has been used. Some school districts have adopted the traditional STEM model while others have also adapted the acronym to include the arts (STEAM), research (STREAM), and a number of other variations in order to include additional academic areas. For the purposes of this analysis, the remaining discussion on STEM will exclude the components of the alternative acronyms unless specifically noted.

In addition to identifying the specific form of STEM to be implemented, school districts must also decide where, how, and to what extent STEM will be infused into their educational practice. Due to each school district operating in isolation from one another and the lack of a prescriptive decision making process to make this determination, a number of STEM programs have evolved within K-12 education.

This section aims to first define the fundamental characteristics of STEM. Next, the importance of STEM literacy and essential goals of STEM initiatives are defined. Finally, the various approaches to infusing STEM within K-12 education are categorized into the prevailing themes of after school programs, curricular changes at the elementary, middle, and secondary levels, and systemic changes that alter the entirety of the educational approach of the institution.

2.3.1 What is STEM?

On the surface, the definition of STEM is simply a statement of its parts: Science, Technology, Engineering, and Mathematics. However, the complexity in the definition lies in the synergistic properties that emerge when considering the S, T, E, and M collectively. When the NSF first

coined the used of the acronym STEM it did not define the term beyond the individual elements from which it was derived thereby leading to a great deal of interpretation within the field of education ("Best practices in elementary STEM programs," 2012).

Traditional definitions of STEM have looked at STEM's components as individual silos operating in isolation from one another (Breiner et al., 2012; Dugger, 2010). This view of STEM has been an issue of concern dating as far back as 1902. Transcripts of an address made by the president of the American Mathematical Society to its members noted the contradiction behind teaching the various courses of mathematics in isolation from one another and from the sciences that naturally integrate them (Breiner et al., 2012).

Barakos et al. (2012) developed a model to illustrate the continuum of STEM education. The representation of STEM operating in silos in isolation from one another can be considered to be the far left end of continuum. Moving towards the right, and subsequent full-scale integration amongst the four content areas, are four intermediary stages of STEM integration. The first intermediary stage includes two content areas being combined in the context of enrichment activities. The second intermediary stage involves integrating the four content areas of STEM via classroom projects that could be project or problem-based in nature. The third involves the construction of curriculum and therefore instructional practice that integrates two or more areas of STEM. The final intermediary stage prior to full scale STEM integration is the use of science as the central pillar to integrate the remaining three areas of STEM (Barakos, Lujan, & Strang, 2012).

In addition to the isolation of each content area from one another and the spectrum of integration observed within STEM, there is also an historical concern for the disproportionate attention given to the science and mathematical components of STEM in relation to that given to

technology and engineering (Bybee, 2010b). Traditionally, K-12 education has placed an emphasis on the science and mathematical aspects of STEM (Bybee, 2010a) and the acronym may be more accurately represented as SteM (Dugger, 2010). However, the importance of placing an emphasis on the technology and engineering components of STEM education lies in the need to promote innovation, creativity, and design while furthering the development of 21st century skills (Bybee, 2010a; Harrison & Royal, 2011; Vilorio, 2014). This can be ahieved by infusing the engineering and technology components of STEM into existing science and mathematics courses (Dugger, 2010). In more advanced cases, the development of specified courses in technology and engineering have begun to emerge as viable alternatives to forcing these areas of content within existing curricular frameworks (Harrison & Royal, 2011).

2.3.2   Effective STEM initiatives - STEM Literacy

The definition of STEM extends beyond the individual components of the acronym. It is an integrative and balanced approach to teaching science, technology, engineering, and mathematics with an emphasis on developing 21st century skills and a literacy associated with each of the four components (Bybee, 2010a). Those 21st century skills include: critical thinking, design, problem solving, application of knowledge in a broader context, collaboration, communication, creativity, and performing the work of those within STEM fields (DeJarnette, 2010; Saxton et al., 2014). STEM, therefore, becomes much broader than having an understanding of the content within each designated area. As Dugger (2010, p. 2) states, "The study of STEM offers students a chance to make sense of the integrated world we live in rather than learning fragmented bits and pieces of knowledge and practices about it." By making sense of that integrated world, students, therefore, develop a literacy associated with the integrated components of STEM.

STEM literacy can be seen as an interdisciplinary approach to understanding the inter-workings of the four components of STEM ("Best practices in elementary STEM programs," 2012; Gallant, 2010). That literacy will allow students to have an understanding of the natural world, an appreciation for the development, use, and importance of technology, knowledge of the design process used throughout the various facets of engineering, and the application of mathematical concepts to convey understanding of a given phenomenon (Bybee, 2010a; *K-12 STEM education overview*, 2011).

2.3.3 Beyond literacy – Essential components of K-12 STEM initiatives

The implementation of STEM initiatives within K-12 education has occurred through a variety of methods aimed to engage, inspire, and prepare students to pursue educational pathways and/or careers in STEM-related fields. However, there are a number of essential elements that have been identified that all STEM programs should possess. Among these include: a focus on core content aligned to state standards, student engagement, development of critical thinking, approaching the content areas within STEM holistically rather than in a segmented fashion, elements of design, foundational concepts of engineering, and a focus on real world problem solving (Anderson, 2010).

The Presidential Council of Advisors on Science and Technology (PCAST) have cited four goals STEM education should possess when considering the implementation of STEM initiatives. Each program should focus on producing a STEM-capable citizenry that is able to use STEM skills to think critically and solve real-world problems. The second and third goals work hand in hand. These goals state there should be a promotion of future STEM experts and the promotion of a STEM-proficient workforce. The final goal is for STEM education to be used

to close the achievement and participation gap found amongst female and minority groups within the United States and in comparison to international competitors within STEM-related fields ("Best practices in elementary STEM programs," 2012, *K-12 STEM education overview*, 2011).

Although these criteria exist, there remains a great deal of variability between the programs K-12 institutions choose to implement. Programs are created at the elementary, middle, and high school levels with varying approaches in how to engage students in STEM (Epstein & Miller, 2011; Scott, 2012; Sneider, 2011). As stated previously, some programs have maintained the standard STEM acronym while others have integrated the arts (STEAM) to emphasize an integrated approach to these areas of the curriculum (Marcoux, 2013; Robelen, 2011; Tarnoff, 2010). In addition to the array of titles being given to STEM programs, the way in which students are exposed to the underlying skills of STEM varies from school to school. Integrating curricula, providing real-world assessments, internships, and job shadowing experiences are all examples of what is implemented within K-12 education (Berry et al., 2005; Breiner et al., 2012; DeJarnette, 2010; Harrison & Royal, 2011). Each variation is designed to engage students while building the competencies essential for careers and educational pathways for STEM. This section will survey the programs that are being implemented at the K-12 level in an effort to address the needs related to STEM education. Table 3, below, illustrates the three frameworks for STEM initiatives that have emerged from the literature. Explanations for each of these frameworks will follow.

Table 3. Frameworks for implementing STEM into K-12 education.

Framework	Focus	Examples
Extension to the School Day (i.e. any activity occurring outside of the traditional school day; before school, after school, and during the summer are examples of this approach.)	• Students get exposed to STEM outside the traditional classroom setting. • Often geared towards underrepresented or specified populations of students (i.e. females, low socioeconomic status, minorities, and the gifted) • Level educational playing field to address achievement gap for minority and low socioeconomic students • Additive Model – connections made back to the traditional classroom curriculum • Expanded Model – focus on engaging students in content • Extended Learning Model – builds from the curriculum occurring within the traditional classrom	• 4-H Tech Wizards • Build IT • Computer Clubhouse • FUSE • Girlstart After School • Science Club • Project GUTS • Techbridge
Modifications to Existing Curricula	• Occurs within traditional school day • Typically occurs at distinct elementary, middle, or high school levels • Programs/Initiatives can be district generated or created by outside entities	• Elementary Level: Engineering is Elementary, Project Lead the Way, ASSET Inc., Math Out of the Box, Seeds of Science/Roots of Reading, and The Partnership for 21st Century Skills • Middle and High School Level: LEGO Mindstorms, ROBOLAB, Physics by Design, Engineering with LEGO Brick and ROBOLAB, Project Lead the Way, The Infinity Project, STEAM (addition of the Arts), Maker Movement

Table 3 (continued). Frameworks for implementing STEM into K-12 education.

STEM-Specific High Schools	• Curriculum driven by STEM • Separate educational entity outside traditional public/private schools • Provide more opportunities to engage in upper level and STEM-specific curricular areas of study	• School-within-a-school model where students participate in a cohort within their home school • Students spend part of their day traveling to another location to participate in a STEM program • Students attend a STEM-specific high school which can be partnered with a local college or university

2.3.4 STEM initiative framework #1: Extending the school day (i.e. before or after school or during the summer)

One approach to providing the opportunity for students to engage in STEM has occurred through the use of after school programs and activities. The exposure of students to STEM experiences outside of the traditional classroom has shown to be positively linked to the pursuit of a related STEM career (Gottfried & Williams, 2013). These programs have often been associated with specific student populations such as the gifted, females, low socioeconomic status, and minorities in order to expose these students to STEM or motivate them to pursue STEM-related careers (Gottfried & Williams, 2013; Krishnamurthi, Ballard, & Noam, 2014; Lee, 2012). After school programs have often been used to level the educational playing field by providing equitable learning opportunities to address the achievement gap for minority students and students of low socioeconomic status (Lee, 2012).

Examples of after school clubs and activities that focus on STEM include: 4-H Tech Wizards, Build IT, Computer Clubhouse, FUSE (Frontiers for Urban Science Exploration),

Girlstart After School, Science Club, Project GUTS, Techbridge, and many more (Krishnamurthi et al., 2014; Paulsen, 2012). After school programs have been found to have a significant positive impact on students in a number of ways. Such programs have been linked to increasing student interest and motivation in the subject being investigated. The increase in interest allows students to more actively engage in science as hands-on learners (Krishnamurthi et al., 2014). In addition, students who participate in after school programs have been found to improve in their social and emotional well-being, increase their academic performance, and experience an improvement in their overall behavior (Krishnamurthi et al., 2014).

Within the after school model, there are multiple approaches that can be taken which have varying degrees of connectedness to what occurs within the traditional school day and curriculum. One such approach is coined the additive model (Bevan & Michalchik, 2013). This approach focuses on generating interest, curiosity, and engagement in STEM in a context-free environment (Bevan & Michalchik, 2013). This model would incorporate a variety of activities and projects that would not be connected back to the classroom environment (Bevan & Michalchik, 2013). The philosophy behind this approach is to generate a positive experience when engaging in the content and that the resulting mindset would be transferred to other educational experiences. As a result, a heightened interest in STEM generated by using this model of exposure would translate to increased interest and engagement within the traditional educational environment (Bevan & Michalchik, 2013).

An extension of the additive model is the expanded learning model. Whereby the additive model stresses a focus on generating interest, the expanded learning model stresses focused opportunities to engage in the content (Bevan & Michalchik, 2013). This model includes summer camps and trips to science museums (Bevan & Michalchik, 2013) as well as

programs such as the Frontiers for Urban Science Exploration (FUSE) which is coordinated by The Collaborative for Building After School Systems (CBASS) (Donner & Wang, 2013). The common thread between the additive and expanded learning models is the lack of connection each has to the daily curriculum. Each model operates in isolation of the traditional school day by providing unique learning opportunities for students in an effort to either foster an interest in STEM or deepen a particular aspect of STEM-related content (Bevan & Michalchik, 2013).

The third model for after school activities is extended learning. The extended learning model builds from the curriculum covered within the traditional school setting (Bevan & Michalchik, 2013). Unlike the previous models, this method directly supplements the school curriculum whereby its effectiveness can be measured by its participants' performance on standardized tests and other measures such as grades and attendance (Bevan & Michalchik, 2013). It is suggested that this model may prevail in low achieving and poverty-stricken school districts. Here, there is an attempt to provide remediation as a means of increasing performance on standardized testing. The previous two models would appear more in affluent and high achieving areas where these opportunities are viewed as a supplemental luxury aimed at generating or satisfying an area of interest (Bevan & Michalchik, 2013).

Each of these models satisfies a specific need that may be pertinent to a given school district. The implementation of STEM, for these districts, may be restricted to occurring outside the school day and may be specific to satisfying the unique needs of the school and/or community. Each school district must evaluate where, and to what extent, district resources are disseminated to best serve the students as well as manage their own fiduciary responsibilities to maintain and sustain the district's budget. As a result, careful consideration must be placed on the desired outcome given the strengths and limitations of each approach.

2.3.5   STEM initiative framework #2: Modifications to existing curricula

The infusion of STEM and STEM-related programs into the existing curriculum, and within the context of the school day, has taken on a variety of forms throughout K-12 education. Some of the more commonly observed practices have concentrated on initiatives at the elementary, middle, or high school level. Within those levels, an introduction of robotics, the infusion of opportunities for creativity and design (makerspaces), and an inclusion of the arts (STEAM) have been specific initiatives aimed to incorporate STEM into the curriculum. Each of these areas will be considered below in an effort to survey the initiatives occurring within K-12 education.

2.3.5.1 STEM at the Elementary Level

Introducing STEM initiatives at the elementary level is based on the ideology of establishing an interest and motivation to pursue STEM-related degrees and careers at a young age and reinforcing that interest as they matriculate through the rest of their education. "Research indicates that early and repeated exposure to STEM subjects is essential for cultivating both future interest and future aptitude in STEM subjects" ("Best practices in elementary STEM programs," 2012, p. 10). DeJarnette (2010, p. 77) provides similar insight into the importance of STEM at the elementary level stating, "early exposure to STEM initiatives and activities positively impacts elementary students' perceptions and dispositions." It is noteworthy that an impediment to any focus on the integration of STEM programs at the elementary level, in particular, is rooted in the focus on meeting and exceeding the criteria established for standardized test scores ("Best practices in elementary STEM programs," 2012).

The following STEM programs have found momentum at the elementary level. Each of these has been recognized by the Bayer Corporation's *Compendium of Best Practice K-12 STEM Education* as having four essential characteristics that has made these programs 'highly effective' ("Best practices in elementary STEM programs," 2012). Each program has a clearly established curriculum that is accessed through an inquiry-based pedagogical approach. In addition, the assessment of a student's understanding of the curriculum is measured by reaching defined outcomes. Finally, there must be sustainability that is first and foremost indicated by leadership that is focused on the program's success. It is equally important that the program's sustainability is evidenced by the availability of resources and the establishment of community support ("Best practices in elementary STEM programs," 2012).

Engineering is Elementary (EiE) is one such program that satisfies the criteria of the Bayer Corporation. This program is a cross-curricular approach to introducing students to problems related to the field of engineering while incorporating elements of mathematics, English, and social studies ("Best practices in elementary STEM programs," 2012; Brophy, Klein, Portsmore, & Rogers, 2008). EiE was designed in response to newly developed engineering standards within the state of Massachusetts. Funding for this program was split between the National Science Foundation and partnering industries (Brophy et al., 2008). Students within this program experience the value of teamwork, failure, solving problems that may have more than one solution, and participating in the collaborative process ("Best practices in elementary STEM programs," 2012).

Project Lead the Way is another program that utilizes problem-based and project-based learning to introduce STEM at the elementary levels. This program has been implemented to a much greater extent within grades 7-12, but it has also created smaller modules (five days to two

weeks in length) for students within the elementary setting ("Best practices in elementary STEM programs," 2012; Brophy et al., 2008).

Other programs cited by the Bayer Corporation for a focus on STEM within the elementary setting include: ASSET Inc., Math Out of the Box, and Seeds of Science/Roots of Reading. Each of these programs has a unique focus. ASSET Inc. is a standards-based curriculum that has shown positive results in improving student scores on standardized tests, while Math Out of the Box is aimed to engage students of low socioeconomic status. Seeds of Science/Roots of Reading focuses primarily on English language learners with the duel purpose of improving literacy while engaging this distinct student population in the sciences ("Best practices in elementary STEM programs," 2012).

Another program that was not cited by the Bayer Corporation, but has been implemented at the elementary level is *The Partnership for 21st Century Skills*. *The Partnership for 21st Century Skills* focuses on relationships built between teachers, politicians, and local businesses and community members (DeJarnette, 2010). This program aims to promote the 21st century skills outlined earlier in this section as key attributes students should possess in order to be successful in a global economy (DeJarnette, 2010). Specifically, students would develop a working knowledge of the competencies and processes by which engineers operate and be able to integrate their knowledge of mathematics, science, and technology by solving unique problems (DeJarnette, 2010).

2.3.5.2 STEM at the middle and high school levels

The shift between elementary STEM initiatives and those introduced at the middle and high school levels is often one from interest an engagement to one of motivation and focus on careers. At the elementary levels, as indicated above, many of the programs are aimed at

engaging students is the activities associated with STEM. By having students participate in the scientific process within the classroom setting, the aim is to generate interest for students to pursue careers as scientists. At the middle and high school levels, the shift in the priorities associated with STEM becomes one of motivation and career exploration with a focus on post secondary pursuits (Hossain & Robinson, 2012).   This is especially relevant for women and minorities as their career interests tend to peek at the middle school level (Brophy et al., 2008).

2.3.5.3 The push for engineering

Some of the efforts to infuse STEM, specifically engineering, into the middle and high school levels have been initiated by outreach programs associated with STEM fields. For example, the American Society developed one such program for Engineering Education (ASEE). The ASEE approached the desire to increase more students' interest and pursuit of engineering careers by incorporating hands-on pedagogical strategies into existing curricular frameworks. This approach is standards-based and interdisciplinary in nature (Brophy et al., 2008). Similar opportunities to promote engineering in grades 7-12 have been developed by the National Academy of Engineering (NAE) (Brophy et al., 2008).   There are specific skills and competencies these organizations wish to make a part of current school curricula that simultaneously represents what is required within the field of engineering and what may be more broadly understood to be necessary to function within a 21st century global economy (Brophy et al., 2008). The "activities of design, analysis, and troubleshooting are what engineers do to develop new devices (e.g., cars, consumer electronics), processes (e.g., food processing, manufacturing, airport scheduling), and infrastructure (e.g., transportation, power distribution, and waste management) and change existing ones that shape our lives" (Brophy et al., 2008, p. 371).

The natural push for the pedagogical approach associated with this ideology of learning is hands-on methodologies such as Kolodner's *Learning by Design* model. This model places emphasis on students openly investigating content by creating, designing, evaluating, and redesigning in order to achieve the desired learning outcome. The student simultaneously acquires the basics of the engineer's design model, the scientific method, and the fundamentals of the content being addressed (Brophy et al., 2008).

2.3.5.4 The use of LEGO to promote engineering concepts

One program that has emerged with widespread use at the middle and high school levels to directly address the concepts of engineering involves LEGO. In collaboration with Tufts University, the LEGO engineering project originally used their Mindstorms line to engage students in hands-on projects that promote the concepts of engineering (Brophy et al., 2008). The use of the accompanying ROBOLAB software has also allowed the use of this robotics technology to simulate surgeries and therefore span into the biological side of engineering as well (Rockland et al., 2010). The LEGO robotics systems allow for students to engage in all areas of STEM simultaneously by solving problems using the engineering process (Gura, 2012). This product line has reached over ten million students and has fueled the development of curriculum such as Barbara Bratzel's *Physics by Design* that is aimed at teaching engineering to middle school students and Eric Wang's *Engineering with LEGO Brick and ROBOLAB* for high school and college students (Brophy et al., 2008).

2.3.5.5 Project Lead the Way (PLTW)

Mentioned earlier for the work of PLTW at the elementary level, the predominant focus of this initiative is at the middle and high school level. PLTW provides students a hands-on

project or problem based experience to engage in STEM-related content areas in an effort to promote students' pursuit of a degree and career in engineering (Brophy et al., 2008; Dickman et al., 2009). The middle school version of this initiative that focuses on five nine-week units in engineering and technology is called the *Gateway to Technology* (Brophy et al., 2008)**.** Courses at this level include: "Design and Modeling, Magic of Electronics, Science of Technology, Automation and Robotics, and Flight and Space" (Brophy et al., 2008, p. 378). At the high school level, courses such as "Introduction to Engineering Design, Principles of Engineering, and Digital Electronics" (Brophy et al., 2008, p. 378) are covered over a four year period. PLTW involves a great deal of teacher professional development and focuses on the top 80% of the student population who are college bound (Brophy et al., 2008; Dickman et al., 2009).

2.3.5.6 The Infinity Project

The Infinity Project was developed through partnerships with businesses and educational institutions such as the Department of Education, NSF, and Texas Instruments through The Institute of Engineering Education at Southern Methodist University (Brophy et al., 2008). This program focuses on student engagement in technologies that are relevant to middle and high school aged children. Technologies such as the Internet and cell phones are used to engage students from all demographics of public schools as well as magnet and parochial schools (Brophy et al., 2008). This program is not as widely implemented as PLTW or the LEGO initiatives, but was found in over 285 schools in 2007-2008, reaching over 7000 students (Brophy et al., 2008).

74

2.3.5.7 STEAM – Adding the arts to STEM

The addition of the arts to STEM is in response to supporting the concepts of creativity, design, and innovation that have been identified as key 21st century skills students should possess (Land, 2013). The benefits of including the arts within STEM education can be linked to the observed increase in the cognitive abilities of students engaged in such activity (Daugherty, 2013). The importance of the arts in innovation can be captured by Land's statement that, "Progress does not come from technology alone but from the melding of technology and creative thinking through art and design" (2013, p. 548). The incorporation of the arts into STEM-related content areas takes place when a conscious effort is made to identify cross-curricular opportunities to infuse creativity and design by way of an artistic approach (Land, 2013). Examples of the types of products that could be produced within the traditional STEM content areas include: "circuit bending, musical compositions, kinetic art, product design, prototype development, and performance art" (Land, 2013, p. 550).

In order to promote the potential of STEAM, a number of programs have been developed to integrate the arts into the traditional STEM fields. The focus of these programs is on "creativity, the benefits of interdisciplinary learning, the interconnectivity between disciplinary concepts, the role that knowledge from one discipline might have in learning in the other, and the benefits of a metadiscipline" (Daugherty, 2013, p. 13). The Art of Science Learning from The Learning Worlds Institute, Time Warner Cable's Connect a Million Minds, The Institute for the Study of Knowledge Management in Education, Discovery Communications' Science of the Movies, The National Aeronautics and Space Administration's Space School Musical, Science, Technology, Engineering, and Mathematics through Art (STEM-A), and CrayonPhysics are all

examples of programs that focus on the integration of various representations of the arts within the traditional STEM setting (Daugherty, 2013).

