EXPLORING K-5 STEM EDUCATORS' PERCEPTIONS OF A SUCCESSFUL STEM ELEMENTARY SCHOOL

by

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DISSERTATION

Presented to the Faculty of

The University of Houston-Clear Lake

In Partial Fulfillment

Of the Requirements

For the Degree

DOCTOR OF EDUCATION

in Curriculum and Instruction

THE UNIVERSITY OF HOUSTON-CLEAR LAKE

DECEMBER, 2018

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Dedication

First and foremost, I would like to thank God for His grace, guidance, and placing the right people to support me throughout my life. There are many instrumental friends and family members who have helped make my dissertation journey possible. Angie Ruggeri, thank you for encouraging me to begin this program and Darbi and Paulette for being my cohort 1 cheerleaders. I especially want to thank dear friends Hillary, Gina, and Tracy for your ongoing encouragement, prayers, and optimism. Thank you all!

A heart-felt thank you also goes to my parents, Jennifer and Lester Curtis, and amazing siblings, Bill, Sylvia, Sandy, David, and Mary. Mom and dad, your unconditional love and support have always been key for our family. Mom, thank you for being an inspiration and getting your doctorate at the age of 70! Also, your keen eye when editing my work from the readers' perspective was extremely helpful. A special thank you goes my other editor and inspiration, my sister, Dr. Mary Curtis. Even though you were tremendously busy working on your writing, you always made time to help edit and provide scholarly suggestions that always propelled me forward. A special thank you goes to my other sister, Sandy Curtis, for the words of reassurance and numerous days of watching Logan so I could write. I am grateful for my nephew, Matthew Curtis, for watching Logan on Wednesday nights so I could attend class. The bond you have formed with Logan is uncanny and priceless.

Lastly and most importantly, I am especially grateful for my husband, Charlie, for supporting me on this incredible path and rearranging your schedule to take Logan on adventures when I needed the extra time to work on coursework and writing. You motivated me to seek more and pursue my educational endeavors. Thank you. Logan, I love the mornings you woke up early as I began to write! You kept me focused that I am still mommy and need my cuddle and game time with my little guy.

Acknowledgements

I am grateful to my committee members and other instrumental professors who contributed to my success at UHCL. I an especially appreciative of my chair, Dr. Brenda Weiser, for helping my dissertation idea come to fruition and encouraging me to research STEM schools. The constant guidance, phone calls, text messages, and feedback you provided to push me to the next level and complete my dissertation were instrumental beyond words. You are amazing, Dr. Weiser! Also, with sincere gratitude and thankfulness, I recognize my methodologist, Dr. Amy Orange, for inspiring me to conduct a qualitative dissertation which paints the picture of this elementary school. Your insightful feedback and questions has taught me to be a better qualitative researcher and writer. Dr. Sandra Watson, I appreciate the encouraging conversations regarding my next steps. The suggestions and feedback were reassuring and insightful. Lastly, I would like to thank Dr. Antonio Corrales for your infectious enthusiasm and encouragement which propelled my dissertation research. Words cannot express the gratitude I feel for each of you. Thank you!

ABSTRACT

EXPLORING K-5 STEM EDUCATORS' PERCEPTIONS OF A SUCCESSFUL STEM ELEMENTARY SCHOOL

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Exposure to integrated STEM curricula in K-5 elementary schools is critical to create equal economic opportunities for all students, meet the needs of the future STEM workforce, and build a stronger understanding of engaging and practical STEM application in the real-world. This mixed methods case study investigated if the implementation of integrated STEM curricula into a K-5 elementary school would increase student achievement as measured by STAAR and STEM educators' perceptions of STEM education and key components of a successful STEM elementary school. A purposeful sample of K-5 STEM educators such as the principal, STEM specialist, librarian, and teachers from an elementary school in Texas participated in either a survey and/or interviews.

Quantitative data were analyzed using descriptive statistics to determine if the implementation of STEM curricula had increased students' Reading and Mathematics

STAAR scores in grades 3-5 and Science STAAR scores in grade 5. Quantitative results were inconclusive. An inductive coding process was used to analyze the qualitative data. The qualitative analysis provided supporting evidence that indicated that the integrated STEM curricula had a positive impact on students' academic achievements and school culture. Additionally, it revealed seven emergent themes for a successful STEM elementary school: instructional leadership team; professional development; teacher collaboration; making connections; vision and school culture; 21st century skills; and the integration of the engineering laboratory.

The implications of the study stress the need for a common, clear vision, importance of a growth mindset, and application of STEM to instruction. Determining the vision begins with leadership, who creates the necessary STEM culture that promotes teacher buy-in. Teacher responses emphasize the importance of embracing a growth mindset and application of the Engineering Design Process (EDP) to teacher professional practice. Recommendations for further research include a qualitative analysis of teachers' and students' perception of how school mottos impact school culture and mindset as well as a longitudinal study assessing K-5 STEM students' academic progress against students who attended a traditional elementary school. This information is important to educators, business leaders and other key community stakeholders, who are interested in impact of STEM education on the local community and public education.