2.3.5.8 The introduction of the Maker Movement

One of the more recent phenomena to have gained momentum concerns that of the maker movement. With the emergence of technological tools such as the 3-D printer and 3-D scanner and software packages that have become financially available or even free to the common household, more and more individuals are utilizing their skills in creativity and design to manufacture their own products (Dougherty, 2012). The maker movement has been categorized into three distinct paths of utility: "making as entrepreneurship and/or community creativity, making as STEM pipeline and workforce development, and making as inquiry-based educative practice" (Vossoughi & Bevan, n.d., p. 5). For the purposes of this review of the literature, the focus will be on the use of maker spaces as a means to foster an inquiry-based approach to STEM education.

The importance of the maker movement as it relates to K-12 education is the ability to incorporate the 21st century skills outlined in many of the previously mentioned programs aimed to promote STEM in the classroom. Within this framework, students are able to create, collaborate, design, problem solve, and manufacture within the context of the classroom environment (Dougherty, 2012; Vossoughi, Escudé, & Kong, 2013). The movement encapsulates the strengths of the scientific and artistic approach to education whereby students are provided the context to innovate within the classroom setting (Vossoughi & Bevan, 2014). In addition, this movement aims to break down the walls between the home and school environments, as students would be encouraged to investigate their own creativity outside of the

classroom and not limit learning to what has been provided to them by their teachers (Reys, 2010).

2.3.6   STEM initiative framework #3: STEM-specific high schools

The establishment of STEM-specific high schools has historically been the result of the pressures to increase the number of students in the STEM pipeline by often drawing from the population of students who are gifted and talented in STEM-related content areas (Thomas & Williams, 2010). Engaging more students to enter a STEM-specific high school would satisfy concerns related to national security and the future prosperity of the United States economy (Atkinson, R.D., Hugo, Lundgren, Shapiro, & Thomas, 2007; Thomas & Williams, 2010). The increased emphasis in these curricular areas, often to a degree greater than that presented within traditional high schools, would translate into more students obtaining degrees in these areas of study at the college level (Atkinson et al., 2007).   As more students enter these fields, the belief is that the US economy benefits from greater levels of innovation and economic competitiveness within a global economy thereby bolstering national security. In an effort to provide legislative support for promoting STEM-specific high schools, the federal government passed the America COMPETES Act of 2007. This Act promoted the establishment of such educational entities to foster student interest and pursuit in STEM-related careers and degrees (Thomas & Williams, 2010).

The history of specialized STEM schools can be dated back to 1904 with Stuyvesant High School. The discussion of the importance and/or relevance of specialized STEM schools has often been brought into the forefront of conversations during times of economic downturn throughout the 20th century and in reaction to events such as the launch of Sputnik (Thomas &

Williams, 2010; Hannover Research, 2011). Pursuing an intensive and focused approach to STEM instruction has led to the development of STEM high schools, magnet schools, governor's schools, and charter schools (Tofel-Grehl & Callahan, 2014). Within these broader generalizations of specialized STEM schools are specific approaches to delivering STEM education.

2.3.6.1 Types of STEM-specific high schools

Tofel-Grehl & Callahan (2014) outline the various models of STEM-specific high schools. The school-within-a-school approach to STEM education allows students to remain in their home school while belonging to a cohort of students pursuing a more concentrated pursuit of STEM content areas. A pullout approach requires students leaving their home school to attend an outside organization to receive their STEM schooling during part of the school day or for entire days during the week. Stand alone, residential, and university-based schools operate independently from a student's home high school. Stand alone schools function as a traditional high school while residential schools provide on-campus housing for its students. University-based schools provide partnerships with universities that allow high school students to take part in the resources and facilities they have to offer within STEM content areas.

2.3.6.2 Characteristics of STEM-specific high schools

In a study conducted by Tofel-Grehl and Callahan (2014), four characteristics emerged as common themes across STEM-specific educational institutions: "a culture of intellectualism and inclusion, a valuation on research, the role of inquiry, and the importance of personal responsibility and independent learning for students" (p. 237). Among the highest achieving STEM schools, a diverse set of course offerings, research and/or internship opportunities, and

focused professional development opportunities for teachers exist (Tofel-Grehl & Callahan, 2014). Although these common themes are present across these institutions, this research also addresses the difficulty in differentiating the attributes that make STEM schools vastly different from traditional high schools that offer advanced opportunities, such as Advanced Placement, College in High School, and International Baccalaureate coursework, to their students (Tofel-Grehl & Callahan, 2014). However, others cite examples of coursework that are not offered within a traditional high school, such as Biomedical Physics, Multivariable Calculus, and Immunology (Atkinson et al., 2007), for example, that provide students a unique and engaging experience not available within their home schools.

2.3.6.3 Support for STEM-specific high schools

In order to support the development of STEM-specific high schools, the National Consortium for Specialized Secondary Schools of Mathematics, Science and Technology (NCSSSMST) was formed in 1988 (Thomas & Williams, 2010). The NCSSSMST originally consisted of 15 schools that focused primarily on areas of STEM. This organization has now grown to have 100 institutional members and over 100 affiliate members which are represented by higher education and outside businesses and organizations that support the pursuit of STEM related degrees and careers (Thomas & Williams, 2010). More specifically, this organization's mission "is to shape national policy, foster collaboration and develop, test implement and disseminate exemplary programs" (Thomas & Williams, 2010, p. 19). Collectively, the NCSSSMST and the existing STEM-specific high schools serve as a framework from which traditional high schools can use when considering the expansion of their own efforts to focus on STEM.

2.3.6.4 Challenges for STEM-specific high schools

However, with each successful model for promoting STEM-specific high schools there are inherent challenges that must be considered before selecting this option. The issue of sustainability, governance (local school boards or colleges/universities), support of the community, determining the scope and sequence of the curriculum, and staffing are all complex variables that are essential for the success of this type of educational institution (Atkinson et al., 2007). In addition, the culture of 'intellectualism' can promote an elitist view of STEM-specific high schools and may further disenfranchise minority students and students of low socio-economic status who may not be afforded the opportunity to attend such selective educational institutions (Atkinson et al., 2007).

2.4   SUMMARY

Collectively, there are a wide range of STEM programs occurring within K-12 education. Each of these programs has its own set of embedded goals and measures of successful implementation, rationale for focus, and impact. The challenge for school districts involves the process of identifying and implementing a comprehensive STEM program for their respective districts. Currently, school districts approach STEM from a variety of perspectives and without a framework from which the decision-making process can be facilitated. At the conclusion of this review of literature, it is evident that there is a need to critically evaluate the STEM programs that are occurring within K-12 education. It is also important to identify the criteria school districts are using to determine the types of STEM programs to be implemented and how those programs are evaluated.

3.0   METHOD

3.1   INTRODUCTION

The rationale and importance of incorporating STEM into K-12 education is evidenced throughout the review of the literature. From the launch of Sputnik in 1957 to the publications of *A Nation at Risk* in 1983 and *Rising Above the Gathering Storm* in 2005, the significance of STEM within K-12 education has continually been presented as a key element to the economic viability and national security of the United States and an essential element in promoting a scientifically and mathematically literate citizenry. A proficiency in STEM has been embraced as a means to promote advancements in technology and innovation. These elements are fundamental to ensure national security. Furthermore, a focus on STEM is also seen as an essential component to promote competition within a global economy and bridge the gender, racial, and ethnic achievement gaps observed within the American educational system, thereby promoting social justice within the US.

This survey research attempted to identify the prevailing motivation behind school districts' pursuit of incorporating STEM into their educational practices, how school districts determine which efforts in STEM to invest in, where to place the selected efforts (elementary, middle, or high school levels) within the school system, and where to integrate STEM programs within the existing framework of the district (i.e. as an after school activity or embedded within

the curriculum). Additionally, the study sought to determine how school districts evaluate the success of STEM program implementation.

The field of education has used STEM as a means to measure and evaluate some wide-ranging issues. The focus on STEM has allowed the American educational system to be evaluated on an international scale as well as promote ethnic, racial, and gender equality within the classroom while satisfying gaps within the job market. STEM, therefore, has the potential to impact issues of equity, national security, and economic viability that may shape the identity of the nation as a whole. At a minimum, the generalized infusion of the skills and competencies associated with STEM and the promotion of student interest in STEM-related careers can have a significant social and economic impact in the United States.

Although the importance of STEM is easily elucidated, the implementation of STEM within K-12 education is much less conclusive. A study of the literature suggests that K-12 educational institutions are left to establish their own criteria to evaluate STEM programs in their respective school systems. As a result, this has manifested into very diverse STEM programs emerging in K-12 education. Districts have chosen to implement a variety of STEM programs ranging from robotics, coding, and inclusion of the arts (STEAM) to more packaged programs such as Project Lead the Way.

In addition to selecting the STEM efforts to be implemented within a given school district, there are a number of other factors to consider. Among those include, the purpose or focus of implementing STEM into the educational setting, the grade level(s) selected for implementation, when that implementation takes place within the confines of the school day, and how the efficacy of that implementation is considered during the early stages of implementation. This study examined the factors school districts considered when selecting and implementing a

STEM program and evaluating how well those factors aligned to the characteristics of comprehensive STEM programs found within the literature.

3.2   RESEARCH QUESTIONS

The research questions for this study aimed to understand the processes school districts use to select, implement, and evaluate STEM programs within K-12 education. The research questions for this study were:

1. What factors influence school districts to implement STEM programs within their respective school systems?

2. How do school districts decide which STEM program(s) to implement and where that implementation will occur within the existing educational framework (i.e. curriculum, school day, and grade level)?

3. How do school districts evaluate the initial implementation of STEM programs within their school systems?

3.3   CONCEPTUAL FRAMEWORK

Due to the phenomenology of STEM being socially constructed, the approach of this study was situated within the constructivist paradigm. As the researcher, I attempted to interpret the meaning behind school districts' selection, implementation, and evaluation of STEM programs within their respective school systems. This interpretation helped to develop an understanding of

this phenomenon by actively seeking the point of view of the participant(s) in the study (Mertens, 2010). The derived conceptual framework "help[s] to organize the entire analysis, pointing to relevant contextual conditions to be described as well as explanations to be examined" (Yin, 2014, p. 136)

It was anticipated that the selection, implementation, and evaluation of STEM programs is guided by the unique reality (culture, environment, mission, vision, leadership, etc.) present within a given school district. Therefore, the ontology of the STEM phenomenon will be based on the various cultural, economic, political, and situational factors unique to the school district. This is in contrast to a school district selecting and implementing a STEM initiative that is a prescribed solution created by an outside entity aimed to satisfy a generalized need. Although the ideal factors associated with implementing a STEM program within K-12 education can be discussed from a philosophical perspective, the economic and political barriers found within each individual school district may impact the implementation of a comprehensive STEM program. This study sought to identify the characteristics of STEM programs found within the participant school districts, how those programs align with the ideals cited within the research and literature regarding STEM, and determine the barriers that may restrict some districts from implementing comprehensive STEM programs.

Tables 4 and 5, below, provide the alignment of the survey questions used in this research to the following: research questions of this study, the survey instrument provided by the Friday Institute, the characteristics of STEM programs as defined by the literature, and the factors driving STEM education as defined by the literature:

Table 4. Alignment of research questions to survey instrument.

Research Questions
RQ1: What factors influence school districts to implement STEM programs within their respective school systems?
RQ2: How do school districts decide which STEM programs to implement and where that initiative will that implementation will occur within the existing educational framework (i.e. curriculum, school day, and grade level)?
RQ3: How do school districts evaluate the initial implementation of STEM programs within their school systems?

Survey Question	Research Question (s)	Modified from Friday Institute Survey	Generated from the literature
1. My District is currently involved in efforts to address the topic of STEM.	RQ2		X
2. The implementation of STEM was addressed within which of the following educational levels? (select all that apply)	RQ2		X
3. In what year did your District begin implementing efforts to address STEM?	RQ1, RQ2		X
4. The number of students within your District is approximately:	RQ1, RQ2		X
5. What is the approximate total budget for your District for the 2014-15 school year?	RQ1, RQ2		X
6. Approximately what percentage of that budget is spent on STEM? Please move the bar to represent your best estimate on the expenditures on STEM education in your school district or place the numerical value in the text box provided below.	RQ1, RQ2		X
7. Which of the following stakeholders were/are included in the development of the efforts to address STEM within your School District? (select all that apply)	RQ1, RQ2	X	
8. Please share a brief description of your District's most recent efforts to address STEM.	RQ1, RQ2, RQ3	X	X
9. Did you consider any alternative programs?	RQ2		X
10. What factors eliminated these alternative programs from consideration?	RQ1, RQ2, RQ3		X

11. What criteria were/are used to make the final decision on the efforts selected to address STEM within your School District? (select all that apply)	RQ1, RQ2, RQ3	X	X
12. Please select the top five characteristics of STEM programs you believe are essential elements of an effective STEM program.	RQ2, RQ3	X	X
13. Which of the following statements best describes the efforts to address STEM within your School District?	RQ2	X	X
14. Given your plan for incorporating STEM into your School District, where do you think your District falls on the continuum below with 0 representing no implementation of STEM and 100 being full implementation of STEM. Please move the bar below to represent your District's position on the continuum.	RQ3	X	
15. Please select the top three reasons for your District's interest in infusing STEM into the educational setting.	RQ1		X
16. Has your School District pursued relationships with outside organizations to supplement your efforts in infusing STEM into the educational setting?	RQ2, RQ3	X	X
17. Which of the following entities has your District established partnerships with as part of your efforts to address STEM (Select all that apply).	RQ2, RQ3	X	X
18. Does your District provide opportunities for students to engage with STEM professionals within the educational setting?	RQ2, RQ3	X	X
19. Please describe those opportunities below:	RQ2, RQ3	X	X
20. What indicators will be used to measure the implementation of STEM within your School District?	RQ3	X	X

21. What are the next steps your District plans to pursue in the area of STEM education?	RQ3	X	
22. Please share any additional comments related to your engagement with STEM within your School District that may not have been addressed in the questions above.	RQ1, RQ2, RQ3		X

Table 5. Alignment of the characteristics of STEM programs to the literature.

Characteristics of STEM Programs	
Characterists	Literature Source
Integration and equal representation of four STEM content areas	Bybee, 2010b; Dugger, 2010; Epstein & Miller, 2011
Promotion of innovation, creativity, and design	Bybee, 2010a; Harrison & Royal, 2011; K-12 STEM education overview, 2011; Viloria, 2014
Critical thinking, problem solving, application of knowledge, collaboration, and communication	DeJarnette, 2010; Saxton et al., 2014
Make sense of the natural world	Bybee, 2010a; K-12 STEM education overview, 2011
Promote interest in pursuing careers and degrees in STEM, content is aligned to state standards	Epstein & Miller, 2011; K-12 STEM education overview, 2011; Scott, 2012; Sneider, 2011
Real world assessments, internships, and job shadowing experiences	Berry, Reed, Ritz, & Lin, 2005; Breiner, Harkness, Johnson, & Koehler, 2012; DeJarnette, 2010; Harrison & Royal, 2011
Survey Questions Aligned to the Characteristics of STEM Programs	
1. My District is currently involved in efforts to address the topic of STEM.	
2. The implementation of STEM was addressed within which of the following educational levels? (Select all that apply)	
8. Please share a brief description of your District's most recent efforts to address STEM.	
9. Did you consider any alternative programs?	
10. What factors eliminated these alternative programs from consideration?	
11. What criteria were/are used to make the final decision on the efforts selected to address STEM within your School District? (Select all that apply)	
12. Please select the top five characteristics of STEM programs you believe are essential elements of an effective STEM program.	
15. Please select the top three reasons for your District's interest in infusing STEM into the educational setting.	
16. Has your School District pursued relationships with outside organizations to supplement your efforts in infusing STEM into the educational setting?	

17. Which of the following entities has your District established partnerships with as part of your efforts to address STEM (Select all that apply).
18. Does your District provide opportunities for students to engage with STEM professionals within the educational setting?
19. Please describe those opportunities below:

3.4   STATEMENT OF THE PROBLEM

School districts across the country have set out to implement a variety of STEM-related reform efforts geared to generate interest in pursuing careers and degrees in STEM, foster STEM literacy, address the gap in global competitiveness in innovation and performance on standardized measures of assessment, and promote women and minority students' interest in STEM-related fields (Bybee, 2010a; Mervis, 2009; Riccards, 2009). There is also an increase in demand for STEM-related occupations (See section 2.2.4). This combined with a decline in the number of United States' students who are underperforming and disinterested in science and mathematics and an underrepresentation of females and minorities within these fields has driven much of this movement (Riccards, 2009).   As a result, a growing pressure and sense of urgency has been assigned to school districts to prepare and produce a labor force capable and willing to fill the demand in this growing sector of the economy while creating a STEM-literate citizenry functioning within a society that demands the everyday use of said skills.

Educational policies such as the No Child Left Behind Act (2001), the development of the Common Core (2010), Career and College Readiness initiatives (2010), and Race to the Top programs (2009) have created a system of accountability focused on producing students capable

of filling economic voids on a national and global scale (R. Atkinson & Mayo, 2010; Bybee, 2010a; Riccards, 2009). However, in spite of this increased focus on STEM, these policies have produced limited results in both the performance of students on standardized assessments and the proportion of students attending college to obtain degrees in STEM fields (Carnevale et al., 2011; Scott, 2012).

After a review of the literature, it is evident, however, that school districts need a decision-making framework to consider when identifying and implementing STEM initiatives within their school district. In addition, school districts lack a clearly articulated purpose for infusing STEM within their respective school systems. School districts can choose to identify the pursuit of STEM as an 'end,' whereby a focus is placed on students' preparedness for career and college readiness within these fields of study, or a 'means,' by which an observable increase in test scores, funding, and/or enrollment in programs is the main objective. As a result, the research identifies many variations of STEM programs that are being implemented within K-12 school districts across the United States which all claim to satisfy the parameters of exposing and engaging students in STEM curricula. This study focused on identifying how school districts address what the literature has identified as the key aspects to consider when implementing a STEM programs within a K-12 school district. Those key aspects include: identifying the purpose or intent behind implementing a STEM initiative within their district, identifying the specific type of STEM programs to implement, determining where within the school day the programs will take place, identifying the age group or groups on which the program will focus and evaluating the success of the initial stages of STEM implementation.

3.5   PURPOSE OF THE STUDY

The purpose of this survey research was to examine and characterize the implementation of STEM programs within a select group of school districts having a collective focus on STEM education.   The literature has identified a variety of critical approaches that can be used to substantiate the need to implement STEM programs within school districts.   Among those suggested: increasing the number of women and minority students pursuing STEM related degrees and careers, provide students an opportunity to gain essential 21st century skills, expose all students to STEM as a means to fulfill the gap in the job market as it relates to STEM-related occupations, and close the achievement gap between US students and their international peers (Augustine, 2005; Bybee, 2010b; Carnevale et al., 2011; Epstein & Miller, 2011b; Gardner et al., 1983; Hossain & Robinson, 2011, 2012; Kuenzi, 2008).   In addition to these global rationales for focusing on STEM, it is also important to consider the local pressures generated by school boards and community members to fulfill a perceived or actual need for these initiatives within their school districts.   This study aimed to identify the rationale and criteria used by school districts to pursue the implementation of STEM programs within their unique educational settings, analyze the responses to establish emergent themes associated with said criteria, and align the responses to district demographic information.   The results from this study also sought to identify what information is used to drive the decision-making processes on selecting and implementing STEM programs and how those decisions are connected to a given district's demographics and unique set of educational circumstances.

After determining the purpose behind each school district's pursuit of STEM, this study also examined where school districts chose to place STEM within their educational framework and which grade level or levels would be impacted by the program(s) selected. A review of the

literature has identified three contextual placements of STEM initiatives within K-12 education. The three contexts that have emerged include the following: STEM as an extension to the school day, STEM as a modification to existing curriculum, instruction, and assessment, and STEM as a separate educational entity. This study looked to determine the prevailing context for STEM implementation being utilized by the school districts selected for this study.

Furthermore, I investigated the specific age groups school districts target for STEM program implementation. The review of literature has stated a case for the need to increase students' interest and pursuits of STEM at all educational levels. Arguments have been made to expose students early and often to STEM, to concentrate on the critical eighth grade cut-off for the interest of female and underrepresented groups of students related to STEM, and to increase the number of high school students considering careers and degrees in STEM-related fields. As a result, this study investigated the frequency of STEM program implementation with respect to grade level to ascertain where, and to what extent, STEM is occurring within K-12 education.

A thorough analysis of the data produced by this study allowed me to construct the criteria and purpose behind school districts' selection of STEM initiatives that exist within the school districts participating in this study. In addition, as previously stated, this study identified the factors that influence school districts to pursue a given STEM program, how school districts identify the program to be implemented within their respective school systems, what grade levels are impacted by the prescribed program, where STEM programs are placed within the existing framework of the school day, and how school districts evaluate the success of the early implementation of a STEM program. In addition, factors such as school district size and budget were examined as potential factors may limit school districts' implementation of STEM. The results of this purposeful sampling were used to generalize the phenomenon of STEM education

within public schools with respect to the criteria and factors that influence the selection, implementation, and evaluation of STEM programs within K-12 education.

3.6   RESEARCH METHODS AND DESIGN

3.6.1   Participants in the Study

The 136 public school districts identified in this study reside in Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Lawrence, Mercer, Washington, and Westmoreland counties in Pennsylvania (Bunt, Shaneyfelt, Rose, & Snyder, 2015). The Carnegie Museums, beginning in 1994, and by way of initial funding provided by the Allegheny Policy Council, selected these counties in order to promote the social and economic prosperity of this region whereby the focus on proficiency in the teaching and learning of mathematics and science would serve as the pillars to a sustainable future (Bunt, et. al., 2015). Multi-million dollar grants, provided by the Pennsylvania Department of Education in 2004 and again in 2007, extended the group's efforts to fund math and science education in resource poor regions of southwestern Pennsylvania. This collective group of school districts is known as the Math & Science Collaborative (Bunt, et. al., 2015). The Math & Science Collaborative will be referred to as the MSC throughout the remaining portions of this document.

The mission of the MSC is to engage all students in math and science to prepare them for an ever-changing world by exposing them to more innovative and evidence-based teaching strategies (Bunt et al., 2015). The vision for this collaborative identifies many of the skills outlined in the review of literature as critical competencies all students should master to be

successful in the evolving job market and literate members of a society who has a growing dependency on science, mathematics, and technology. Among those include the need for students to do the following: think critically, enhance problem-solving skills, collaborate, understand the role of math and science within the context of economics and innovation, and to communicate effectively (Bunt et al., 2015). These skills are also aligned to the essential components of an effective STEM program or initiative as cited in the literature.

3.6.2 Data Collection - Survey

In order to answer the research questions above, this survey research involved a purposeful sampling of the 136 public school districts that are members of the MSC. A purposeful sampling was used to gain a better understanding of the overall STEM phenomenon within this localized population by "select[ing] a sample from which the most can be learned" (Merriam, 2009, p. 77).

The superintendents of each school district were informed, via email, of this study and my desire to solicit information regarding the status of their school district's commitment to STEM education (See Appendix G). The email explained the use of the partnering districts within the Math & Science Collaborative as the vehicle to conduct this research. Each of these school districts has identified a point person to serve as a liaison between the individual school district and the Math & Science Collaborative (Bunt, et. al., 2015). This individual is able to communicate with all necessary stakeholders involved in the selection, implementation, and evaluation of efforts to address STEM within a given school district. These individuals received a survey that was created using the Qualtrics Survey System and sent to them via email (See Appendix A and Appendix B). Participants who had not completed the survey after a two-week period were sent a reminder email using the Qualtrics Survey System. A third and fourth

reminder were sent four and six weeks after that. The gap in communication allowed for the start of the 2015-16 school year. The content of this survey included questions that probed into the STEM programs that exist within each of their unique educational settings and ultimately address the research questions of this study. Some questions created for this survey were taken directly or indirectly from the instruments created by The William & Ida Friday Institute for Education Innovation at North Carolina State University.

Established in 2003, the Friday Institute is a full-time research facility whose focus is to evaluate local and federal educational innovations, including the Race to the Top-funded initiatives, across the state of North Carolina (Friday Institute, 2015). This organization has developed tools to evaluate a variety of variables including student, teacher, administrative and organizational interests and outcomes (Friday Institute, 2015). A copy of the survey used to frame some of the questions of this research can be found in Appendix E and Appendix F.

3.6.2.1 Origin of the Survey Instruments to be Used in This Study

The survey instrument used to collect data for this study was framed from the literature and the instruments recently used in a study conducted by The Golden LEAF Foundation. The North Carolina General Assembly established the Golden LEAF Foundation in 1999 as part of the settlement reached between the state of North Carolina and the cigarette manufacturers in that region (Golden Leaf Foundation, 2015a). As of April 30, 2013, Golden LEAF has acquired $1.1 billion from the cigarette manufacturers (Golden Leaf Foundation, 2015b). This organization's focus is to stimulate economic and educational growth and development within the region. Golden LEAF creates grant opportunities for 501(c)(3) nonprofits and governmental institutions using the settlement funds from the tobacco companies. Monies are made available for sustainable projects aimed especially at economically depressed regions or those that

were/are tobacco-dependent throughout the state. To date, this organization has provided over $563 million to various organizations and educational entities throughout the state of North Carolina by way of 1,280 grants (Golden Leaf Foundation, 2015c).

The Golden LEAF Foundation's research occurring between 2011-2013 focused on influencing students in grades four through nine to pursue careers necessitating STEM skills. These students resided in areas within North Carolina that had low socioeconomic status and/or were traditionally dependent upon the tobacco industry for economic viability (Faber et al., 2014). Fourteen grants ranging between $100,000 and $600,000 were provided by the Golden LEAF Foundation that ultimately impacted 43 school districts throughout North Carolina (Faber et al., 2014). The survey instruments to be to be used to address the research questions of this study have been used to study the implementation of STEM initiatives funded by the aforementioned grants provided by the Golden LEAF Foundation beginning in 2011.

In addition to the survey instruments discussed above, Survey questions were also developed using the literature cited previously within this document. These questions specifically address the research questions pertaining to the purpose each district has chosen to implement STEM, the type of STEM program that was selected for each district, where within the school day the program is placed, and the grade level STEM implementation occurred. Survey question alignment can be found in Table 4 located on pages 69 and 70 of this document.

3.6.2.2 Permission to Use Survey Instruments

The permission to use the survey instruments developed by the Friday Institute was provided by Mr. Mark Sorrells, Senior Vice President of the Golden LEAF Foundation and Dr. Sherry Booth, Senior Research Scholar at the Friday Institute. Each of these individuals was contacted via phone conversations held on March 2, 2015 and March 6, 2015 respectively.

Follow-up email correspondence has occurred pertaining to the provision of relevant research results made available by the Golden LEAF Foundation and the survey instruments that require online requests made to the Friday Institute. Copies of email correspondence can be found in Appendix C and Appendix D.

3.7   PILOT STUDY

The survey used for this study was piloted to a group of 39 doctoral students at the University of Pittsburgh. This group consisted of superintendents, assistant superintendents, principals, assistant principals, and individuals working at the University of Pittsburgh who were/are pursuing doctoral degrees. These individuals provided feedback on the survey instrument used for this study. In addition, pilot study participants reported the time necessary to complete the survey. Feedback was incorporated into the finalized version of the survey instrument sent to the participants of this study. Changes were made to clarify survey questions and refine the questions so as to generate data commensurate with a comprehensive study.

3.8   DATA COLLECTION AND ANALYSIS

Survey data were collected and aligned to the research questions of this study. The data gathered from the surveys received from the 136 public school districts of the MSC was used to generalize the phenomenon that is STEM education across all participant members of this group. The first phase of data analysis involved the creation of a geographic information system (GIS) to visually

represent the location of the original sample of school districts selected by this study (MSC participants). Layered upon this initial set of data were the school districts that chose to participate in this study. As a result, analysis of this geographic representation of participants with respect to the original sample was conducted.

In addition to the analysis conducted via GIS, a descriptive analysis of the data was conduced within and between responding school districts for each closed-ended variable of the survey in alignment to each of the research questions of this study. Next, responses to open-ended questions were collected and analyzed.

Open-ended questions were coded to derive the emergence of thematic responses amongst/between participants. Prevailing themes as well as linkages to the fundamental attributes of STEM efforts in education, as defined by the literature outlined in section 1.5 of this document, were identified. Presence or absence of these linkages helped to determine the alignment of district STEM efforts to those characteristics identified within the literature as critical to satisfying the demands for comprehensive STEM programs. This data was then used to define the phenomenon that is STEM within the participating K-12 school districts by identifying prevailing themes that emerge in relation to the three research questions of this study. The themes emerging from the open-ended responses also underwent a descriptive analysis with respect to the closed-ended responses within the survey to determine if what has been shared in an open-ended format is consistent with what has been shared in the closed-ended responses in the survey.

Finally, a crosstab and subsequent Chi Square analysis of the closed-ended variables within the survey was performed. The crosstab analysis was used to determine the presence or absence of a relationship occurring between any two variables within the survey. A Chi Square

analysis was used to determine, with statistical significance, if the observed descriptive statistics for each pair of variables are aligned to the expected values for that pair thereby indicating a significant relationship between the two variables. Specifically, a crosstab and Chi Square analysis was conducted between closed-ended responses within the survey and responses provided for district size and budget. This data was used to determine if the participants in this study were limited or provided an advantage in their efforts to address STEM education by district size or budget.

3.9   LIMITATIONS

One of the limitations of this study was the use of the constructivist paradigm to construct the 'reality' that is the phenomenon of implementing STEM initiatives within K-12 education. By its nature, the data of this study were used to describe a reality of STEM initiatives within the participating school districts through the interactions of the participants of this study and myself as the researcher (Mertens, 2010).

Another limitation of this study resided in the response rate of those school districts belonging to the Math & Science Collaborative. Due to the fluidity of educational professionals, particularly administrators, it was evident that, in some instances, the individual cited as a district representative for the MSC was no longer an employee of that district. In addition, the administration of the survey during the summer months and beginning of the school year may have further impacted the response rate due to administrators being on vacation, involvement in district-wide hiring processes, and investment in the planning for the upcoming school year.

3.10   REPORTING CONVENTIONS

The remaining sections of this study contain chapters on the findings, interpretations, and recommendations made from the data collected throughout this qualitative survey research.

The descriptive statistics and subsequent analysis of research questions one, two and three are presented in chapter four of this study. The coding and analysis of the open-ended survey items for research questions one, two, and three are presented in chapter five. Chapter six represents the data generated by cross tabulation and subsequent analysis using Chi Square of closed-ended survey questions with respect to district size and budget. Chapter seven includes the summary analysis of research questions one, two, and three. The final chapter, chapter eight, contains conclusions drawn from this study, a framework for STEM program selection, implementation, and evaluation, and recommendations for additional areas of inquiry.

4.0   FINDINGS AND ANALYSIS OF DESCRIPTIVE STATISTICS

4.1   GEOGRAPHIC DISTRIBUTION OF SCHOOL DISTRICTS SOLICITED BY THIS STUDY

The 136 public school districts selected to be part of the Math & Science Collaborative were solicited to be participants in this research study. The number of school districts solicited for this study (found in parenthesis) and their respective counties in western Pennsylvania are as follows: Allegheny (44*), Armstrong (7*), Beaver (15*), Butler (8*), Fayette (8*), Greene (5), Indiana (9*), Lawrence (9*), Mercer (13*), Washington (14*), and Westmoreland (17*) (Bunt et al., 2015). Twelve school districts solicited for this study are located in more than one county. An asterisk indicates some school districts may be counted more than once due to being located in more than one county. The geographic locations of these school districts are represented in Figure 1, below. The 136 school districts were loaded into the Google Maps application. A red pin represents each district solicited for this study.

Figure 1. Geographic distribution of the 136 school districts solicited in this study.
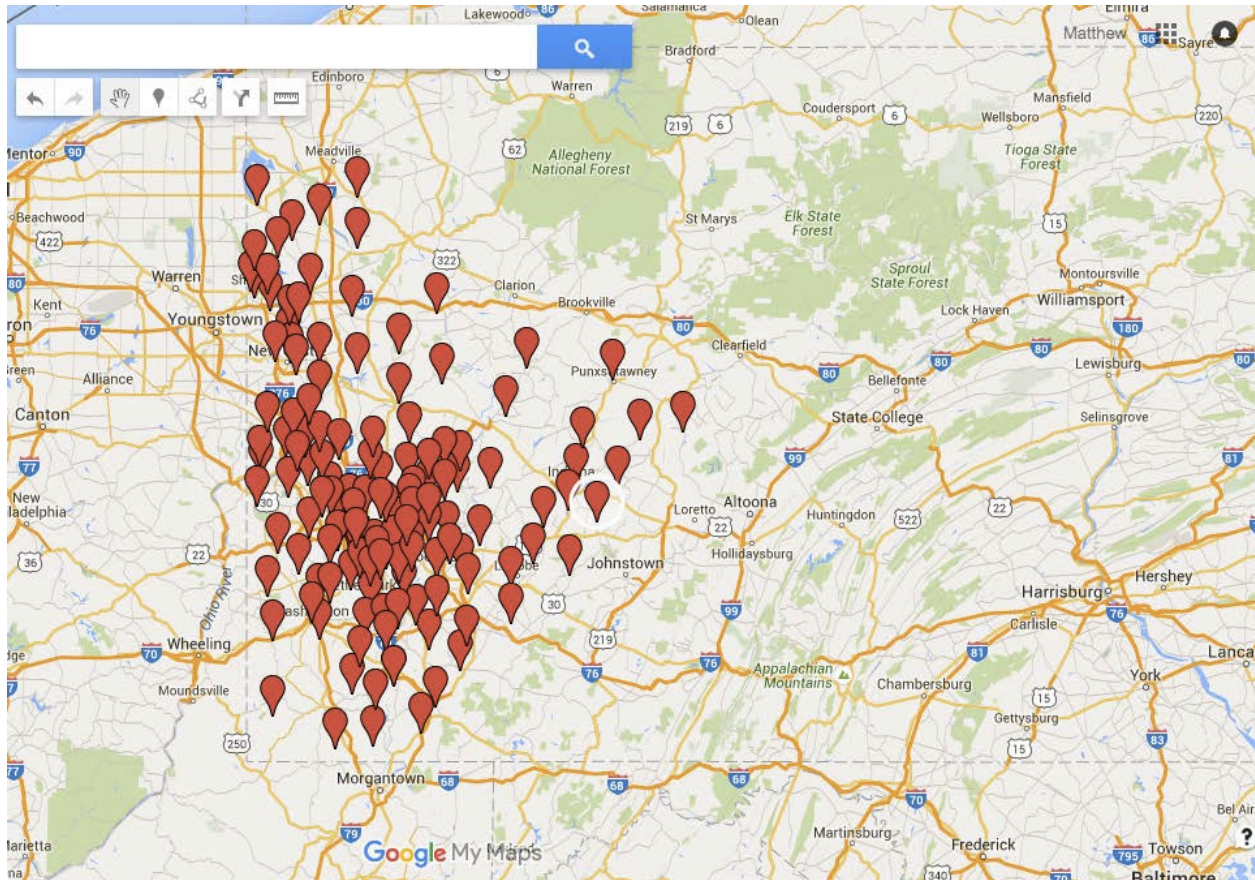
Figure 1 illustrates most school districts solicited for this study reside in and around the city of Pittsburgh, Pennsylvania with lesser concentrations of potential participants being located in northwestern, southwestern, and central Pennsylvania.

4.2   SCHOOL DISTRICTS PARTICIPATING IN THIS STUDY

Table 6. Total number of survey participants in relation to original survey population.

Total Population of Potential Respondents (N)	Emails Delivered Unsuccessfully (U)	Total Population of Viable Respondents (N-U)	Total Number of Respondents Participating in the Survey (n)	Total Number of Respondents Completing the Survey
136	39	97	30 (30.9%)	23 (23.7%)

Table 6 above indicates the breakdown of potential and actual participants in this study. Of the 136 school districts that were emailed the survey instrument for this study, 30 districts elected to participate. This population represented 22.1% of the sample. However, of the original 136 participants surveyed for this study, 39 of those recipients were unable to be reached by email. The emails sent to these 39 individuals resulted in a hard bounce, whereby one of several factors may have occurred: the district's firewall did not permit the email; the participant no longer worked in the district due to such factors as retirement or positional changes; and/or permission to solicit the participant had to be done independently from his or her email. Returned emails detailed the aforementioned information.

In order to address the 39 school districts that did not receive the original survey, each returned email was researched for potential changes in point person designation and updates to email addresses. Updates were made to the master list of potential respondents. In order to address restrictions due to district firewalls, the survey was distributed using a bypass through a University of Pittsburgh email account. This bypass allowed the sender, myself, to be from a University email address rather than an address generated by the Qualtrics Survey System. The bypass continued to allow the Qualtrics Survey System to conduct the mass mailing by way of

the University email account. This process was created so that the address of the sender would

potentially be permitted by the firewall of the participating school districts. Unfortunately, this

process did not result in successfully reaching the aforementioned 39 participants. None of these

potential recipients received the survey as indicated by bounced emails returned to the University

email address.

Due to the inability to access these 39 potential respondents in this study, the total

number of participants was reduced to 97; the total number of original participants selected for

this study (136) less the 39 districts that could not be reached via email. Therefore, it was

determined that the percentage of participation in this study was 30.9% (n=30). The geographic

distribution of those participating school districts can be observed in Figure 2, below. The blue

stars represent the 30 school districts participating in this study.

Figure 2. Geographic distribution of school districts participating in the study (stars) in relation to the population of solicited school districts (pins).
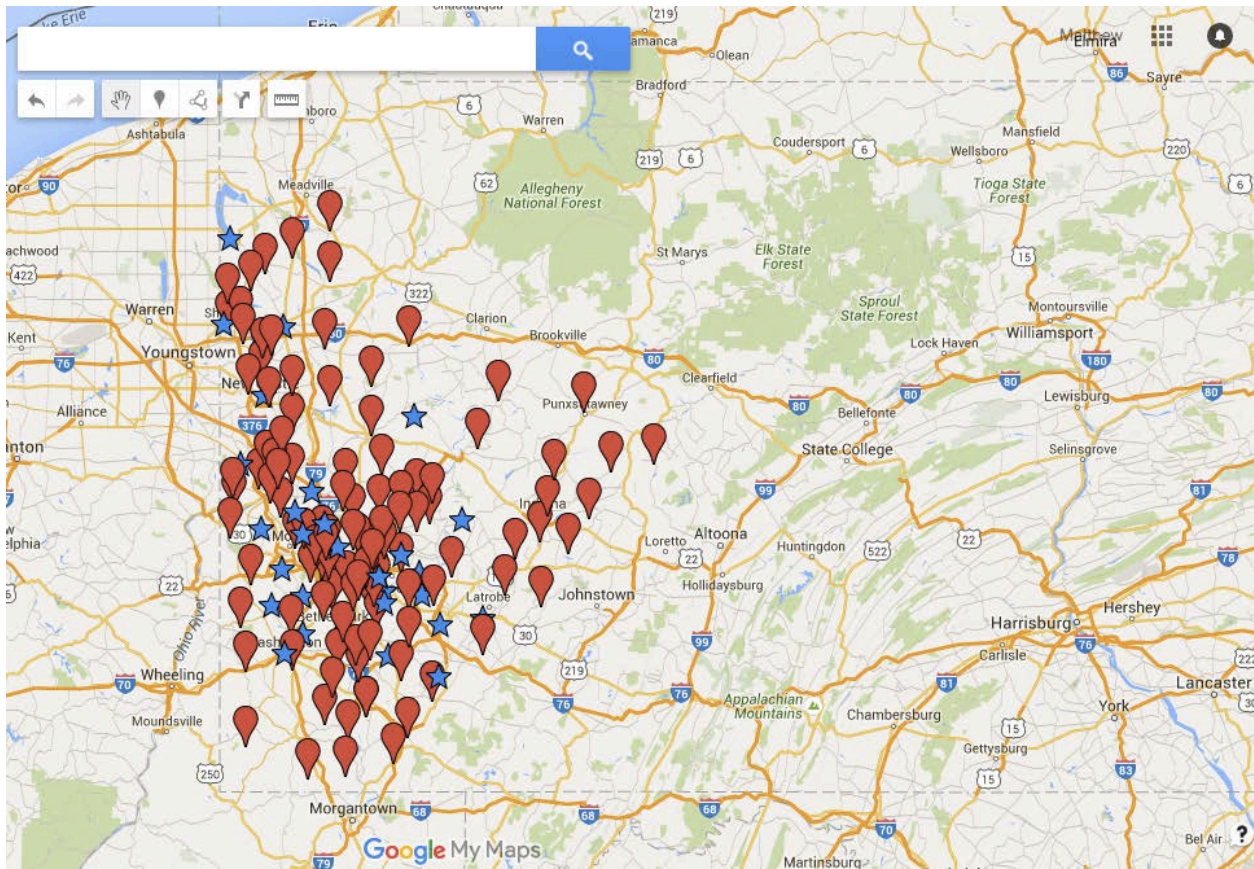
Based on the geographic distribution of participating school districts found in Figure 2, there appears to be an even distribution of participants similar to the original distribution of the 136 school districts solicited for this study. The population of participating school districts differed from that of the sample population with respect to the proportion of school districts representing the size categories established for this study. These differences are further defined in section 4.3 below. The following indicates the breakdown of school districts participating in this study, by county: Allegheny (13*), Armstrong (3*), Beaver (3*), Butler (3*), Fayette (1), Greene (0), Indiana (1*), Lawrence (2*), Mercer (3), Washington (2), and Westmoreland (4). Four school districts participating in the study reside in multiple counties. The asterisk above indicates those

counties. The greatest percentage of participating school districts in this study resides in Allegheny County (12/30 or 40%) and there were no participating school districts from Greene County (0/5). However, the 12 school districts within Allegheny County represent 28 percent of the total population of school districts in that county (12/43). The remaining ratios and percentages for participating school districts by county are as follows: Armstrong (3/7 or 43%), Beaver (3/15 or 20%), Butler (3/9 or 33%), Fayette (1/8 or 13%), Green (0/5 or 0%), Indiana (1/11 or 9%), Lawrence (2/9 or 22%), Mercer (3/14 or 21%), Washington (2/15 or 13%), and Westmoreland (4/19 or 21%). By proportion, Armstrong and Butler counties present a more comprehensive picture of the selection, implementation, and evaluation of STEM programs within school districts within their respective counties. The efforts to address STEM within the five school districts within Greene County are not represented in this research due to the absence of participants from this county.

Of the 30 districts that accessed the survey instrument for this study, only 23 fully completed the survey. The remaining seven school districts varied in the number of questions they completed with one district indicating that they were not currently involved in pursuits related to STEM. The later response restricted this participant from answering any other questions on the survey. The partially completed surveys of the other six respondents were included in the overall analysis of the data resulting in a variation in the number of participants answering each of the survey questions in this study. Each question independently provided information pertinent to the phenomenon of STEM being studied. As a result, participation on each question within the survey was seen as an independent event and important to the overall goal of this research.

4.3   FACTORS CONTRIBUTING TO STEM IMPLEMENTATION

The first research question addressed in this study asked, "What factors influence school leaders to implement STEM within their respective school districts?" The survey questions aligned to this research question provided the underlying factors aligned to the selection and implementation of STEM programs within school districts. One of the factors that may influence the selection and implementation of STEM programs within a given school district is the size of the student population. At the time of this study, the Pennsylvania Interscholastic Athletic Association's (PIAA) criteria for classifying a school was A, AA, AAA, and AAAA for the sport of football were used to establish the ranges below (Pennsylvania Interscholastic Athletic Association, 2015). These ranges allow for schools to be grouped and analyzed with schools of similar size and against schools of larger population ranges. The PIAA has since modified its system of classification to include 5A and 6A designations (Pennsylvania Interscholastic Athletic Association, 2015). The PIAA uses the total number of males enrolled in grades nine, 10, and 11. This information was extrapolated for grade 12. This information was used to determine an average graduating class size. This information was extended for each grade level (K-12) to determine an approximate population size for a district within each classification. Of the 136 school districts surveyed in this study, 33.8% of the districts were classified as A, 30.1% were AA, 19.9% were AAA, and 16.2% were AAAA.

4.3.1 Distribution of school districts participating in this study with respect to size and budget.

Table 7. The number of students within your District is approximately:

Population Range - Number of Students (PIAA Classification)	Number of School Districts	Percentage of Districts Represented in this Study
0-749 (A)	1	3.6%
750-1389 (AA)	5	17.9%
1390-2449 (AAA)	9	32.1%
More than 2450 (AAAA)	13	46.4%
Total:	28	

Table 7 above illustrates the size of student populations of the participating school district in this study. Of the 28 school districts responding to this survey item, only one school fell within the smallest classification (A), representing 3.6% of the survey population. This is only 10.7% of the expected respondents for this reporting category given the percentage of school districts within this classification who were among the 136 school districts solicited for this study. Five responding school districts (17.9%) fell within the AA classification. This represents 59.5% of the expected percentage of respondents for this category. Nine districts (33.3%) were AAA; a 13.4% increase in the proportion of school districts expected for this classification. Finally, 12 school districts (44.4%) were of the largest AAAA classification. This percentage is 30.2% greater than the proportion of respondents expected for this classification. As a result, the participants in this study more accurately represent the efforts of STEM selection,

implementation, and evaluation of larger school districts and do not proportionately represent the 136 members of the MSC.

In addition to the number of students within the school district potentially impacting the development and implementation of STEM programs, the size of a district's budget was also examined as a contributing factor. Budget ranges (Table 8) were constructed by separating the 2013-14 annual budgets of school districts in Pennsylvania (public, career and technical centers, and charter schools) into quartiles. The 2013-14 profiles were the most recently reported annual budgets of school districts in Pennsylvania. (Pennsylvania Department of Education, 2015).

Table 8. What is the approximate total budget for your District for the 2014-15 school year?

Budget Range (millions of dollars)	Number of School Districts	Percentage of Districts Represented in this Study
Less than $8.5	1	4.2%
Between $8.5 and $19.65	1	4.2%
Between $19.65 and $42.7	11	45.8%
Greater than $42.7	11	45.8%
Total:	24	

Of the 24 school districts that provided information regarding their annual budget, 45.8% (11 school districts) have annual budgets in the upper quartile, 45.8% (11 school districts) have annual budgets between $19.65 and $42.7 million dollars, and one school district (4.2% of responding school districts) has an annual budget within each of the lower two quartiles. This indicates that the majority of the school districts participating in this study represent STEM program selection, implementation, and evaluation efforts in districts having budgets in the top half of school districts within the state of Pennsylvania. This information may impact the results of this study as it relates to school districts' focus on students of low socioeconomic standing.

4.3.2   Year of STEM implementation for participating school districts.

Another factor that was examined with respect to influencing the implementation of STEM within school districts from 2001 to 2014 was that of federal policy and landmark publications. In 2001, the Federal government launched the No Child Left Behind Act. In addition, the National Science Foundation formally adopted the conversion of the acronym referencing Science, Technology, Engineering, and Mathematics from SMET to STEM (Breiner, 2012). In 2005, *Rising Above the Gathering Storm*, a publication created by The National Academies Committee on Prospering in the Global Economy of the 21st Century and likened to *A National at Risk,* published in 1983, created a bleak picture of the competitiveness of the United States in a global economy with respect to STEM-related fields (Augustine, 2005). In 2007, Congress passed the America COMPETES Act. In 2011, President Obama launched the Race To The Top program. The America COMPETES Act and the Race To The Top program aimed to address the lack of students entering STEM-related careers or achieving STEM-related degrees (Kuenzi 2008, Stine and Matthews 2009, Johnson 2011).

Responses provided by the participants in this study illustrated an increase in number of STEM programs that have been implemented in their respective school districts. This observed increase runs parallel to the increased focus placed on such programs by the federal government. Between 2001 and 2007, only three school districts in this study had begun to implement STEM programs. Between 2008 and 2010, six additional school districts pursued efforts to address STEM. The prevalence of STEM increased significantly since 2011. Another 17 school districts began implementing STEM. Although there is no direct evidence gathered in this study to establish that the policies created by the federal government are having or have had a direct causative effect on the increase in STEM programs within the participating school districts in

this study, the increase in STEM programs implementation in these districts in correspondence to the timeline of federal policy implementation suggests a relationship exists.

4.3.3 Factors influencing the implementation of STEM amongst participating school districts

The factors that influence the implementation of STEM within K-12 education, beyond that of federal policy and landmark publications, are also investigated in this study (Beering, 2010; *Increasing the number of STEM graduates : Insights from the U.S. STEM education & modeling project*, 2010). The potential responses within this survey item are broken down into three categories: locally generated political factors, addressing the STEM pipeline, and global competitiveness. The latter two categories are supported by the literature as fundamental reasons to pursue STEM programs within K-12 education while the former aimed to capture extraneous factors impacting education at the local levels. Respondents were asked to select their top three reasons for having an interest in infusing STEM into their school districts. These responses, therefore, indicate the respondent's prioritization for pursuing STEM as it relates to the options below. It is worth noting that no school districts selected "Other" as a response, thereby suggesting school districts' limited focus relating to the impact STEM program implementation can have within their educational systems.

The survey responses associated with the political and environmental factors that may have resulted in a school district's pursuit of STEM programs are examined in Table 9, below.

Table 9. Potential political facors influencing the development and implementation of STEM programs within a given school district.

Area of Potential Influence in the Implementation of STEM Programs	Number of School Districts (n=22)
1. Satisfy the needs/demands of the community within the District.	7
2. Satisfy the needs/demands of the School Board.	0
9. To compete with the STEM initiatives implemented by other School Districts.	7

Of the 22 school districts that addressed these questions, none of these districts indicated that the school board was singularly influencing the pursuit of STEM. However, it was evident that the local environment, as represented by the community and other school districts, was a factor in determining if a school district was interested in investing in STEM programs for their students. The local community (7/22 or 31.8%) and other school districts' implementation of STEM (7/22 or 31.8%) were the third (tie) and fourth most common reasons for infusing STEM into their respective districts.

Table 10, below, illustrates the responses selected by school districts that have a focus on increasing underrepresented populations pursuing careers and degrees in STEM and having an overall impact on the number of students entering the STEM pipeline.

Table 10. Survey responses aligned to school district's pursuit of STEM programs to satisfy underrepresented populations of students pursuing STEM and an overall increase in the STEM pipeline.

Area of Potential Influence in the Implementation of STEM Programs	Number of School Districts (n=22)
3. To increase the number of students taking advanced STEM-related courses within the District.	14
6. To increase the number of female students pursuing careers and/or degrees in STEM-related fields.	5
7. To increase the number of African American and/or Latino students pursuing careers and/or degrees in STEM-related fields.	1
8. To increase the number of low socioeconomic students pursuing careers and/or degrees in SEM-related fields.	7

As stated earlier in the review of literature, the percentage of college-bound students pursuing degrees in STEM-related fields is significantly fewer than that of our international competitors such as China and India (Atkinson & Mayo, 2010; Dodson, 2013; Riccards, 2009).   The percentage is even less as it relates to females and minority students pursuing such degree and career pathways (National Science Foundation, 2015) . A large percentage of participants (14/22 or 63.6%) indicate the reason for pursuing STEM programs is to increase the number of students taking STEM-related coursework. However, only one of 22 (4.5%) and five of 22 (22.7%) respondents are specifically addressing STEM in order to increase the number of African American and Latino students and female students pursuing STEM, respectively.   These responses suggest that the majority of school districts participating in this study are not explicitly focused on increasing the numbers of underrepresented populations of students pursuing careers and degrees in STEM but do indicate a holistic approach to increasing all students interest and pursuits of careers and degrees in STEM. However, seven of the 22 school districts, or 31.8%, chose a focus on increasing the number of students classified as low socioeconomic status (SES). This number of respondents tied for the third highest number of responses for this question of the

study and may indicate an indirect measure of the demographics of the responding districts in this study. Furthermore, students of low SES may include some of the underrepresented populations specifically addressed in the other responses.

Response option four singularly addressed the reported achievement gap with international peers as measured on assessments such as PISA, NAEP, and TIMSS (Carnevale et al., 2011; Gonzalez & Kuenzi, 2012; Hossain & Robinson, 2011; Kuenzi, 2008; Riccards, 2009; Steele, Brew, & Beatty, 2012). Only five of 22 (22.7%) respondents selected this option as a primary reason for pursuing STEM in their school districts (See Table 11, below).

Table 11. **Schools using STEM to address the achievement gap between U.S. and International students.**

Area of Potential Influence in the Implementation of STEM Programs	Number of School Districts (n=22)
4. To bridge the achievement gap identified between U.S. and International students.	5

Finally, response option 5 addressed both the STEM pipeline and closing the achievement gaps and other factors impacting global competitiveness with our international peers (Table 12).

Table 12. **School districts using STEM programs to increase the number of students pursuing careers and degrees in STEM-related fields.**

Area of Potential Influence in the Implementation of STEM Programs	Number of School Districts (n=22)
5. To increase the number of students pursuing careers and/or degrees in STEM-related fields.	19

This survey response option had the greatest number of school districts selecting this as the reason to pursue STEM. School districts using this as the rationale to pursue STEM within their

schools have the potential to greatly impact the current concerns for deficits in the labor market within STEM fields as well as matters of national security due to lacking innovation and global economic competitiveness. More students pursuing careers and degrees in STEM supports the pipeline of potential professionals entering these fields (Atkinson & Mayo, 2010; Gallant, 2010; Hossain & Robinson, 2012; Johnson, 2011). A byproduct of having a larger STEM workforce is the ability of US laborers to compete with their international counterparts in STEM-related occupations. In addition, more students pursuing degrees and careers in STEM results in more technological innovation, global competitiveness, and economic prosperity that collectively result in an increase in national security (Beering, 2010; Bybee, 2010a; Johnson, 2011. The data suggest the participating school districts understand and are responding to the call for more degrees and careers in STEM.

A secondary focus of the participants in this study is the promotion of underrepresented populations of students pursuing careers and degrees in STEM. These results may be representative of community demographics and other community-based pressures. These responses address females, African American, Latino, and low SES students that comprise underrepresented populations within the demographic breakdown of those individuals currently possessing or pursuing careers and/or degrees in STEM (Brophy et al., 2008; Hitz & Robinson, 2007). These responses align to the literature and addresses more complex social issues that may be present within a school district. Given the majority of school districts (22/24 or 91.7%;) responding to this survey had budgets within the top 50th percentile in the state, it may not be surprising that serving underrepresented populations is a secondary focus amongst the school districts in this study. This suggests that school district with resources do not focus on matters related to social equity or bridging the achievement gap that exists within underrepresented

populations of students.   As a result, underrepresented students are not afforded the same opportunities to become engaged in STEM-related opportunities, thereby falling further behind their peers from more affluent resource-rich school districts.

4.4   STEM IMPLEMENTATION WITHIN K-12 EDUCATION

The following section describes and analyzes the descriptive data for research question number two of this study. This question asked, "How do school leaders decide which STEM efforts to implement within their school districts and where that initiative will be integrated into the existing educational framework (i.e. curriculum, school day, and grade level)." Of the 30 school districts that participated in the survey, only one of those districts stated that they were not currently involved in an initiative to address STEM. This data suggests that the pursuit of some degree of STEM within K-12 education is somewhat ubiquitous. However, the comprehensive set of data within this study illustrates the diversity in which school districts address the selection and implementation of STEM.

4.4.1   Distribution of STEM implementation by grade level

Table 13, below, identifies the grade levels the 27 participating school districts chose as grades where STEM is being implemented.

Table 13. The implementation of STEM was addressed within which of the following educational levels? (Select all that apply.)

Grade Level	Number of Responses	Percentage of School Districts Implementing STEM at Selected Grade Level (n=29)
Kindergarten	16	57.1%
1st	15	53.6%
2nd	15	53.6%
3rd	16	57.1%
4th	18	64.3%
5th	21	75%
6th	22	78.6%
7th	26	92.9%
8th	26	92.9%
9th	23	82.1%
10th	22	78.6%
11th	24	85.7%
12th	23	82.1%

Although each grade level is represented in this study as an area of STEM implementation, it is apparent that the seventh and eighth grade levels are a targeted student population amongst the respondents. 92.9% of the respondents selected both seventh and eighth grade for STEM implementation. Furthermore, the data illustrates a greater degree of STEM implementation at the secondary level (grades seven to 12) in comparison to the elementary level (Kindergarten through sixth grade). The data point toward a focus on addressing STEM education at the middle school level (grades seven and eight) in order to increase the interest of students in

STEM-related coursework as they enter high school. The lack of a balanced approach to STEM implementation, with an equal focus on STEM at all grade levels, suggests that districts are fixed on the means approach to STEM. By increasing interest in STEM-related coursework, more students will take courses aligned to STEM at the high school level. However, as the data indicate, the focus on STEM implementation recedes in grades nine through 12. The data imply that districts rely on previously established coursework to fulfill their vision of STEM rather than continuing the efforts to formally infuse the characteristics of comprehensive STEM programs throughout all educational levels.

4.4.2 Stakeholder groups participating in the selection/development/implementation of STEM programs

An important element of the process used to select the STEM program to be implemented within the K-12 educational system involves the stakeholders involved in that process. 23 school districts participating in this study identified all of the stakeholders that were involved in the development of the efforts to address STEM in their respective school districts.

The data for this survey item naturally disaggregated into three tiers. The tier of stakeholder groups included in the development of efforts to address STEM in the surveyed school districts include the teachers, building level administration, and central office administration. All participants in this study (23 of 23) have teachers and building level administration involved in the process to address STEM in their school districts. In addition, central office administration is involved in 22 of 23 school districts' (95.7%) efforts to address STEM. This group of stakeholders represents those individuals who are directly involved in the everyday operations within the school district.

118

A second tier of stakeholders includes a slightly broader outreach into the community. In this tier of stakeholders the students, parents, and school board members are represented. The third and final tier of stakeholders includes the broadest outreach into the community that involved the local businesses, community colleges, and universities. It is apparent that school districts rely upon stakeholder groups to whom they have immediate access (i.e. teachers, building administrators, and central office administration) with secondary and tertiary stakeholder groups branching out from there.

4.4.3 Characteristics of STEM programs used as criteria for selection and implementation

The criteria school districts use to select and implement STEM initiatives and the priority they place on those criteria can be observed in Table 14, below. 22 respondents identified the criteria they considered when choosing the STEM program to be implemented within their school district.

Table 14. What criteria were/are used to make the final decision on the efforts selected to address STEM within your School District? (Select all that apply.)

Criteria Considered to Select STEM Program	Number of School Districts Prioritizing Said Criteria	Percentage of School Districts Selecting Said Criteria (n=22)
Aligned to existing curriculum	19	86.4%
Was appropriate for the grade levels(s) being considered	19	86.4%
Cost was aligned to budgetary constraints	16	72.7%
Aligned to the District's mission/vision	19	86.4%
Aligned to the District's strategic plan	17	77.3%
Addressed the needs of underrepresented groups of students (i.e. females and minorities in STEM and students of low socioeconomic status	15	68.2%
Least disruptive to current building operations	8	36.4%
Aligned to state standards	20	90.9%
Promoted a connection to career and college readiness	21	95.6%
Improve standardized test scores	8	36.4%
Provided a means to solicit funding	3	13.6%
Increase enrollment in STEM-related coursework	16	72.7%
Other	1	4.5%

The most common response provided by participants in this study that influenced the selection of STEM programs to be implemented in a given school district is the connection made to career and college readiness (21 responses or 95.6%). This criterion aligns with the need to influence the number of students pursuing careers and degrees in STEM as aligned to federal policy, national security concerns and global economic competitiveness as cited in the literature (Augustine, 2005; Gardner et al., 1983)). The impact of standardized testing is evident in these results, as well. 90.9% of respondents (20 of 22) state that an alignment to state standards was driving the selection process.

It is also apparent that the criteria having a great impact on the selection process involves how a given STEM program fits into the present framework of the school district. 86.4% of respondents indicate that the selected STEM program needs to be aligned to existing expectations for each grade level, current curriculum, and the District's mission/vision statement. One element of noticeable contrast, however, is the number of participants selecting a desire to increase the number of students taking STEM-related coursework (16 of 22 respondents or 72.7%). The literature suggests that in order to increase the number of student pursuing careers and degrees in STEM-related fields those students must be exposed to engaging STEM coursework in their middle and high school experiences (Hossain & Robinson, 2012). However, the data illustrate that not all of the respondents who selected the increase in career and college readiness (19) and those choosing to increase student participation in STEM coursework (16) were in alignment. This suggests that some school districts do not see the connection between these two responses.

4.4.4   Description of STEM program implementation in relation to the current educational framework

An equally important aspect of STEM-program selection is determining where and how that program will be implemented in relation the current educational framework. Of the 22 respondents for this question, 90.9% (20 of 22 school districts) implement STEM as a an adaptation or modification to the existing curriculum while only two of the 22 school districts (9.1%) have selected an outside program to address their need for STEM. None of the school districts surveyed in this study have approached STEM as a program occurring outside of the school day, as an enrichment program to an identified sub-population of students (i.e. gifted

students or students of low socioeconomic status), or as a separate educational experience such as a magnet school. This data suggest that school districts tend to work within the established educational framework rather than implement major programmatic change often associated with the other four options identified by the literature as viable options for STEM implementation.

4.5   EVALUATING STEM IMPLEMENTATION

The following section presents and analyzes the descriptive data aligned to the evaluation of STEM program implementation. Research question three stated, "How do school leaders evaluate the initial implementation of STEM within their school districts?" This research question attempted to evaluate the alignment of STEM programs to the characteristics identified by the literature as critical components and attributes. In addition, this question solicited feedback from school districts on how they evaluated the implementation of their programs and what measures were used to determine the efficacy of their efforts.

4.5.1   District self-evaluation of the initial implementation of STEM within their respective districts

In an effort to have districts reflect on the implementation of STEM within their school districts, the survey asked participants to indicate, on a sliding scale, where they believed their implementation process was with 0 being no implementation and 100 being full implementation. Of the 22 school districts responding to this question, it is evident that the level of STEM implementation varies greatly amongst them. With the minimum level of implementation being

self-reported at 10.0%, the highest at 85.0%, and a standard deviation of 21.0, the distribution of responses suggests that this population of school districts is at varying stages of the STEM implementation process. The data, however, do not measure the quality of implementation or the impact that implementation is having on students. The data suggest that many school districts are attempting to implement STEM within their schools, but the degree to which that implementation is occurring varies.

4.5.2   Evaluation of STEM-program characteristics

The literature has identified a number of characteristics that are considered to be essential elements of STEM programs in K-12 education (Bybee, 2010a, 2010b; Epstein & Miller, 2011; DeJarnette, 2010). One aim of this study was to determine if a consensus existed amongst respondents with respect to prioritizing a subset of these characteristics in the development and implementation of STEM programs within their school districts. Participants in this study were asked to examine a list of characteristics identified by the literature as the key components to STEM programs in K-12 education. The respondents were asked to choose the top five characteristics from that list that aligned to an "effective" STEM program. Table 15, below, illustrates the responses given by the 21 respondents to this survey question.

Table 15. Please select the top five characteristics of STEM programs you believe are essential elements of an effective STEM programs.

Characteristics of STEM programs	Number of Responses	Percentage of Districts Selecting Characteristic (n=21)
Integration between the four content areas within STEM	8	38.1%
Promote innovation	12	57.1%
Promote creativity	7	33.3%
Integrate elements of design	3	14.3%
Promote critical thinking	14	66.7%
Promote problem solving	16	76.2%
Promote application of content knowledge	9	42.9%
Foster collaboration and communication between students	10	47.6%
Real world and relevant content, instruction, and assessments	12	57.1%
Alignment to state standards	3	14.3%
Provides connections to careers	4	19.0%
Encourages students to pursue degrees in STEM-related fields	6	28.6%
Cutting edge curriculum	0	0.0%
Other	1	4.8%

The highest level of consensus amongst districts, with respect to the essential elements of STEM programs, is the promotion of problem solving (76.2%). This response is followed closely by the promotion of critical thinking (66.7%) and a tie between the promotion of innovation and real world and relevant content, instruction, and assessments (57.1%). The responses indicated in Table 15, above, illustrates the diversity in ideology and philosophies between and amongst school districts as it pertains to what they believe to be essential elements of STEM programs. This variety in responses may also contribute to the diversity of STEM programs in K-12 education as the development, selection, and implementation of those programs are based in the foundational beliefs of individual school districts and, perhaps, not those characteristics identified by the literature as the essential elements of STEM programs.

It is also important to note that only 19.0% and 28.6% of participants in this study select responses aligned to the promotion of careers and degrees in STEM respectively. The small number of school districts prioritizing a focus on students' career and degree choice, specifically as they relate to STEM, suggests a greater degree of focus on pedagogical practices within the classroom rather than relating those practices to students' future career and degree pathways.

Another characteristic identified by the literature as an essential element used to connect and engage students with the field of STEM is the link to outside organizations as a resource to students and staff. Of the 21 school districts responding to this survey item, all answer positively to having connections to outside organizations. Of the 21 responding school districts, only 42.9% have established partnerships with other school districts, community members, local businesses, and post-secondary institutions as part of their STEM program. However, the remaining 12 school districts that participated in this survey item reported establishing a partnership with at least one of the aforementioned outside organizations as part of their STEM program. All 21 respondents to this survey item identify making relationships to post-secondary institutions as it relates to their respective STEM programs. It is also evident that many school districts responding to this survey item (81.0%) make connections to local businesses and other school districts.

5.0 FINDINGS AND ANALYSIS OF OPEN-ENDED SURVEY ITEMS

The previous chapter addressed the data associated with the closed-ended survey questions of this study. This chapter will address the open-ended responses to survey questions that provided respondents an opportunity to share a more detailed description of the STEM program they have implemented or are currently implementing within their respective school districts. Those responses will be reported thematically throughout this chapter.

5.1 DESCRIPTION OF STEM PROGRAMS

One focus of this study was to identify the types of STEM programs that are currently being implemented within the solicited sample of school districts. 20 school districts provided a deeper look into the STEM programs they have implemented. The description of programs, even within this small sample, illustrates great diversity in how school districts have addressed the topic of STEM education. However, within that diversity emerges some themes this sample of school districts are pursuing in order to address the topic of STEM.

One of the emerging themes was that of the creation of Maker Spaces, Situated Multi-media Art Learning Labs (SMALL-labs), and Fabrication Labs (Fab-labs) that were closely associated with the repurposing of district library and multi-media centers. Respondents did not elucidate upon how these areas were being utilized. However, it is evident that middle school

students were targeted as the age group to be exposed to the technology and learning opportunities that exist within these learning laboratories.

Another common theme was the intentional inclusion of a STEM course at both the elementary and middle school levels. Responding school districts identify the infusion of a STEM "special" course at the elementary level whereby all students would rotate through a STEM course. A similar experience is also being created by some middle schools within this sample of school districts. In this case, students are being exposed to advanced technologies such as 3-D printers and other forms of technology.

The theme of technology integration was also referenced by school districts as their main method to address STEM. These districts often referred to the establishment of 1:1 environments, the use of Promethean Boards, Chrome Books, Mac Books, and iPads, and the exposure to robotics, coding, and gaming to a lesser extent. It is interesting to note the wide range of technology students are being exposed to. In addition, the integration of these technologies across the four silos of STEM, how these technologies supplement or enhance the curriculum, and/or the products designed or created using these tools was not expressed by the respondents of this study.

Another commonly cited method being used by the sampled school districts to address STEM was modifications to the curriculum. These respondents shared that they were looking for opportunities to modify existing areas of the curriculum to supplement, enhance, or infuse STEM as part of the educational process and/or introduce new STEM courses. Respondents who were searching for in-house solutions to address the needed changes to the curriculum did not provide specifics as to how the curriculum would be addressed to infuse STEM. However, some districts cited programs facilitated by NSF, Lowes, and the Science, Technology, Research,

Engineering, Arts, and Mathematics (STREAM) grants, and outside organizations such as the Carnegie Science Center, Project Lead the Way, and the Gateway curriculum as specific solutions to addressing the needed changes to the curriculum.

The final methods cited to address STEM was the use of connections to local businesses in order to provide students and staff unique educational experiences embedded in real-world scenarios and the use of an in-district 'magnet' program that used a lottery system to select students who would attend a building that was specifically focused on STEM.

The responses provided by the participants in this study helped to illustrate the diversity in the manner by which school districts are addressing the integration of STEM with respect to resources, curriculum, instruction, and the grade levels focused upon in their efforts. The respondents were also asked if they had considered alternative STEM programs outside those they ultimately selected to implement within their school districts. Seven participants in the study shared that they had considered alternative programs but there was one resounding factor that eliminated those programs from consideration, cost. Other factors that were cited included the lack of research-based validity and concerns for implementation due to needs surrounding training, resources, and sustainability.

5.2   CONNECTION TO STEM PROFESSIONALS

The opportunities for students to connect and interact with professionals embedded within STEM-related fields is supported by the literature to be a means to engage students and promote their pursuit of degrees and careers in STEM (DeJarnette, 2010; Kochler, 2012). Therefore, it is important to include the presence or absence of these connections as a necessary element of

evaluating the implementation of efforts to address STEM. Of the 21 respondents to this survey item, 15 (71.4%) acknowledged they provide such opportunities. Participants who acknowledged providing these opportunities to students were asked to expand upon the nature of those interactions.

The nature of the opportunities to connect with STEM professional varied similarly to that found in the STEM programs being implemented within school districts. The most common experiences provided by school districts came in the form of speakers coming on-site to visit specific classrooms and/or offer lecture series to expose students to the nature of their careers. This was followed closely by two uniquely different interactions with industry.

The first interaction with industry involves job shadowing, internships, and field trips to the sites of STEM professionals. One school district defined this interaction to be a required aspect of a graduation requirement where students had to shadow and interview an individual within a prospective career. Another respondent also noted facilitating a field trip for female students to Cisco. Aside from the graduation project, however, the nature of the interactions being held between the students and professionals during job shadowing, internships, and field trips was not clearly defined.

The second series of interactions were all explained to be partnerships with a local business or businesses to complete a real world problem as part of a project or problem-based learning opportunity. These generally came in the form of working with STEM professionals on a common project (i.e. a Rube Goldberg machine), partnerships with organizations such as the Carnegie Mellon University, taking classes on site with select professionals in industry, and working on real world and relevant problems designed by local industries.

5.3   INDICATORS USED TO MEASURE STEM IMPLEMENTATION

The indicators used to measure the efficacy of STEM programs implemented in K-12 education can speak volumes. The participants in this study were asked to share what measures they will be considering when determining the effectiveness of STEM implementation within their school district.   Responses to this survey item can be compared to the measures indicated by the literature linked to the characteristics of comprehensive STEM programs. The literature suggests the following areas should be measured to determine the efficacy of a STEM program: increase women and minority students pursuing STEM degrees and careers, gain 21st century skills, address the STEM pipeline (more students taking courses in STEM and pursuing careers and degrees in STEM), and to close the achievement gap between US and international student (Augustine, 2005; bybee, 2010b; Carnevale et al., 2011; Epstein & Miller, 2011b; Gardner et al., 1983; Hossain & Robinson, 2011, 2012a; Kuenzi, 2008). It is also important to identify if school districts see STEM as an 'ends' strategy to focus on preparing students for a career or degree within these fields, or a 'means' to see an increase in performance-based measures such as test scores. Responses provided to the survey item, "What indicators will be used to measure the implementation of STEM within your School District?" provided insight into the true value districts see in implementing a STEM initiative within their respective school districts.

Of the 17 respondents to this survey item, nine (52.9%) indicated that the measures they will be using to determine STEM implementation include performance on local assessments, state assessments (specifically the Pennsylvania System of School Assessment and Keystone Exam), and AP exam scores. These responses suggest that the incorporation of STEM is a mechanism or 'means' to increase the performance of their school district as measured by standardized tests and to a lesser degree student performance on local assessments. When these

respondents were not provided closed-ended responses that were aligned to the literature they reverted back to focusing on student achievement as measured by the aforementioned assessments rather than align themselves with measures that were 'ends' focused such as the pursuit of degrees and careers in STEM-related fields and the acquisition of 21st century skills. Although some of these districts also included measuring student enrollment in STEM-related coursework, the frequency in which assessments were referenced suggests that even those numbers would be used as measures of a school performance profile rather than a means to promote students' interest and pursuit of STEM-related degrees and careers.

Other responses to this survey item continued the theme of being focused in the present rather than on the students' future. Two school districts referenced responses on student, teacher, and parent surveys and measures associated with students' interaction with technology in the form of 1:1 initiatives. Although soliciting feedback from your stakeholders is an essential piece of the feedback loop for continued growth and the use of technology in a ubiquitous fashion could prove to be invaluable resources for students, each of these responses do not directly align with the literature-based purposes STEM programs should set out to achieve as stated earlier in this section. In addition, one district referenced data on absenteeism and student engagement. Again, this response suggest the measurement of STEM program implementation was to be that of a 'means' rather than an 'ends'-based initiative.

Although the school districts referenced above provided measures of STEM implementation that were not aligned to the literature-based purposes of STEM programs in K-12 education, there were a few districts that referenced measures that were in alignment with those tenants. Five school districts provided responses to this survey item that referenced a measure of implementation associated with an increase in enrollment and/or pursuit of

coursework within the high school and college settings. One district expounded on their response by including the measure of students' pursuit of STEM careers.

Three districts went a step further in defining the skills they wanted their students to acquire. These responses aligned directly with the 21st century skills measured throughout the survey and cited throughout the review of literature in Chapter 2 of this study. One district, however, provided the most comprehensive citation of the skills to be measured as part of the STEM implementation process. Respondent 12 of this study gave the following response:

> *Develops the 21st Century's Learning and Innovation Skills: Critical thinking and problem solving, creativity and innovation, communication and collaboration while engaging in relevant, authentic tasks.*

The response cited above addresses the skills and competencies identified by the literature as essential elements of a STEM program, specifically as they related to 21st century skills and competencies.

5.4   DISTRICT IDENTIFIED NEXT STEPS

An important aspect of the self-evaluation process and measurement of program efficacy is taking the information collected by the evaluation process and determine next steps to continue growth and modifications to the program being implemented. The participants in this study were asked, "What are the next steps your District plans to pursue in the area of STEM education?" Of the 17 responses provided, nine (52.9%) planned to look more deeply into the interrelated concepts of course offerings at all educational levels and curriculum. This information suggests the districts' desire to continue evolving within the field of STEM education and look for more

opportunities for their students. Three school districts had a focus on the acquisition of more or refinement of technology and its use in classroom instruction. The technology included the incorporation of iPads, 3-D printers, and the execution of a 1:1 initiative. The participants providing these responses did not explicitly define the pedagogical expectations and/or instructional outcomes associated with the use of these technologies. Two school districts also looked to further develop the use of maker space types of learning environments, but, again, did not identify the instructional outcomes or connections to curriculum these spaces might promote.

Interestingly, only two districts approached the next steps of its STEM programs from an instructional perspective. One district planned to pursue partnerships with a local school district to acquire greater skills in the teaching and learning processes associated with STEM education specifically using a program called, *Habits of the Mind*, while another was examining professional development surrounding the teaching and learning process as an alignment with the 21st century skills to be promoted within the classroom. These two districts have identified the needs of its teachers and how those needs impact the necessary instructional practices necessary to promote what the literature identifies as essential components of STEM programs.

6.0   CROSS-TABULATION ANALYSIS OF SURVEY ITEMS

The following chapter incorporates the use of cross-tabulation analysis to determine if a relationship exists between two variables, in this case survey item responses, examined in this study.   The following data were generated using the cross-tabulation function within the Qualtrics Survey System.   Cross-tabulation analysis is used in "more than 90% of all research analyses" as a means of comparing two variables measured in a study (https://www.qualtrics.com/wp-content/uploads/2013/05/Cross-Tabulation-Theory.pdf).

Furthermore, Chi-square analysis was used to determine if a relationship exists between the two variables being compared within the cross tabulation or if the two variables are independent from one another.   It is important to note that even if a relationship exists between the two variables this does not necessitate a causal relationship between the two variables.

6.1   THE IMPACT OF SCHOOL DISTRICT SIZE ON RESPONSES PROVIDED TO CLOSED-ENDED SURVEY ITEMS

The first series of data that were examined was the impact of school district size on the responses given to closed-ended survey items in this study. Table 16, below, illustrates a cross-tabulation analysis of district size and responses provided to the grade levels impacted by the

134

STEM programs in that district. This analysis was conducted to determine if the size of a school district impacted the grade levels addressed when implementing STEM. A cross-tabulation analysis between two survey items below was used to determine if a significant relationship exists between two variables that would otherwise be expected to act independently of one another. In Table 16, survey questions two and four were examined for such a relationship. For each of the tables that have utilized cross-tabulation analysis, the value in each cell represents the actual data generated by the survey questions as it relates to the two variables being assessed for independence.

Table 16.   Cross-tabulation analysis of district size and educational level of STEM program implementation.

		4. The number of students within your District is approximately?				
		0-749	750-1389	1390-2449	more than 2450	Total
2. The implementation of STEM was addressed within which of the following educational levels? (Se...	Kindergarten	0	3	3	10	16
	1st	0	3	3	9	15
	2nd	0	3	3	10	16
	3rd	0	3	5	10	18
	4th	0	3	3	9	15
	5th	0	3	8	10	21
	6th	0	3	8	11	22
	7th	1	5	7	13	26
	8th	1	5	8	12	26
	9th	0	5	7	11	23
	10th	0	4	7	11	22
	11th	1	4	8	11	24
	12th	0	4	8	11	23
Total		1	5	9	13	28

		4. The number of students within your District is approximately:
2. The implementation of STEM was addressed within which of the following educational levels? (Se...	Chi Square	15.06*
	Degrees of Freedom	36
	p-value	1.00

*Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

The data in Table 16 indicate that the two variables being assessed, district size and educational level, were independent from one another due to a Chi-square (X^2) value of 15.06, degrees of freedom (d.f.) of 36, and a p-value greater than .05 (p = 1.00) . Therefore, it appears as if the size of the school district is independent of the data with respect to grade levels where STEM implementation is occurring.

Further analysis indicated school district size was also independent of the following areas of interest: stakeholders included in the development of the STEM program (X^2 = 16.18, d.f. = 27, p-value = 0.95), partnerships established as part of STEM program development (X^2 = 4.25, d.f. = 12, p-value = 0.98), and the types of STEM programs being selected in K-12 education (X^2 = 1.83, d.f. = 12, p-value = 1.00). Chi-square analysis found each of these assessed areas to have a p-value greater than .05, thereby indicating that the two variables being assessed in each instance were operating independently from one another. This suggests, for the participants of this study, school district size does not directly influence any of the variables listed above as analyzed by cross-tabulation. It is important to note that although these variables have been determined to be independent from one another, the sample size was so small (expected frequency less than 5) that the determination may be inaccurate.

6.2   THE IMPACT OF SCHOOL DISTRICT BUDGETS ON RESPONSES PROVIDED TO CLOSED-ENDED SURVEY ITEMS

In addition to looking at the impact of a school district's size on the responses provided to closed-ended survey items, this study examined the role school districts' budgets might play on the various areas assessed via the survey. The following indicate the results of the cross-

tabulations conducted between school district size and the variables assessed in section 6.1, above. Those variables include: grade level of STEM implementation ($X^2 = 19.16$, d.f. = 36, p-value = 0.99), stakeholders included in the development of the STEM program ($X^2 = 8.51$, d.f. = 27, p-value = 1.00), partnerships established as part of STEM program development ($X^2 = 5.17$, d.f. = 12, p-value = 0.95), and the types of STEM programs being selected in K-12 education ($X^2 = 1.16$, d.f. = 12, p-value = 1.00) were examined to determine if a relationship existed between school district budgets and the aforementioned variables assessed within the survey. In each case, the p-value of the Chi-square analysis for each variable listed above was greater than .05. This suggests, for the participants of this study, school district budget does not directly influence any of the variables listed above as analyzed by cross-tabulation. As stated in section 6.1, it is important to note that although these variables have been determined to be independent from one another, the sample size was so small (expected frequency less than 5) that the determination may be inaccurate.

7.0   SUMMARY OF DATA ALIGNED TO RESEARCH QUESTIONS

This study sought to characterize the various STEM programs within the 136 school districts of the Math & Science Collaborative. This characterization included the motivating factors behind school districts' pursuits of implementing STEM programs within their respective school systems, the criteria used to develop or select a given STEM program, where school districts place STEM within the K-12 framework, the types of STEM programs being implemented, and how those programs are evaluated. Furthermore, this study examined the impact of district size and budget on STEM programs implemented within K-12 education. Finally, this study aimed to determine if school districts were using the implementation of STEM as a means to drive school performance indicators such as an increase in scores on standardized assessments or as an ends to prepare students for the post-secondary transition to careers and degrees within STEM-related fields.

The following sections will share the findings of this survey research with respect to the aforementioned areas of interest. This data identify the themes that arose within the population of school districts that chose to participate in this study and conclusions that can be drawn as a result. The final section in this chapter presents additional areas of inquiry that can be researched to help further identify and understand the profile and focus of STEM programs within K-12 education.

7.1 WHAT FACTORS INFLUENCE SCHOOL DISTRICTS TO IMPLEMENT STEM PROGRAMS WITHIN THEIR RESPECTIVE SCHOOL SYSTEMS?

The data gathered in alignment to this research question create an understanding of what school districts within this study value when considering the implementation of STEM programs. In addition, factors that might limit or influence the programs developed or selected for STEM implementation such as size and district budgets are considered.

7.1.1 Rationale for Implementing STEM

Throughout the literature a number of factors have been cited as rationale for implementing STEM programs in K-12 education. Those factors include: increasing underrepresented populations of students (women, minority students, and students of low socioeconomic status) pursuing careers and degrees in STEM, promoting the acquisition of 21st century job skills, address the narrow STEM pipeline as it relates to the job market, and closing the achievement gap between U.S. and international students (Augustine, 2005; Bybee, 2010b; Carnevale et al., 2011; Epstein & Miller, 2011b; Gardner et al., 1983; Hossain & Robinson, 2011, 2012a; Kuenzi, 2008). The results from the population of school districts surveyed in this study suggest that the predominant foci for pursuing STEM resides in the desire to increase the number of students taking advanced STEM courses and to increase the number of students pursuing careers and degrees in STEM. Of the 22 participants in this study, 19 identified the focus on careers and degrees in STEM as the primary reason for STEM implementation and 14 of 22 participants selected an increase in students taking STEM courses as their rationale. Each of the areas of focus aligns to increasing the number of students entering the STEM pipeline.

These responses support existing and future demands for increasing global competitiveness within the international job market and promoting economic stability associated with students graduating with degrees in fields that drive innovation, technological advancement, and national security. These demands are cited throughout the literature as areas of concern that need to be addressed within K-12 education. School districts are also focusing on increasing the curricular opportunities within their educational framework in order to promote students pursuing careers and degrees within STEM. Concentrating on careers and degree pathways in STEM-related fields also aligns to the literature. Furthermore, the data from this study suggest that addressing the STEM pipeline is a higher priority within the participating school districts than promoting STEM within underrepresented populations of students, infusing 21st century skills within current curriculum and assessments, or addressing the achievement gap that exists between U.S. and international students. This is supported by the significant decline in participant responses to the line of questioning as it relates to each of the categories listed above.

However, in order to properly evaluate participant responses within the other three areas, more questions need to be asked of responding school districts. For example, the demographics of responding school districts were not evaluated to determine if there was a direct or indirect lack of focus with respect to underrepresented populations of students pursuing careers and degrees in STEM. Evaluating the data related to this potential focus of STEM implementation lends to matters of social equity and addressing the lack of underrepresented student populations within STEM-related fields. Although the data generated by this study does not allow for conclusions to be drawn regarding these specific populations of students, it would be important to investigate the impact additional courses in STEM and a focus on careers and degrees in

STEM has on promoting the interest in and pursuit of these potential opportunities within the aforementioned student populations.

In addition, the infusion of 21st century skills may be viewed as a separate initiative implemented separately from that of a STEM program. Therefore, responding school districts may see these two areas as individually addressed curricular objectives and thus not a considered to be an embedded element of their STEM programs.

Lastly, although it is important to address the gap that exists between U.S. and international students, school districts within this study may be more interested in how student achievement compares to local and regional school districts than comparisons made to their international peers. Student achievement may be more confined to local and regional comparator groups of schools and school districts to measure growth and success. How school districts within this study are evaluating STEM program implementation will be addressed in greater detail when discussing research question three in section 7.3.

7.2   HOW DO SCHOOL DISTRICTS DECIDE WHICH STEM PROGRAMS TO IMPLEMENT AND WHERE THAT INITIATIVE WILL BE INTEGRATED INTO THE EXISTING EDUCATIONAL FRAMEWORK (I.E. CURRICULUM, SCHOOL DAY, AND GRADE LEVEL)?

The data gathered for this research question defines the types of STEM programs school districts participating in this study are implementing within their educational systems. This section summarizes the characteristics of those programs and shares the underlying themes that have emerged.

7.2.1   Diversity of STEM Programs

The data collected via closed and open-ended survey questions illustrate the diversity in STEM programs implemented within the school districts participating in this study. As discussed in the review of literature, STEM can be a very abstract and loosely defined ideology that has resulted in different interpretations of how K-12 education should address or are addressing the topic. The development of Maker Spaces, curricular modifications, and the generic incorporation of technology show that school districts participating in this study define STEM and the ways to address STEM education in very different ways. As stated in section 7.1.1, most school districts' rationale for implementing STEM is to prepare students for careers and college degrees in STEM. However, the variety of STEM programs being implemented brings to question if there is an alignment to the goal of career and college readiness or is the philosophy of STEM coming into conflict with the implementation of STEM. Further investigation would reveal how school districts define the alignment of their version of STEM implementation with the preparation of students for careers and degrees in STEM and/or stimulate their interest in taking more STEM-related coursework while still in high school.

7.2.2   STEM Implementation – Grade Level

A potential link to motivating more students to take more STEM-related coursework may reside in where school districts are implementing STEM. The focus on middle level students (grades seven and eight) is nearly ubiquitous in the school districts participating in this study. Although the presence of STEM implementation exists secondarily at the high school level and at a tertiary level within the elementary grades, it is clear that the participants in this study have focused on

implementing STEM within grades seven and eight. The focus on the middle level has a number of potentially positive outcomes that are supported by what has been found in the literature. Concentrating on students in these grade levels affords the opportunity to engage all students at an impressionable age. As stated in the literature, this is a critical benchmark for generating interest in underrepresented populations of students, i.e. females, students of low socioeconomic standing, and minority students (Brophy et al., 2008; Hitz & Robinson, 2007). Many school districts did not indicate a focus on engaging these student populations in STEM. However, by generating programs at the seventh and eighth grade levels these students are provided the opportunities to be exposed to STEM at critical times within their educational pathways. Furthermore, this exposure creates opportunities for students to develop an interest within STEM-related areas that can be satisfied as they matriculate through the high school levels, thereby potentially guiding these students towards the pursuit of degrees and careers in STEM.

7.2.3 Stakeholder Groups Used in the Planning of STEM Program Development and Implementation

Data from this study suggest there is an over-reliance of internal resources during the planning and implementation efforts to address STEM. Although 86% of school districts participating in this study provide a self-reported interest in preparing students for careers and degrees in STEM, fewer than 50% of school districts report the involvement of community colleges and universities in the process of developing and implementing STEM within their educational systems. In addition, only 52% included local businesses in that process.

It is likely that school districts within this survey believe they are satisfying connections to local businesses, colleges and universities by creating job shadowing experiences, internships,

and field trips. It is apparent, however, that these events are isolated opportunities rather than defined attributes of STEM program development and implementation. The knowledge and experiences that local colleges, universities and businesses could provide to students would serve to solidify a comprehensive plan to engage students in pursuing careers and degrees in STEM.

7.2.4   STEM Developed within Existing Educational Frameworks

A final element drawn from the data related to research question number two is the criteria school districts considered to determine the type of STEM program to be implemented within their respective educational systems. The data provided by school districts necessitate a deeper look into their mission and vision statements and strategic plans to determine if the foundational elements of STEM education exist within those statements or is the development and implementation of STEM being inserted into pre-existing district doctrine. Although 95.6% of participating school districts selected the alignment of career and college readiness to the STEM program being selected, there were other responses that suggest the implementation of STEM must be a compliment to what already exists within the districts. This is evidenced by 86.4% of school districts identifying an alignment to existing curriculum and district mission and vision statements. This data suggests that the implementation of STEM is a 'means' of improving the district profile rather than an 'end' whereby success is measured by students pursuing careers and degrees in STEM. The current framework drives the type and degree by which STEM is implemented rather than the ends dictating the process of STEM program development and implementation. This is further supported by 90.9% of responding participants in this study that indicated STEM implementation occurs as an adaptation or modification to existing curriculum rather than a separately infused program to drive student interest and engagement in STEM.

Further support to the 'means' versus 'ends' argument lies in the second most frequent response to the criteria used to select STEM programs. Nearly ninety-one percent (90.9%) of responding school districts identified the alignment to state standards as a key determinant in the selection of a given STEM program. Therefore, participants in this study, by selecting an alignment to state standards, have indirectly indicated that standardized testing is a significant factor driving the implementation of a new initiative that impacts their curriculum. Rather than using measures such as the number of students matriculating to college who are pursuing careers and degrees in STEM, alignment to standards and performance on standardized testing significantly influences program selection. Performance on state standardized assessments ('means') will be discussed further in section 7.3.

7.3   HOW DO SCHOOL DISTRICTS EVALUATE THE INITIAL IMPLEMENTATION OF STEM PROGRAMS WITHIN THEIR SCHOOL SYSTEMS?

The data gathered with respect to this research question defines how school districts are evaluating the implementation of STEM programs within their respective school systems. Data suggest that districts exhibit diversity in how they evaluate STEM program implementation similarly to the diversity observed in the programs themselves.

7.3.1 Evaluation of STEM Programs – Characteristics of STEM

The responses provided by participants in this study show that districts value the characteristics of STEM. However, their responses also indicate that aside from 76.2 % of districts selecting an emphasis on problem-solving skills as an essential characteristic of a given STEM program, there was variation among school districts selecting the other characteristics defined by the literature. This data aligns with the diversity in STEM programs discussed in section 7.2.1. It is evident that within the population of school districts participating in this study there is not a defined set of criteria used to evaluate the elements that should exist within the program being implemented. Each district is left to determine what it values in STEM programs and which characteristics of STEM it decides must be present. This diversity in STEM ideologies and philosophies leads school districts to determine not only if, but to what degree, STEM is being effectively implemented within their school systems. This determination is aligned to district-defined (i.e. mission/vision statements and strategic plans) parameters rather than those found within the literature.

7.3.2 Evaluating the connections made to outside organizations

In section 7.2.3, the stakeholder groups involved in the development and selection of STEM programs to be implemented within their respective school districts lacked the involvement of local businesses, colleges, and universities. However, it is evident that those relationships emerge after STEM program implementation. School districts participating in this study have identified and pursued the importance of establishing these connections as part of their STEM programs but do not involve these entities at the planning stages of program implementation.

Additionally, many of the connections made between these outside organizations take the form of speakers presenting on site within the school districts. With only one school district citing the establishment of job shadowing, internship, and field trip experiences (limited to industry and not post-secondary education) there is a need to place emphasis on providing students with opportunities to engage in the real-world application of and exposure to STEM. As cited in section 7.1.1, many school districts maintain that a primary goal of their STEM program is to foster students' progress towards degrees and careers in STEM. However, there are limited examples of doing so within the programs being implemented.

7.3.3   Evaluating STEM implementation

The participants of this study were provided the opportunity to share how they planed to evaluate the progress of STEM implementation within their school districts. The measures they reported often coincided with an increase in standardized test scores (state assessments and Advanced Placement) and survey responses provided by key stakeholder groups. The focus of STEM implementation, therefore, remains in the present rather than forecasting the future of the students being impacted. Results of this study suggest that school districts implementing STEM need to utilize longitudinal sources of data to determine if said program is having a lasting and sustained impact on students. For example, data collected on the number of students taking more STEM courses, exemplifying the use of 21st century skills on assessments, projects, etc., and increasing the number of students pursuing careers and degrees in STEM will measure the lasting impact of STEM program implementation. A shift in ideology that places the focus on the 'ends' associated with student pursuits beyond K-12 education rather than have a short term

focus on STEM as a 'means' to improve scores on standardized assessments helps to foster a sustained and more profound impact on student success.

8.0   CONCLUSIONS AND AREAS FOR FUTURE RESEARCH

8.1   A STEM FRAMEWORK FOR PROGRAM DEVELOPMENT, IMPLEMENTATION, AND EVALUATION.

When examining the results of this study, it is evident that there exists a great deal of diversity in the types of STEM programs being implemented and how those programs are evaluated within the cohort of school districts participating in this study. There also appears to be a disconnect between the rationale school districts use as a platform to implement STEM programs within their districts (i.e. promote more students towards careers and degrees in STEM) and the measures they use to determine the efficacy of STEM program implementation (i.e. increased scores on standardized assessments). The presence of more STEM programs is evident within the participating school districts of this study. However, the impact those programs are having on student engagement, interest, pursuit of STEM-related careers and degrees, and use of 21st century skills is not a consistent and measured focus of these districts. These observations suggest the need for school districts to work from a framework from which the planning, implementation, and evaluation of their program can be done intentionally.

As a principal and practitioner within the field of education, it was important for me to consider the implications of my study's results on my own practice, what those results suggest about STEM in K-12 education, and how the data can help school districts make informed

decisions when considering the selection, implementation, and evaluation of a STEM program. The review of the literature and results of this study has led me to the development of the following framework to address STEM program selection, implementation, and evaluation in K-12 education. The diversity of STEM programs found as a result of this research along with the lack of a comprehensive planning strategy and evaluation process for STEM program implementation in K-12 education has identified a need for a framework to support school districts in their efforts to provide students a comprehensive STEM experience. This framework will allow school districts to utilize a backwards mapping approach to develop or select the STEM program they intend to implement, determine where that program will be implemented, and provide measures to formally evaluate that implementation.

It is important for school districts to first determine the 'why' behind the desire to implement STEM within their educational system. A comprehensive STEM program will infuse the following criteria and later evaluate said criteria to determine program efficacy:

How does the STEM program address students engagement, interest, and pursuit of careers and degrees in STEM?

How does the STEM program infuse the characteristics of comprehensive STEM programs (see Table 5) into the curriculum, instruction, and assessment practices within the classroom?

Has the development and selection of the STEM program included the following stakeholders: school board members, administrators, teachers, students, parents, local businesses, and post-secondary institutions?

How has the program addressed the needs and interests of underrepresented student populations (i.e. female students, students of low socioeconomic status, and minority students)?

How will partnerships with local businesses and universities be woven into the curriculum, instruction, and assessment of students?

Following the establishment of the 'why' aspect of STEM program implementation, districts will then need to determine 'where' this program will be implemented.

Has there been a clear rationale developed for the grade level in which STEM program implementation will occur and does that rationale align to the criteria listed above?

What longitudinal impact will the implementation of the STEM program at the selected grade level have on future student course selections and potential pursuits of careers and degrees in STEM-related fields?

How will this STEM program be supported prior to and after the grade level of implementation? (i.e. What pre-requisite skills will students need to successfully engage in the program and how will the development of those skills be sustained in subsequent coursework and grade levels?)

Finally, a clearly defined evaluation strategy must be developed in order to measure the success of the STEM program both within the K-12 educational framework and the longitudinal impact on post-secondary pursuits.

How will student course selections in STEM be tracked?

How will the implementation of the characteristics of comprehensive STEM programs be supported in terms of professional development of teachers?

How will the implementation of the characteristics of comprehensive STEM programs be evaluated at the curricular, instructional, and assessment levels?

How will the pursuit of STEM-related careers and degrees be tracked?

How will student engagement and interest be measured and how often?

How will partnerships with local businesses and universities be evaluated within the framework of the curriculum, instruction, and assessment of students?

What additional electives must be created to support students' interest in and continual pursuit of STEM-related coursework?

How often will the committee of stakeholders meet to evaluate the data associated with STEM program implementation?

Utilizing the framework allows for school districts to follow a process that is fundamentally based on the literature in STEM education and supports a focused program that can be strategically developed, implemented, and evaluated.

8.2 SUGGESTED AREAS FOR FUTURE RESEARCH

The findings of this study establish a foundation from which the profile of STEM programs implemented within K-12 education can be characterized. The results of this research have identified the factors influencing participating school districts' pursuits, implementation, and evaluation of STEM programs. However, a number of additional questions could be asked of these districts that might further define their responses to survey items. Future inquiries on the topic of STEM program selection, implementation, and evaluation are as follows:

What demographic data of participating school districts might be impacting the selection, implementation, and evaluation of STEM programs?

How is the creation of learning labs, maker spaces, and the integration of technology being used to foster student interest and skill development in STEM?

How do students' interactions with local businesses impact their interest and pursuits of STEM-related careers and degrees?

What level of interest do local businesses, colleges, and universities have in partnering with local school district to establish job shadowing experiences, internships, and field trips in STEM-related areas?

How might school districts best go about establishing and fostering relationships with local businesses, colleges, and universities to benefit their students?

How might school districts best go about establishing and fostering relationships with local businesses, colleges, and universities during the planning and evaluation phases of STEM program implementation?

What impact will the infusion of STEM programs at the middle school level have on future STEM course selections and the pursuit of careers and degrees in STEM?

What impact will infusing STEM at the middle school level have on the expectations, skills, and opportunities provided at the grade levels below and above the grade level or levels of implementation?

How do current STEM programs implemented within K-12 education align to the skills and expectations of STEM-related careers and degrees?

How do school districts current strategic plans, mission, and vision statements align to the infusion of STEM in K-12 education?

154

Future research in the areas listed above may help to further define and elucidate the thought processes behind school districts' selection, implementation, and evaluation of their STEM programs and generate more comprehensive STEM programs within K-12 education.

APPENDIX A

STEM INVENTORY QUESTIONNAIRE

Figure 3. Appendix A. STEM Survey Questionnaire.

STEM Inventory Questionnaire

The following survey consists of multiple choice, rating scale, and short answer questions pertaining to the characteristics of Science, Technology, Engineering, and Mathematics (STEM) implementation efforts within your school district. For the purposes of this research, STEM is an all encompassing term that include the variations often found within K-12 education (i.e. STEAM or STREAM).

Some questions within this survey are modified, with permission, from the instruments created by The William & Ida Friday Institute for Education Innovation at North Carolina State University and/or have been generated from and aligned to the literature that addresses K-12 STEM education.

Please answer the following questions to the best of your ability. Some of your responses may require you to solicit information from other stakeholders within your school district. Once you have started the survey you will be able to close and return to the survey for one week if you cannot complete the survey in one sitting.

As a reminder, by completing this survey you are voluntarily agreeing to participate in this research and verifying that you understand and agree to the terms outlined in the Informed Consent. The Informed Consent document can be found in the original email correspondence inviting you to participate in this study.

Thank you, once again, for your time and participation in this study.

Sincerely,
Matthew Delp
mjd91@pitt.edu

1. My District is currently involved in efforts to address the topic of STEM.

○ Yes

○ No

2. The implementation of STEM was addressed within which of the following educational levels? (Select all that apply.)

Elementary

☐ Kindergarten

☐ 1st

☐

2nd

☐ 3rd

☐ 4th

☐ 5th

Middle School

☐ 6th

☐ 7th

☐ 8th

High School

☐ 9th

☐ 10th

☐ 11th

☐ 12th

3. In what school year did your District begin implementing efforts to address STEM?

○ Prior to 2001

○ 2001

○ 2002

○ 2003

○ 2004

○ 2005

○ 2006

○ 2007

○ 2008

○ 2009

○ 2010

○ 2011

○ 2012

○ 2013

○ 2014

4. The number of students within your District is approximately:

○ 0-749

○ 750--1389

○ 1390-2449

○ more than 2450

158

5. What is the approximate total budget for your District for the 2014-15 school year?

○ Less than $8.5 million

○ Between $8.5 and $19.65 million

○ Between $19.65 and $42.7 million

○ Greater than $42.7 million

6. Approximately what percentage of that budget is spent on STEM? Please move the bar to represent your best estimate on expenditures on STEM education in your school district or place the numerical value in the text box provided below.

	0	10	20	30	40	50	60	70	80	90	100
Percentage											
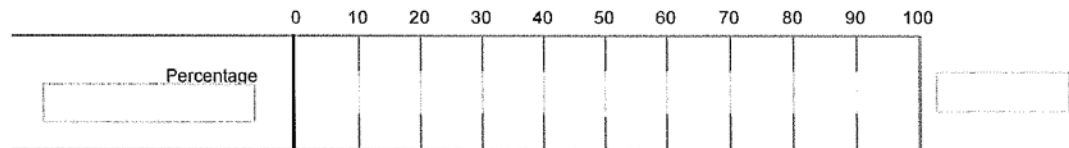
7. Which of the following stakeholders were/are included in the development of the efforts to address STEM within your School District? (select all that apply)

☐ Students

☐ Teachers

☐ Building Level Administrators

☐ Central Office Administrators

☐ School Board Members

☐ Parents

☐ Local Business Owners

☐ Community College(s)

☐ University(ies)

☐ Other
(Please describe in the text box below.)

8. Can you share a brief description of your District's most recent efforts to address STEM?

159

[text box]

9. Did you consider any alternative programs?

○ Yes

○ No

10. What factors eliminated these alternative programs from consideration?

[text box]

11. What criteria were/are used to make the final decision on the efforts selected to address STEM within your School District? (select all that apply)

☐ Aligned to existing curriculum

☐ Was appropriate for the grade level(s) being considered

☐ Cost was aligned to budgetary constraints

☐ Aligned to the District's mission/vision

☐ Aligned to the District's strategic plan

☐ Addressed the needs of underrepresented groups of students (i.e. females and minorities in STEM and students of low socioeconomic status)

☐ Least disruptive to current building operations

☐ Aligned to state standards

☐ Promoted a connection to career and college readiness

☐ Improve standardized test scores

☐ Provided a means to solicit funding

☐ Increase enrollment in STEM-related coursework

☐ Other
(Please describe in the text box below.)

[text box]

12. Please select the top five characteristics of STEM programs you believe are essential elements of an effective STEM program.

- ☐ Integration between the four content areas within STEM
- ☐ Promote innovation
- ☐ Promote creativity
- ☐ Integrate elements of design
- ☐ Promote critical thinking
- ☐ Promote problem solving
- ☐ Promote application of content knowledge
- ☐ Foster collaboration and communication between students
- ☐ Real world and relevant content, instruction, and assessments
- ☐ Alignment to state standards
- ☐ Provides connections to careers
- ☐ Encourages students to pursue degrees in STEM-related fields
- ☐ Cutting edge curriculum
- ☐ Other
  (Please describe in the text box below.)

13. Which of the following statements best describes the efforts to address STEM within your School District?

- ○ Occurs as an adaptation or modification to the existing curriculum
- ○ Curriculum is replaced by an outside program (i.e. Project Lead the Way or The Infinity Project).
- ○ Occurs as an after school program (i.e. 4-H Tech Wizards, Girlstart After School, etc.).
- ○ Occurs as an enrichment program to an identified subgroup of students (i.e. Gifted and talented students)
- ○ Occurs by way of a separate educational experience (i.e. students are transported to a magnet school to participate in a STEM-specific curriculum).

14. Given your plan for incorporating STEM into your School District, where do you think your District lies on the continuum below with 0 representing no implementation of STEM and 100 being full implementation of STEM. Please move the bar below to represent your District's position on the continuum.

	Zero Implementation							Complete Implementation			
	0	10	20	30	40	50	60	70	80	90	100
Implementation of STEM											
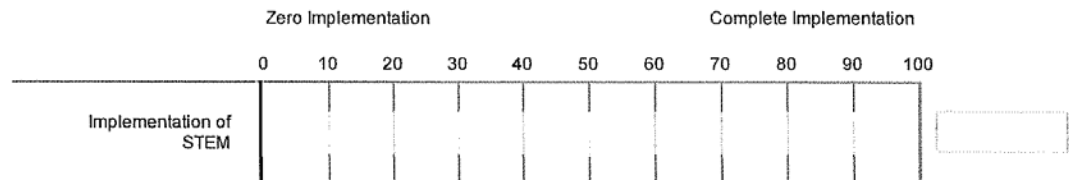
15. Please select the top three reasons for your District's interest in infusing STEM into the educational setting.

☐ Satisfy the needs/demands of the community within the District

☐ Satisfy the needs/demands of the School Board

☐ To increase the number of students taking advanced STEM-related courses within the District.

☐ To bridge the achievement gap identified between US and international students.

☐ To increase the number of students pursuing careers and/or degrees in STEM-related fields.

☐ To increase the number of female students pursuing careers and/or degrees in STEM-related fields.

☐ To increase the number of African American and/or Latino students pursuing careers and/or degrees in STEM-related fields.

☐ To increase the number of low socioeconomic students pursuing careers and/or degrees in STEM-related fields.

☐ To compete with the STEM initiatives implemented by other School Districts.

☐ Other
(Please describe in the text box below.)

16. Has your School District pursued relationships with outside organizations to supplement your efforts in infusing STEM into the educational setting?

○ Yes

○ No

17. Which of the following entities has your District established partnerships with as part of your efforts to address STEM? (Select all that apply.)

☐ other school districts

☐ community members

☐ local businesses

☐ post-secondary institutions

☐ all of the above

☐ none of the above

18. Does your District provide opportunities for students to engage with STEM professionals within the educational setting?

○ Yes

○ No

19. Please describe those opportunities below:

20. What indicators will be used to measure the implementation of STEM within your School District?

21. What are the next steps your District plans to pursue in the area of STEM education?

22. Please share any additional comments related to your engagement with STEM within your School District that may not have been addressed in the questions above.

Thank you for taking the time to participate in this survey. The rest of the questions relate to school districts who have recently implemented efforts to address STEM in their respective educational settings. Please continue to the next screen to submit your completed survey.

Thank you!

Block 1

Thank you for completing this survey! Please be sure to submit the survey below. If you have any questions, comments, or concerns or would like to provide additional information, please feel free to contact me at mjd91@pitt.edu.

APPENDIX B

STEM SURVEY INTRODUCTION

Figure 4. Appendix B. STEM Survey Introduction.

STEM Survey Introduction

Dear (FirstName, LastName),

My name is Matthew Delp, and I am a doctoral candidate at the University of Pittsburgh within the School of Education's Administrative and Policy Studies Program. The purpose of this email is to request your participation in a research study I am conducting pertaining to the infusion of Science, Technology, Engineering, and Mathematics (STEM) within K-12 education. The research I am conducting relates to the criteria and processes school leaders use to select and implement STEM within their respective school districts. This study seeks to identify the characteristics of STEM initiatives within the 136 participating public school districts within the Math & Science Collaborative. As a result of this study, I aim to answer the following research questions:

1. What factors influence school leaders to implement STEM within their respective school districts?

2. How do school leaders decide which STEM efforts to implement within their school districts and where STEM will be integrated into the existing education framework (i.e. curriculum, school day, and grade level)?

3. How do school leaders evaluate the initial implementation of STEM within their school districts?

The term STEM, in this instance, refers to all variations of the acronym that includes the traditional reference made to Science, Technology, Engineering, and Mathematics (e.g. STEAM).

By clicking on the link below you are acknowledging that your participation in this research is entirely voluntary. The study should take approximately 20 minutes to complete and consists of multiple choice, rating scale, and short answer questions. Some of the questions in this survey may require you to solicit information from other stakeholders, administrators, or teachers, for example. As a result, once you have started the survey, it will remain active for one week for you to be able to return to complete information you may have had to gather from another source.

Please review the **Informed Consent** document attached to this email for additional information concerning your participation in this research. Your responses to this questionnaire will remain confidential. In addition, all data will be reported thematically and/or in a collective fashion thereby avoiding the individual identification of the participants in this study.

Click here to access the survey: STEM Inventory Survey

Thank you for your time and participation in this study.

Sincerely,

Matthew Delp
Assistant Principal
North Allegheny Intermediate High School
350 Cumberland Road
Pittsburgh, PA 15237
mjd91@pitt.edu
412.369.5530

Doctoral Committee Chairperson:
Dr. Cynthia Tananis, Associate Professor
University of Pittsburgh, School of Education
4314 Wesley W Posvar Hall
230 South Bouquet Street
Pittsburgh, PA 15260
412-648-7171
tananis@pitt.edu

APPENDIX C

LETTER OF CONSENT FROM GOLDEN LEAF FOUNDATION

Figure 5. Appendix C. Letter of Consent From Golden Leaf Foundation.

Delp, Matt

From:	Mark Sorrells <msorrells@goldenleaf.org>
Sent:	Monday, March 02, 2015 5:07 PM
To:	Delp, Matt
Subject:	RE: Survey Information
Attachments:	STEMAttributesRubric_ELEMENTARY_v3_11012012.docx; STEMAttributesRubric_HIGH_v3 _11012012.docx; STEMAttributesRubric_MIDDLE_v3_11012012.docx; GLFSTEM_FinalReport_Appendices_June2014_DRAFTFORREVIEW.docx; GLFSTEM_FinalReport_Narrative_June2014_DRAFTFORREVIEW.docx

Matt,

Here are the Attribute Rubrics that I spoke to you about yesterday. These were created by the NCSU Friday Institute for Education Innovation in collaboration with the NC Department of Public Instruction and the NC Science, Mathematics and Technology Center. The assessments are used to designate schools as model STEM Schools by NCDPI. Golden LEAF uses the assessment instruments to assess the readiness of districts / schools to implement STEM initiatives and as an evaluation tool to monitor progress toward overall targets.

In addition, I am including the **DRAFT** Year 3 Final Report on the STEM Evaluation. It is a draft and is incomplete in that it does not include student data for 2013-14 due to NCDPI delays in releasing the information and does not have information related to program success. I am including a number of criteria that I would consider being important to Golden LEAF as best practice in STEM Education.

I am happy to share the final evaluation report when received (still a couple of months out) and discuss any aspects of what we learned in the 3-year initiative.

Feel free to contact me if needed.

Lessons Learned:
1. Intentional strategies to engage employers in design of training to ensure targeted skills match employment demands
2. Strong instructional supports with front-loaded and on-going professional development along with instructional coaches
3. Build time on the front-end for leadership development and planning to guide implementation and create buy-in
4. Emphasize integration – cross curricular or interdisciplinary approaches to drive connections between conceptual learning and practical application
5. Build community partnerships

Characteristics of Success:
1. Hands-on learning using project and inquiry-based instruction
2. Promote collaboration across the curricula where teachers are given time to collaborate across instructional content areas
3. Teacher and student interaction with STEM environment and applications through real world experiences
4. Appropriate resources, personnel, equipment and materials
5. Develop Pathways that lead students from education to employment tied to local and regional economic hubs or opportunities
6. Cultivate a culture that values all students and career pathways (professional and occupational)
7. Early and on-going engagement by employers
8. Enrichment opportunities and support for under-represented students

1

9. Professional development that is hands-on, content specific, grade level appropriate and job-embedded that gives teachers time to design, model and reflect on instructional practice
10. Long-term planning, sustainability and continuous improvement emphasized
11. Get the right people in the right places

Mr. Sorrells,

Thank you, once again, for the timely response to my request for information. I greatly appreciate the opportunity to utilize aspects of your survey instruments for my dissertation and would be happy to share any information I might gather at the conclusion of my research. I look forward to reading through the materials I anticipate receiving from you and am very interested in the conclusions garnered from your research. I certainly have a passion for STEM, having been a former AP Biology teacher, and hope to utilize that passion to support students from an administrative level.

Sincerely,

Matt

2

APPENDIX D

LETTER OF CONSENT FROM THE FRIDAY INSTITUTE

Figure 6. Appendix D. Letter of Consent from the Friday Institute.

Delp, Matt

From:	Malinda Faber <mmfaber@ncsu.edu>
Sent:	Thursday, March 19, 2015 10:52 AM
To:	Delp, Matt
Subject:	STEM Program Implementation Rubrics and Principal Leadership for STEM Survey
Attachments:	STEMAttributesRubric_ELEMENTARY_v4_Aug2013.pdf; STEMAttributesRubric_HIGH_v4 _Aug2013.pdf; STEMAttributesRubric_MIDDLE_v4_Aug2013.pdf; FI_P-STEM_April2014 _VERSION3.pdf

Hi Matt,

I got derailed at the end of the day yesterday, so attached are the materials and information below. Thank you again for your interest in our evaluation instruments and best of luck with your research. Keep me posted - would be great to see what you find when it is all said and done.

Regards,
Malinda

YOUR CONSENT:

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

It is not likely that we will follow-up with a data request, but we use this standard language for all our instrument requests and do include in the outside chance that the data would be needed for further psychometric testing.

STEM PROGRAM IMPLEMENTATION RUBRICS:

See attached.

Friday Institute for Educational Innovation (2013). *Elementary School STEM Implementation Rubric*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2013). *Middle School STEM Implementation Rubric*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2013). *High School STEM Implementation Rubric*. Raleigh, NC: Author.

PRINCIPAL LEADERSHIP FOR STEM (P-STEM) SURVEY:

See attached.

Friday Institute for Educational Innovation (2014). *Principal Leadership for STEM Survey*, Raleigh, NC: Author.

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Malinda Faber
Research Associate
Friday Institute for Educational Innovation, College of Education
North Carolina State University
1890 Main Campus Drive, Campus Box 7249
Raleigh, NC 27606
919.513.8564 (office)
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malinda_faber@ncsu.edu
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2

APPENDIX E

STEM ATTRIBUTION RUBRIC – FRIDAY INSTITUTE

Figure 7. Appendix E. STEM Attribution Rubric - Friday Institute

STEM Attribute Implementation Rubric
HIGH SCHOOL

North Carolina Department of Public Instruction's **STEM Attributes**	Early	Developing	Prepared	Model
Integrated Science, Technology, Engineering and Mathematics (STEM) curriculum, aligned with state, national, international and industry standards				
1) Project-based learning with integrated content across STEM subjects				
2) Connections to effective in- and out-of-school STEM programs				
3) Integration of technology and virtual learning				
4) Authentic assessment and exhibition of STEM skills				
5) Professional development on integrated STEM curriculum, community/industry partnerships and postsecondary education connections				
6) Outreach, support and focus on underserved, especially females, minorities, and economically disadvantaged				
On-going community and industry engagement				
7) A communicated STEM plan is adopted across education, communities and businesses				
8) STEM work-based learning experiences, to increase interest and abilities in fields requiring STEM skills, for each student and teacher				
9) Business and community partnerships for mentorship, internship and other STEM opportunities that extend the classroom walls				
Connections with postsecondary education				
10) Alignment of student's career pathway with postsecondary STEM program(s)				
11) Credit completion at community colleges, colleges and/or universities*				

* Applies only to high schools.

(1) *Curriculum*: Project-based learning (PBL) with integrated content across STEM subjects				
KEY ELEMENT	Early ⟶	Developing ⟶	Prepared ◉	Model ◉
1.1 Frequency of PBL	Project-based learning[1] is used rarely in all STEM content areas	Project-based learning[1] is used monthly in all STEM content areas	Project-based learning[1] is used monthly throughout all subject areas, which includes all STEM content areas as well as additional subjects	Project-based learning[1] is regularly used throughout all subject areas, which includes all STEM content areas as well as additional subjects
1.2 Frequency of STEM Integration	Up to 25% of STEM core and elective teachers regularly make explicit efforts to integrate science, technology, engineering and math, requiring students to organize knowledge across disciplines	25-50% of STEM core and elective teachers regularly make explicit efforts to integrate science, technology, engineering and math, requiring students to organize knowledge across disciplines	50-75% of STEM core and elective teachers regularly make explicit efforts to integrate science, technology, engineering and math, requiring students to organize knowledge across disciplines	Over 75% of STEM core and elective teachers regularly make explicit efforts to integrate science, technology, engineering and math, requiring students to organize knowledge across disciplines
1.3 Collaborative PLCs	Semiannually, STEM teachers share STEM activities or ideas and plan learning outcomes through professional learning community meetings and common planning time	Quarterly, STEM teachers share STEM activities or ideas and plan learning outcomes through professional learning community meetings and common planning time	Monthly, STEM teachers share STEM activities or ideas and plan learning outcomes through professional learning community meetings and common planning time	Weekly, STEM teachers share or co-create STEM activities or ideas and plan learning outcomes through professional learning community meetings and common planning time
1.4 Physical Space	On special occasions computer labs or classrooms are transformed into collaborative spaces and project work areas for face-to-face and/or virtual collaboration among students and teachers, or to be used as exhibition spaces	Occasionally computer labs or classrooms are transformed into collaborative spaces and project work areas for face-to-face and/or virtual collaboration among students and teachers, or to be used as exhibition spaces	Frequently computer labs or classrooms are transformed into collaborative spaces and project work areas for face-to-face and/or virtual collaboration among students and teachers, or to be used as exhibition spaces; may include a STEM lab	One or more facilities or spaces are available specifically for students to collaborate and do project work; the spaces can be used for face-to-face and/or virtual collaboration among students and teachers; they can also be used as exhibition spaces; may include a STEM lab

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[1] Project-based learning (PBL) activities have students working in small, collaborative groups; the groups go through a process of inquiry and eventually produce high-quality products/presentations; projects can mirror the real work of professionals and move beyond classroom in purpose or audience

176

(2) *Curriculum:* Connections to effective in- and out-of-school programs			
KEY ELEMENT	Early	Developing	Prepared	Model
2.1 STEM Network	School/program is seeking to establish partnerships with other schools, communities, postsecondary institutions, and businesses to identify solutions for building a quality STEM school/program	School/program engages with other schools, communities, postsecondary institutions, and businesses to identify solutions for executing a quality STEM school/program	School/program has documented partnerships with other schools, communities, postsecondary institutions, and businesses to identify solutions for executing a quality STEM school/program	School/program has partnerships with other schools, communities, postsecondary institutions, and businesses to identify solutions for executing a quality STEM school/ program; partnerships are purposeful, mutually beneficial, monitored, and evaluated
2.2 Students and STEM Professionals	Leaders are creating plans to provide opportunities for students to meet STEM professionals and/or to experience professional STEM work environments during and/or outside school[2]	Direct experiences with STEM professionals, professional STEM work environments, and/or practical applications of STEM content during and/or outside school[2] are available to students at least 2 times throughout the year	Direct experiences with STEM professionals, professional STEM work environments, and/or practical applications of STEM content during and/or outside school[2] are available to students at least 4 times throughout the year	Direct experiences with STEM professionals, professional STEM work environments, and/or practical applications of STEM content during and/or outside school[2] are available to students approximately monthly
2.3 Research & Development	On an annual basis school/program leaders and other STEM teachers share with each other research and information on best practices related to their STEM program goals	On a semiannual basis school/program leaders and other STEM teachers share with each other research and information on best practices related to their STEM program goals	On a quarterly basis school/program leaders and other STEM teachers share with each other research and best practices related to their STEM program goals	On a monthly basis school/program leaders and other STEM teachers share with each other research and best practices related to their STEM program goals

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[2] For example, presentations or workshops, field trips, clubs, competitions, study trips, and summer/afterschool/weekend programs taught by STEM teachers and/or industry professionals

177

(3) *Curriculum:* Integration of technology and virtual learning				
KEY ELEMENT	Early ⇒	Developing ⇒	Prepared ◐	Model ◉
3.1 Instructional Tech for STEM	Technology tools relevant to the STEM program have been identified[3]	Technology tools relevant to the STEM program are available to STEM teachers and students;[3] up to 50% of students and teachers are proficient in these technology tools	Technology tools relevant to the STEM program are being used by most STEM teachers and students;[3] 50-75% of students and teachers are proficient in common technology tools	Technology tools relevant to the STEM program are being used by almost all STEM teachers and students;[3] more than 75% of students and teachers are proficient in common technology tools
3.2 Instructional Tech Resources for STEM	STEM teachers rarely receive information regarding computer-based and/or online instructional resources for STEM aligned to the NC Essential Standards for Technology (e.g. links to instructional technology tools, articles about effective use of instructional technology, meetings with peers focused on instructional technology, etc.)	STEM teachers annually receive information regarding computer-based and/or online instructional resources for STEM aligned to the NC Essential Standards for Technology (e.g. links to instructional technology tools, articles about effective use of instructional technology, meetings with peers focused on instructional technology, etc.)	STEM teachers semiannually receive information regarding computer-based and/or online instructional resources for STEM aligned to the NC Essential Standards for Technology (e.g. links to instructional technology tools, articles about effective use of instructional technology, meetings with peers focused on instructional technology, etc.)	STEM teachers monthly receive information regarding computer-based and/or online instructional resources for STEM aligned to the NC Essential Standards for Technology (e.g. links to instructional technology tools, articles about effective use of instructional technology, meetings with peers focused on instructional technology, etc.)
3.3 Computer & Web-based Technology	STEM teachers occasionally use a few computer-based, online, mobile, virtual, and/or other technology tools to support instruction	STEM teachers weekly use computer-based, online, mobile, virtual, and/or other technology tools to support instruction	STEM teachers daily use computer-based, online, mobile, virtual, and/or other technology tools, as appropriate, to support instruction; the technology is often in the hands of students	STEM teachers seamlessly integrate computer-based, online, mobile, virtual, and/or other technology tools are into instruction; the technology is consistently in the hands of students
3.4 Tech Support	STEM teachers have limited access to maintenance support for instructional technology; IT equipment is regularly inoperable for extended periods of time	STEM teachers occasionally have access to maintenance support for instructional technology; IT equipment is occasionally inoperable for extended periods of time	STEM teachers have regular access to maintenance support for instructional technology; IT equipment is rarely inoperable for extended periods of time	STEM teachers and students have on-demand access to maintenance support instructional technology; IT equipment is rarely inoperable for extended periods of time

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[3] For example, spreadsheet applications in biology, robotics in programming, design software in engineering, or calculators in math

178

(5) *Curriculum*: Professional development on integrated STEM curriculum, community/industry partnerships and connections with postsecondary education				
KEY ELEMENT	Early	Developing	Prepared	Model
5.1 Individualized PD	STEM teachers participate in large group professional development sessions that introduce novice STEM teaching skills	STEM teachers participate in large group professional development sessions focusing on critical STEM teaching skills – may include strategies for inquiry-based instruction, for integrating STEM, or information on cutting edge content	STEM teachers have identified unique professional development goals and tailor as much as 25% of their STEM professional development activities to meet their individual, professional needs – may include strategies for inquiry-based instruction, for integrating STEM, or information on cutting edge content	STEM teachers have identified unique professional development goals and tailor at least 50% of their STEM professional development activities to meet their individual needs – may include strategies for inquiry-based instruction, for integrating STEM, or information on cutting edge content
5.2 Job-embedded PD	A job-embedded or practice-based approach to professional development[4] is used twice during the school year for STEM teachers	A job-embedded or practice-based approach to professional development[4] is used quarterly during the school year for STEM teachers	A job-embedded or practice-based approach to professional development[4] is used monthly during the school year for STEM teachers	A job embedded or practice-based approach to professional development[4] is used multiple times a month for STEM teachers
5.3 Specific to Teachers & Students	Professional development activities for STEM teachers focus on standardized, scripted teaching strategies	On an annual basis professional development activities for STEM teachers focus on strategies for teaching specific content to specific types of learners[5]	On a quarterly basis professional development activities for STEM teachers focus on strategies for teaching specific content to specific types of learners[5]	Professional development activities for STEM teachers that focus on strategies for teaching specific content to specific types of learners[5] are frequently available
5.4 Frequency of PD	STEM teachers participate in 10-20 hours per year of STEM-related professional development which addresses integrated content, community/industry partnerships, connections with postsecondary education, pedagogy, and/or digital learning	STEM teachers participate in 20-25 hours per year of STEM-related professional development which addresses integrated content, community/industry partnerships, connections with postsecondary education, pedagogy, and/or digital learning	STEM teachers participate in 25-30 hours per year of STEM-related professional development which addresses integrated content, community/industry partnerships, connections with postsecondary education, pedagogy, and/or digital learning	STEM teachers participate in 30 or more hours per year of STEM-related professional development which addresses integrated content, community/industry partnerships, connections with postsecondary education, pedagogy, and/or digital learning

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[4] Job-embedded professional development includes action research, peer observation, critical friends feedback, curriculum alignment, coaching, lesson study, or problem-solving
[5] Specific by content area and grade-level, and for either high-performing, low-performing, average-performing, English as Second Language, or Exceptional Children, etc.

179

(4) *Curriculum:* Authentic assessments and exhibition of STEM skills				
KEY ELEMENT	Early	Developing	Prepared	Model
4.1 Authentic Assessments	STEM core and elective teachers are encouraged and supported to use multiple indicators of student success, including knowledge- and performance-based assessments (projects, portfolios, etc.)	As many as 50% of STEM core and elective teachers use multiple indicators of student success, including knowledge- and performance-based assessments (projects, portfolios, etc.)	50-75% of STEM core and elective teachers use multiple indicators of student success, including knowledge- and performance-based assessments (projects, portfolios, etc.) multiple times during the school year	Over 75% of STEM core and elective teachers regularly use multiple indicators of success, including knowledge- and performance-based assessments (projects, portfolios, etc.)
4.2 Teachers Collaboratively Develop Assessments	Twice a year STEM teachers share assessment strategies	Quarterly STEM teachers share assessment strategies; they occasionally co-create measures of student success and examine and reflect on student work	STEM teachers collaborate at least monthly to reflect on student work, to discuss strategies for using the results to inform instruction, and to co-create various measures of student success	STEM teachers collaborate at least biweekly to reflect on student work, to discuss strategies for using the results to inform instruction, and to co-create various measures of student success
4.3 Celebrate STEM Work	Students, teachers and administrators annually celebrate high-quality student work in STEM	Students, teachers and administrators celebrate high-quality student work in STEM with semiannual on-site and online exhibits	Students, teachers and administrators celebrate high-quality student work in STEM with quarterly on-site and online exhibits	Students, teachers and administrators celebrate high-quality student work in STEM through on-going student exhibits on-site, online and/or in state and national forums
4.4 Culture of Innovation	Program leadership annually honors and encourages innovation in STEM among students	Program leadership semiannually honors and encourages innovation in STEM among students	Program leadership and program participants quarterly honor and encourage innovation in STEM among students	Program culture consistently honors, encourages and incentivizes innovation in STEM among students

(6) *Curriculum:* Outreach, support and focus on underserved students, especially females, minorities and economically disadvantaged students			
KEY ELEMENT	Early ⇒	Developing ⇒	Prepared	Model
6.1 Culture of Inquiry	A few school/program leaders have articulated what a culture of inquiry and creativity looks like as it relates to STEM, emphasizing the inclusion of all students in the culture	A core group of school/program participants maintain a culture of inquiry and creativity as it relates to STEM, and emphasize the inclusion of all students in the culture	A culture of inquiry and creativity exists throughout a majority of participants in the STEM school/program and emphasizes the inclusion of all students in the culture	A culture of inquiry and creativity exists between and among the STEM school/program students, teachers and administrators and emphasizes the inclusion of all students in the culture
6.2 Recognize Under-represented Students	No clear guidelines and/or practices explicitly focus on increasing long-term participation by students from underrepresented groups[6] in the STEM education pipeline	1 guideline and/or practice focuses on increasing long-term participation by students from underrepresented groups[6] in the STEM education pipeline	At least 2 guidelines and/or practices focus on increasing long-term participation by students from underrepresented groups[6] in the STEM education pipeline	Several guidelines and/or practices focus on increasing long-term participation by students from underrepresented groups[6] in the STEM education pipeline

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[6] In North Carolina and nationally groups of students underrepresented in stages of the education and workforce pipeline include female students, students of color, and students from low socio-economic backgrounds

181

(7) *Community:* A communicated STEM plan is adopted across education, communities and businesses				
KEY ELEMENT	Early ⟹	Developing ⟹	Prepared ◦	Model ●
7.1 STEM Program Plan	Program leaders have created a basic STEM program plan[7] in which actions toward 1-4 *STEM Attributes* are outlined	Program leaders have created a detailed STEM program plan[7] grounded in research and in which actions toward 5-10 *STEM Attributes* are outlined	At least 50% or more of a STEM Leadership Team[8] is formed and has created a STEM program plan[7] that is grounded in research, aligned with school and/or school-system strategic plans, focused on student participation in the STEM pipeline[9], and outlines action toward 11 *STEM Attributes*	A fully-formed STEM Leadership Team[8] has led stakeholders in a collaborative design process to create a STEM program plan[7] that is aligned with school and/or school-system strategic plans, focused on student participation in the STEM pipeline[9], and demonstrates evidence of 11 *STEM Attributes*
7.2 Communicate STEM Program Plan	Program leaders' communication of the STEM program plan garners minimal participation and buy-in from STEM teachers and key stakeholders	Program leaders' annual communication of the STEM program plan develops some participation and buy-in from STEM teachers and key stakeholders	Program leaders' semiannual communication of the STEM program plan develops participation and buy-in from STEM teachers and key stakeholders	Program leaders' quarterly communication of the STEM program plan secures participation and buy-in from STEM teachers and key stakeholders
7.3 Program Data	A variety of school/program-level student data on STEM performance (from test scores to work samples) is available annually to administrators and teachers and is used to inform decisions	A variety of school/program-level student data on STEM performance (from test scores to work samples) is available semiannually to administrators and teachers, and is used to inform instructional and programmatic decisions	A variety of school/program-level student data on STEM performance (from test scores to work samples) is available quarterly to administrators and teachers, and is used to inform instructional and programmatic decisions throughout the year	A variety of school/program-level student data on STEM performance (from test scores to work samples) is available monthly to administrators and teachers, and is used to inform instructional and programmatic decisions throughout the year
7.4 Resource Allocation	Limited discretionary funds or other resources are allocated for implementation of STEM strategies	Discretionary funds or other resources are allocated to advance implementation of some strategies outlined in the STEM Program Plan	Discretionary funds or other resources are allocated to advance implementation of most of the STEM strategies outlined in the STEM Program Plan and a sustainability plan is in place	Discretionary funds or other resources are allocated to advance implementation of all the strategies outlined in the STEM Program Plan and a sustainability plan is in place

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[7] A school- or district-level STEM plan which already exists, including detailed sections in a School Improvement Plan or a 5 Year Plan, may be substituted
[8] A fully-formed STEM Leadership Team is at the school-level, and includes at least 1 or more representatives of the following groups: students, teachers, administrators, community college staff, college or university staff, business persons (at least one person for each career pathway, if pathways are a focus), community leaders, and parents
[9] This includes student participation in any identified STEM career pathways/clusters

182

(8) *Community*: STEM work-based learning experiences to increase interest and abilities in fields requiring STEM skills for each student and teacher			
KEY ELEMENT	Early ⟹	Developing ⟹	Prepared ◉	Model ◉
8.1 Learning Connected to Industries	Program leaders are researching and planning in-school learning opportunities for students on content that is directly connected to current work in STEM-related industries	1-2 in-school learning opportunities (projects, activities, etc.) for all students focus on content directly connected to current work in STEM-related industries	Several in-school learning opportunities (projects, activities, etc.) for all students focus on content directly connected to current work in STEM-related industries	In-school learning opportunities (projects, activities, etc.) for all students frequently focus on content directly connected to current work in STEM-related industries
8.2 Students Work in Teams	Students rarely learn in teams to frame problems and test solutions that incorporate STEM content and/or apply STEM skills	Students occasionally learn in teams, with clearly defined individual and team expectations, to frame problems and test solutions that incorporate STEM content and/or apply STEM skills	Students weekly learn in teams, with clearly defined individual and team expectations, to frame STEM-related problems and test solutions that incorporate STEM content and/or apply STEM skills	Students regularly learn in teams, with clearly defined individual and team expectations, to frame problems and test solutions that incorporate STEM content and/or apply STEM skills
8.3 Applied Learning for STEM Teachers	Very few STEM teachers ever participate in applied learning experiences[10] to increase their STEM content or career knowledge	At least 25-50% of STEM teachers participate every-other-year in at least 1 applied learning experience[10] to increase their STEM content or career knowledge	50-75% of STEM teachers participate every-other-year in at least one applied learning experience[10] to increase their STEM content or career knowledge	Over 75% of STEM teachers participate every-other-year in at least one applied learning experience[10] to increase their STEM content or career knowledge
8.4 Students Interact with STEM Industries	Students rarely have an active, work-based learning experience[11] with an external STEM industry partner, either during or outside of the school day	At least 25% of students have at least 1 active, work-based learning experience[11] annually with an external STEM industry partner, either during or outside of the school day	At least 50% of students have at least 1 active, work-based learning experience[11] annually with an external STEM industry partner, either during or outside of the school day	At least 75% of students have an active, work-based learning experience[11] annually with an external STEM industry partner, either during or outside of the school day

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[10] For example, study trips, fellowships, externships, etc.; durations of experiences could vary from 1 day to 1 year

[11] An active, work-based learning experience may include competitions, service-learning, apprenticeships, internships, or other opportunities; durations of experiences could vary from 1 day to 1 year

(9) *Community*: Business and community partnerships for mentorships, internships and other opportunities extend the classroom walls			
KEY ELEMENT	Early	Developing	Prepared	Model
9.1 Collaboration in Network of Schools	School/program leadership rarely participate in a network of schools or school leaders which addresses STEM education issues	School/program leadership participates semiannually in an active, online network of schools or school leaders which addresses STEM education issues	School/program leadership participates annually in a face-to-face or at least quarterly in an active, online network of schools or school leaders which addresses STEM education issues	School/program leadership participates annually in a face-to-face and at least quarterly in an active, online network of schools or school leaders which addresses STEM education issues
9.2 Communication Tools	One-way communication tools, such as websites and newsletters, and/or two-way tools, like social media platforms, webinars, and meetings, are used annually to communicate internally and externally about STEM program activities	One-way communication tools, such as websites and newsletters, and/or two-way tools, like social media platforms, webinars, and meetings, are used semiannually to communicate internally and externally about STEM program activities	One-way communication tools, such as websites and newsletters, and/or two-way tools, like social media platforms, webinars, and meetings, are used quarterly to communicate internally and externally about STEM program activities	One-way communication tools, such as websites and newsletters, and/or two-way tools, like social media platforms, webinars, and meetings, are used monthly to communicate internally and externally about STEM program activities
9.3 Stakeholders & Funding	A team of community stakeholders has assembled to discuss STEM education solutions or to create funding streams	A team of community stakeholders assembles at least every 2 years to discuss STEM education solutions, including long-term funding; these individuals include the STEM Leadership Team, local business partners, and other STEM industry professionals	A team of community stakeholders assembles annually to continue building a STEM program and long-term funding streams; these individuals include the STEM Leadership Team, local business partners, and other STEM industry professionals	A team of community stakeholders assembles semiannually to maintain a STEM program and long-term funding streams; these individuals include the STEM Leadership Team, local business partners, and other STEM industry professionals

184

(10) *Connections:* Alignment with students' career pathways to postsecondary programs				
KEY ELEMENT	Early	Developing	Prepared	Model
10.1 Vertical Planning	Every 2 years STEM teachers vertically plan within their school; every 2 years STEM teachers plan across school-levels (elementary, middle and high)	Once a year STEM teachers vertically plan within their school; once a year STEM teachers plan across school-levels (elementary, middle and high)	At least twice a year STEM teachers vertically plan within their school; once a year STEM teachers plan across school-levels (elementary, middle and/or high)	At least twice a year STEM teachers vertically plan within schools; twice a year STEM teachers plan across school-levels (elementary, middle, and/or high)
10.2 Information Sharing	Information about postsecondary STEM programs and STEM career topics is shared annually among counselors and some teachers	Information about postsecondary STEM programs and STEM career topics is shared semiannually among counselors and some teachers	Information about postsecondary STEM programs and STEM career topics is shared quarterly among counselors and some teachers	Information about postsecondary STEM programs and STEM career topics is shared quarterly among counselors and all teachers
10.3 Diverse Course Selection	Courses in 1 STEM-related career field are available to students	Courses in 2-3 STEM-related career fields are available to students both face-to-face and/or virtually	Courses in 4 STEM-related career fields are available to students both face-to-face and/or virtually	A wide variety of courses in STEM-related career fields are available to students both face-to-face and/or virtually
10.4 Counselor & Student Relationships	Counselors and students interested in STEM communicate rarely about the students' future plans and coursework	Counselors and students interested in STEM communicate at least annually in a face-to-face and/or virtual setting about the students' future plans and coursework	Counselors and students interested in STEM have developed one-on-one relationships, communicating at least quarterly in a face-to-face or virtual setting to discuss, plan and track the connections and alignment of students' plans to careers and postsecondary education	Counselors and students interested in STEM have developed one-on-one relationships and use both face-to-face and virtual communication frequently, including at least quarterly face-to-face meetings, to plan, discuss and track the connections and alignment of students' plans to careers and postsecondary education
10.5 Counselors & Teachers	Counselors and STEM teachers meet rarely to discuss the alignment of students' coursework to postsecondary careers and/or education	Counselors and STEM teachers meet annually to discuss the alignment of students' coursework to postsecondary careers and/or education	Counselors and STEM teachers communicate semiannually to discuss the alignment of students' coursework to postsecondary careers and/or education	Counselors and STEM teachers communicate at least quarterly (with at least 1 face-to-face meeting) to discuss the alignment of students' coursework to postsecondary careers and/or education

185

(11) *Connections*: Availability of credit completion with postsecondary institutions, including community colleges, colleges and/or universities			
KEY ELEMENT	Early	Developing	Prepared	Model
11.1 Credit Completion Availability	STEM school/program has 1-2 offerings in STEM-related career fields based upon agreements with at least 2 postsecondary institutions[12]	STEM school/program has a few offerings in STEM-related career fields based upon agreements with at least 2 postsecondary institutions[12]	STEM school/program has multiple offerings in STEM-related career fields based upon agreements with 2-3 postsecondary institutions; offerings were thoughtfully selected based upon other course availabilities at the school[12]	STEM school/program has a wide variety of offerings in STEM-related career fields based upon agreements with 4 or more postsecondary institutions; offerings were thoughtfully selected based upon other course availabilities at the school[12]
11.2 Student Enrollment	Less than 10% of a diverse target group of students are enrolled STEM courses that provide access to postsecondary institutions	10-25% of a diverse target group of students are enrolled STEM courses that provide access to postsecondary institutions	25-50% of a diverse target group of students are enrolled STEM courses that provide access to postsecondary institutions	Over 50% of a diverse target group of students are enrolled STEM courses that provide access to postsecondary institutions
11.3 Comprehensive Advising	Counselors understand the postsecondary enrollment process but rarely advise students on STEM opportunities	Counselors understand the postsecondary enrollment process and advise students on STEM opportunities	Both counselors and STEM teachers understand the pathway completion and postsecondary enrollment process and occasionally advise students on STEM opportunities	Both counselors and STEM teachers understand the pathway completion and postsecondary enrollment process and regularly advise students on STEM opportunities

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[12] The NC STEM Program Plan offers three major education choices for students: (1) Future-Ready Core Course of Study including a four elective credit concentration in a STEM field; (2) Career and College Promise with three options: Core 44 College Transfer programs in Engineering and Mathematics or Life and Health Sciences; Career Technical Education Pathway; and Cooperative Innovative High School Program; and/or (3) Access to advanced coursework in college/university courses that lead to a STEM related degree

186

References

Friday Institute for Educational Innovation (2008). *North Carolina Learning Technology Initiative (NCLTI) framework for planning.* Raleigh, NC: Author. Available from http://www.fi.ncsu.edu/assets/research_papers/nc-11-learning-technology-initiative-planning/nclti-planning-framework-.doc.

Ready, Set Go (2011). *Statewide STEM Strategy.* Raleigh, NC: Author.

Rowley, J. (2010). *STEM Education Quality Rubrics.* University of Dayton, Ohio

Texas High School Project T-STEM Initiative (2010). Texas Science Technology Engineering and Mathematics Academies Design Blueprint, Rubric, and Glossary. Available from: http://ntstem.tamu.edu/Academies/blueprint.pdf

APPENDIX F

PRINCIPAL LEADERSHIP FOR STEM SURVEY – FRIDAY INSTITUTE

Figure 8. Appendix F. Principal Leadership for STEM Survey - Friday Institute

Principal Leadership for STEM (P-STEM) Survey

Last Updated May 2014

Appropriate Use

The Principal Leadership for STEM (P-STEM) Survey is intended to measure a principal's assessment of their own leadership for STEM education, at the school-level. The survey measures more traditional activities and behaviors of principals that support STEM education, and activities and behaviors characteristic of the 21st century STEM education specifically. The survey is available to help program coordinators make decisions about possible improvements to their program.

The Friday Institute grants you permission to use these instruments for educational, noncommercial purposes only. You may use an instrument as is, or modify it to suit your needs, but in either case you must credit its original source. By using this instrument you agree to allow the Friday Institute to use the data collected for additional validity and reliability analysis. The Friday Institute will take appropriate measures to maintain the confidentiality of all data.

Recommended citation for this survey:

Friday Institute for Educational Innovation (2014). *Principal Leadership for STEM Survey*, Raleigh, NC: Author.

The development of this survey was supported by The Golden LEAF Foundation.

DIRECTIONS: Please indicate your level of agreement with the following statements. Regarding the STEM work at my school, I ...		Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1	Make sure teachers have access to instructional technology tools that facilitate their work (e.g. laptops digital projectors software virtual applications learning management systems etc.).					
2	Ensure technical support is available for instructional technology tools.					
3	Support teachers to incorporate the teaching of career readiness skills (e.g. communication collaboration problem-solving).					
4	Enable collaboration of teachers across content areas.					
5	Support teachers to have students work in teams.					
6	Support teachers to implement project-based learning.					
7	Share research and best practices with teachers.					
8	Set ambitious yet realistic (i.e. not too high and not too low) goals.					
9	Provide space for students to collaborate work on projects hold exhibitions etc.					
10	Include teachers in decision-making.					
11	Encourage a culture of innovation among teachers and students.					
12	Ensure technical support is available for lab equipment and/or other resources for STEM teaching.					
13	Celebrate students' work.					
14	Understand that incorporating inquiry-based teaching may take more time for some teachers.					
15	Support teachers using a variety of indicators of student success (e.g. performance-based project-based portfolios etc.).					
16	Communicate clearly how teacher performance will be assessed.					
17	Set clear expectations for teachers.					
18	Provide constructive feedback to teachers.					
19	Model inquiry-based learning.					
20	Have articulated a vision.					
21	Implement practices to increase participation of students from groups underrepresented in STEM.					
22	Support the formal in-school provision of authentic learning experiences (e.g. industry tours study trips job shadowing workshops fellowships etc.).					

190

THE WILLIAM & IDA
FRIDAY INSTITUTE
FOR EDUCATIONAL INNOVATION
NC STATE UNIVERSITY COLLEGE of EDUCATION

Golden LEAF
FOUNDATION
This project received support from The Golden LEAF Foundation.

23	Communicate how the program supports or is itself the larger strategic plan for the school.					
24	Support the formal in-school provision of authentic learning experiences connected to current STEM research or industry for students.					
25	Include teachers in decisions about measuring student success in STEM.					
26	Maintain partnerships with relevant post-secondary education programs.					
27	Support the informal extracurricular provision of authentic learning experiences connected to current STEM research or industry for students.					
28	Include teachers in decisions about measuring teacher success in STEM.					
29	Communicate to the larger community about the STEM program.					
30	Request feedback from teachers on the progress of the STEM program.					
31	Feel knowledgeable about the characteristics of STEM teaching.					
32	Maintain strategic partnerships with STEM industries.					
33	Feel knowledgeable about the characteristics of STEM learning.					
34	Use an action plan to implement the program.					
35	Provide consistent professional development specific to the STEM program.					
36	Feel confident in leading a STEM program.					
37	Feel prepared to lead the STEM program.					

APPENDIX G

LETTER TO SUPERINTENDENT

Figure 9. Appendix G. Letter to Superintendent

Letter to Superintendent

Dear (FirstName, LastName),

My name is Matthew Delp, and I am a doctoral candidate at the University of Pittsburgh within the School of Education's Administrative and Policy Studies Program. The purpose of this email is to request your participation in a research study I am conducting pertaining to the infusion of Science, Technology, Engineering, and Mathematics (STEM) within K-12 education. The research I am conducting relates to the criteria and processes school leaders use to select and implement STEM within their respective school districts. This study seeks to collect data on STEM initiatives within the 136 participating public school districts within the Math & Science Collaborative. As a result of this study, I aim to answer the following research questions:

1. What factors influence school leaders to implement STEM within their respective school districts?

2. How do school leaders decide which STEM efforts to implement within their school districts and where STEM will be integrated into the existing education framework (i.e. curriculum, school day, and grade level)?

3. How do school leaders evaluate the initial implementation of STEM within their school districts?

Throughout this study, the term STEM refers to all variations of the acronym that includes the traditional reference made to Science, Technology, Engineering, and Mathematics (e.g. STEAM).

Within the next week, I will be sending a survey out to the individual identified by your District as being the point person for the Math & Science Collaborative. Participation in this study is entirely voluntary. The study should take approximately 20 minutes to complete and consists of multiple choice, rating scale, and short answer questions that may require the point person to solicit information from a variety of stakeholders, including yourself, in order to complete the survey. Responses to this questionnaire will remain confidential as each district's response to the survey will be coded and used for follow-up purposes only. All data will be reported thematically and/or collectively in order to avoid the individual identification of the participants in this study.

Thank you for your time and considered participation in this study.

Sincerely,

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BIBLIOGRAPHY

Adams, J. E., & Ginsberg, R. (2007). Education reform: Overview, reports of historical significance. *Education Encyclopedia.*

Anderson, D. (2010). S.T.E.M. initiatives. *The Principal Partnership.*

Atkinson, R. D., Hugo, J., Lundgren, D., Shapiro, M. J., & Thomas, J. (2007). Addressing the STEM challenge by expanding specialty math and science high schools. *NCSSSMST Journal*, (Spring), 14–23.

Atkinson, R., & Mayo, M. (2010). Refueling the U.S. innovation economy: Fresh approaches to science, technology, engineering, and mathematics (STEM) education. *Information Technology and Innovation Foundation*, (December), 1–2.

Augustine, N. R. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.*

Banning, J., & Folkestad, J. E. (2012). STEM education related dissertation abstracts: A bounded qualitative meta-study. *Journal of Science Education and Technology*, *21*(6), 730–741. Retrieved from http://link.springer.com/10.1007/s10956-011-9361-9

Barakos, L., Lujan, V., & Strang, C. (2012). *Science, technology, engineering, and mathematics (STEM): Catalyzing change amid the confusion.*

Barrow, L. H. (2006). A brief history of inquiry : From Dewey to standards. *Journal of Science Education and Teacher Education*, *17*, 265–278.

Beering, S. C. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital.*

Berry, R. Q., Reed, P. A., Ritz, J. M., & Lin, C. Y. (2005). Stem initiatives. *The Technology Teacher*, (January), 23–30.

Best practices in elementary STEM programs. (2012). *Hanover Research.*

Bevan, B., & Michalchik, V. (2013). Where it gets interesting: Competing models of STEM

learning after school. *Afterschool Matters*, (Spring), 1–8.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3–11. Retrieved from http://doi.wiley.com/10.1111/j.1949-8594.2011.00109.x

Brody, L. (2006). Measuring the effectiveness of STEM talent initiatives for middle and high school students, 1–7.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 Classrooms. *Journal of Engineering Education*, (July), 369–387.

Bunt, N., Shaneyfelt, S., Rose, G., & Snyder, M. (2015). Math & science collaborative: Building the pillars of STEM. *Math & Science Collaborative Journal*, *20*.

Burke, L. M., & Mcneill, J. B. (2011). Educate to innovate: How the Obama plan for STEM education falls short. *Backgrounder*, (2504), 1–8.

Bybee, R. W. (2010a). Advancing STEM education: a 2020 vision. *Technology and Engineering Teacher*, (September), 30–35. Retrieved from http://opas.ous.edu/Work2009-2011/InClass/Bybee-Integrated STEM Plan.pdf

Bybee, R. W. (2010b). What is STEM education? *Science (New York, N.Y.)*, *329*, 996. Retrieved from www.sciencemag.org

Carnevale, A. P., Smith, N., & Melton, M. (2011). *STEM: Science, technology, engineering, mathematics*. Retrieved from http://www9.georgetown.edu/grad/gppi/hpl/cew/pdfs/stem-complete.pdf

Daugherty, M. K. (2013). The Prospect of an " A " in STEM Education. *Journal of STEM Education*, *14*(2), 10–16.

Deboer, G. E. (2000). Scientific literacy : Another look at its historical and contemporary meanings and its relationship to science education reform, *37*(6), 582–601.

DeJarnette, N. K. (2010). America's children: Providing early exposure to STEM (Science, Technology, Engineering, and Math) initiatives. *Education*, *133*(1), 77–84.

Dickman, A., Schwabe, A., Schmidt, J., & Henken, R. (2009). *Preparing the future workforce: Science, technology, engineering and math (STEM) policy in K-12 education*.

Dodson, A. (2013). STEM Education is important for our future. *Diverse*, 16–17. Retrieved from www.diverseeducation.com

Donner, J., & Wang, Y. (2013). Shifting expectations: Bringing STEM to scale through expanded learning systems. *Afterschool Matters*, (Spring), 50–57.

Dougherty, D. (2012). The maker movement. *Innovations*, *7*(3), 11–14.

Dugger, W. E. (2010). Evolution of STEM in the United States. In *6th biennial international conference on technology education research* (pp. 1–8). Retrieved from http://www.iteea.org/Resources/PressRoom/AustraliaPaper.pdf

Epstein, D., & Miller, R. T. (2011a). Elementary school teachers and the crisis in STEM education. *Center for American Progress*, (September), 4–10. Retrieved from www.eddigest.com

Epstein, D., & Miller, R. T. (2011b). Slow off the mark: Elementary school teachers and the crisis in science, technology, engineering, and math education. *Center for American Progress*.

Faber, M., Booth, S., Parker, B., Corn, J., Ross, N., & Lauen, D. (2014). *The Golden Leaf STEM initiative evaluation: Final report*.

Foster, K. M., Bergin, K. B., Mckenna, A. F., Millard, D. L., Perez, L. C., Prival, J. T., … Hamos, J. E. (2010). Partnerships for STEM education. *Science*, *329*, 9–10. Retrieved from www.sciencemag.org

Friday Institute. (2015). Retrieved from http://www.fi.ncsu.edu.

Friedman, T. (2005). *The world is flat: A brief history of the twenty-first century*. New York: Farrar, Straus and Giroux.

Gallant, D. J. (2010). Science , technology , engineering , and mathematics (STEM) education. Retrieved from https://www.mheonline.com/glencoemath/pdf/stem_education.pdf

Gardner, D. P., Larse, Y. W., & Baker, W. (1983). *A Nation at Risk : The imperative for educational reform*. Washington, D.C.: U.S. Government Printing Office. Retrieved from http://www.ed.gov/pubs/NatAtRisk/risk.html

Golden Leaf Foundation. (2015a). Retrieved from http://www.goldenleaf.org/charter.html.

Golden Leaf Foundation. (2015b). Retrieved from http://www.goldenleaf.org/faq.html.

Golden Leaf Foundation. (2015c). Retrieved from http://www.goldenleaf.org/faq.html.

Gonzalez, H. B., & Kuenzi, J. J. (2012). *Science, technology, engineering, and mathematics (STEM) education: A primer*.

Gottfried, M. A., & Williams, D. N. (2013). STEM club participation and STEM schooling outcomes. *Educational Policy Analysis Archives*, *21*(79), 1–27.

Gura, M. (2012). Lego robotics : STEM sport of the mind. *International Society for Technology in Education*, *5191*(August), 12–16.

Harrison, M., & Royal, T. (2011). Supporting the T and the E in STEM : 2004-2010. *Design and Technology Education: An International Journal*, *16*(1), 17–25.

Hitz, R., & Robinson, S. P. (2007). *Preparing STEM teachers : The key to global competitiveness*.

Hossain, M., & Robinson, M. (2011). Is the US plan to improve its current situation in science , mathematics , and technology achievable ? *US-China Education Review*, *1*(1), 1–9.

Hossain, M., & Robinson, M. G. (2012). How to Motivate US Students to pursue STEM (Science, Technology, Engineering and Mathematics) careers. *US-China Education Review*, *4*(1), 442–451.

Hyman G. Rickover. (2015). *In Wickipedia, The Free Encyclopedia*. Retrieved from https://en.wikipedia.org/wiki/Hyman_G._Rickover.

Increasing the number of STEM graduates : Insights from the U.S. STEM education & modeling project. (2010).

Jenkins, B. C., & Hill, M. H. (2011). *Role of federal government in public education: Historical perspectives*.

Johnson, C. C. (2011). Implementation of STEM education policy : Challenges, progress, and lessons learned. *Stem Education Policy*, *112*(1), 45–55.

Jolly, J. L. (2009). The National Defense Education Act, Current STEM Initiative, and the Gifted. *Gifted Child Today*, *32*(2), 50–53.

K-12 STEM education overview. (2011).

Kelley, T. (2010). Staking the Claim for the " T " in STEM. *The Journal of Technology Studies*, 2–11.

Kline, J., & Hunter, D. D. (2012). Science, technology, engineering, and mathematics education: Strategic planning needed to better manage overlapping programs across multiple agencies, (January).

Krishnamurthi, A., Ballard, M., & Noam, G. G. (2014). *Examining the impact of afterschool STEM programs*.

Kuenzi, J. J. (2008). *Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action*. *Congressional Research Service*.

Land, M. H. (2013). Full STEAM ahead : The benefits of integrating the arts Into STEM. *Procedia Computer Science*, *20*, 547–552. http://doi.org/10.1016/j.procs.2013.09.317

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). STEM: Good jobs now

and for the future.

Lee, O. (2012). Effective STEM education strategies for diverse and underserved learners. In *Workshop on Successful STEM education in K-12 schools*. Washington, D.C.

Marcoux, E. (2013). Infusing the arts in STEM. *Teacher Librarian*, *40*(3), 69–70.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. Jossey-Bass.

Mertens, D. M. (2010). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods* (3rd ed.). Thousand Oaks: Sage Publications, Inc.

Mervis, J. (2009). U.S. STEM education: Report calls for grassroots but comprehensive changes, *324*(June), 1498. Retrieved from www.sciencemag.org

Moore, J. W. (2007). Critical Needs of STEM Education. *Journal of Chemical Education*, *84*(12), 1895. http://doi.org/10.1021/ed084p1895

National Defense Education Act. (2015). Retrieved from www.edu.oulu.fi/tohtorikoulotus/jarjestettava_opetus/Troehler/NDEA_1958.pdf.

National Science Foundation (2015). Retrieved from www.nsf.gov.

Nelson, A., & Weinbaum, E. (2009). *Federal education policy and the states, 1945-2009 : A brief synopsis*. Albany, New York. Retrieved from http://www.archives.nysed.gov/edpolicy/altformats/ed_background_overview_essay.pdf

Paulsen, C. A. (2012). Implementing out-of-school time STEM resources. *Afterschool Matters*, 27–35.

Pennsylvania Department of Education. (2015). Retrieved from http://www.portal.state.pa.us/portal/server.pt/community/summaries_of_afr_data/7673.

Pennsylvania Interscholastic Athletic Association. (2015). Retrieved from www.piaa.org.

Reys, B. (2010). The future of STEM curriculum and instructional design : A research and development agenda for learning designers. In *Center for the Study of Mathematics Curriculum*.

Riccards, P. (2009). Advocating STEM education as a gateway to economic opportunity. *Education News*. Retrieved from https://exemplarpr.com/uploads/Advocating_STEM_Education_As_a_Gateway_To_Economic_Opportunity.pdf

Robelen, B. E. W. (2011). STEAM : Experts make case for adding arts to STEM. *Education Week*, (December).

Rockland, R., Bloom, D. S., Carpinelli, J., Burr-alexander, L., Linda, S., & Kimmel, H. (2010). Advancing the " E " in K-12 STEM education. *The Journal of Technology Studies*, 53–64.

Salinger, G., & Zuga, K. (2009). *The overlooked STEM imperatives : Technology and engineering K-12 education*.

Saxton, E., Burns, R., Holveck, S., Kelley, S., Prince, D., Rigelman, N., & Skinner, E. A. (2014). Studies in Educational Evaluation A Common Measurement System for K-12 STEM education : Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking. *Studies in Educational Evaluation*, *40*, 18–35. http://doi.org/10.1016/j.stueduc.2013.11.005

Scott, C. (2012). An Investigation of science, technology, engineering and mathematics (STEM) focused high schools in the U. S. *Journal of STEM Education*, *13*(5), 30–39.

Sneider, C. (2011). *A possible pathway for high school science in a STEM world*. Retrieved from http://ncete.org/flash/research.php.

Steele, A., Brew, C. R., & Beatty, B. R. (2012). The Tower Builders : A consideration of STEM , STSE and ethics in science education. *Australian Journal of Teacher Education*, *37*(10), 118–133.

Stine, D. D., & Matthews, C. M. (2009). The U . S . Science and Technology Workforce.

Tarnoff, J. (2010). STEM to STEAM -- Recognizing the value of creative skills in the competitiveness debate. *The Huffington Post*.

Thomas, J., & Williams, C. (2010). The history of specialized STEM schools and the formation and role of the NCSSSMST. *Roeper Review*, *32*, 17–24.

Thomasian, J. (2011). *Building a science, technology, engineering, and math education agenda: An update of state actions*.

Tofel-Grehl, C., & Callahan, C. M. (2014). STEM high school communities : Common and differing features. *Journal of Advanced Academics*, *25*(3), 237–271.

Varma, R., & Frehill, L. M. (2010). Special issue on science and technology workforce. *American Behavioral Scientist*, *53*(7), 943–948. http://doi.org/10.1177/0002764209356229

Vilorio, D. (2014). STEM 101: Intro to tomorrow's jobs. *Occupational Outlook Quarterly*, 2–12. Retrieved from www.bls.gov/ooq

Vossoughi, S., & Bevan, B. (2014). Making and Tinkering : A Review of the Literature.

Vossoughi, S., Escudé, M., & Kong, F. (2013). Tinkering , Learning & Equity in the After-School Setting.

Wang, Z., & Oreskes, N. (2008). History of science and American science policy. *Isis*, *99*(2), 365–373.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Sage Publications, Inc.