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INTRODUCTION

In the past, the United States (U.S.) had been known as the land of opportunity—one that had the world's scientific and technological innovations (National Science Foundation, 2016). However, its future world standing may depend on its populace being prepared to think from a scientific and technical perspective, and personal economic opportunities may be limited to those with science, technology, engineering, and mathematic (science, technology, engineering, mathematics; STEM) backgrounds (Langdon, McKittrick, Beede, Khan, & Doms, 2011; Sargent, 2017). Olson and Riodan (2012) had projected that more than 1 million STEM professionals will be needed in the next few years. Pearsall (2015) had been more specific, stating the U.S. will need 1.7 million additional engineers and computer scientists. Quality jobs have been critical to keep the U.S. competitive because of the purchasing power they provide its citizens to have fueled the national and global economies. To remain competitive in a global economy, which is driven by technological and scientific advancements, stakeholders such as educators, school districts, policymakers, and scientists have encouraged students' interests and achievement in science, technology, engineering, and mathematics (STEM) courses and careers (Cunningham, Sparks, & Ralph, 2015; National Science Board, 2007; President's Council of Advisors on Science and Technology, 2012). Lack of students' STEM preparedness threatens the U.S.' economic growth (Rozek, Svoboda, Harackiewicz, Hulleman, & Hyde, 2017). Building a strong understanding of the importance of an engaging and practical STEM application may involve capturing students' interest at an earlier age to help develop them for a competitive and innovative global market.

Some students in the U.S. may not be able to take advantage of the coming years' 1 million STEM job opportunities. Women and minorities have been especially excluded from STEM jobs and compensation. According to Belec (2015), of the women who hold an engineering degree, 40% either leave the profession or never enter the field. Women represent only 12% of engineers and 26% of computer professionals, and the statics for women of color are worse: African American females comprised 1% of engineers and 3% of computer professionals, and Hispanic females, 1% in each field (Pearsall, 2015). As STEM jobs have increased globally, it has become important for all students to obtain the requirements to compete in the workforce.

A rapidly changing world has demanded that students be flexible and respond quickly to the new innovations and advancements STEM careers require. For instance, the chairman of Intel had noted that 90% of products available, at the end of the year, were unknown on the first day of that same year (Augustine, 2005). Therefore, businesses have been compelled to adapt quickly and require a workforce trained in critical thinking and problem-solving skills and to meet complex 21st century challenges (Miller, 2017). The U.S. educational system needs to be renovated to incorporate real-world problem solving and critical thinking that provide students with the 21st century skills needed to create innovative products for the global economy.

A valid concern is that the graduation rates for students with majors in science, technology, and engineering are declining (Watkins & Mazur, 2010); trends regarding U.S. students and STEM include disinterest, inadequate preparation, lack of diversity, and little persistence (Weaver et al., 2013). Gammon (2011) noted 1.3 million out of 1.9 million students pursuing a STEM career had to take remediation courses in college prior to completing regular STEM courses. In addition, the findings of Bottia, Stearns, Mickelson, and Moller (2018) findings suggested that students who attended a STEM magnet school or who were enrolled in a STEM program in high school did not have enhanced odds of pursuing a STEM career when compared to students in non-STEM programs. These findings indicate that some students are predisposed to pursuing a STEM career due to factors such as individual determination, family influence, and prior educational experiences. Research such as the above indicates emphasis should be placed on K-12 STEM education.

High levels of academic preparedness and intense curriculum is a predictor for success in a STEM degree, and can impact a successful STEM career (Museus, Palmer, Davis, & Maramba, 2011). Therefore, it is important to encourage students to enroll in critical STEM high school courses (i.e., algebra I & II, calculus, and physics) so they develop an interest in STEM and the necessary skills to be able to enter a STEM career successfully (Department of Education, 2012). Schools must interest students before they select career paths as they enter high school and better prepare them to be able to take advantage of future job STEM growth and triple their salary possibilities.

Considering a historical context, the National Assessment of Educational Progress (NAEP), known as the Nation's Report Card, features student achievement in mathematics, reading, science, writing, the arts, civics, economics, geography, and U.S. history over time for public and private school students in grades 4, 8, and 12. Student achievement levels are basic, proficient, and advanced. Less than 20% of the nation's 12th-grade students scored proficient in science knowledge, 19% passed proficiency, and 1% earned advanced proficiency (National Center for Education Statistics, 2005; NCES). Less than one third of the nation's fourth- and eighth-grade students scored proficient, and internationally, U.S. 15-year-olds ranked 28th in mathematics literacy and 24th in science literacy (Kuenzi, 2008). In addition, in 2005 NAEP reported that there was no improvement over 15 years in reading scores for students performing at the basic level

(Kuenzi, 2008). When compared with other nations' schools, whether a developing nation or not, our schools compare "abysmally" (Augustine, 2005, p. 5). Accordingly, the U.S. had begun placing more emphasis on mathematics and science literacy.

Recent data from NCES and Trends in International Mathematics and Science Study (TIMSS, 2015) indicate that the U.S. has made some improvements in science and mathematics achievement. Grade 4 science scores increased four points from 2009 to 2015, with 38% of students at or above Proficient in 2015 (NCES, 2015). Grade 8 science scores increased four points from 2009 to 2015, with 34% of students at or above proficient level in 2015 (Cunningham et al., 2015). Grade 12 science scores, however, had not changed from 2009 to 2015; 20% had scored proficient and 2% scored advanced in 2015 (Cunningham et al., 2015). Even though the U.S. Grade 4 students' average science score had been higher in 2015 than 1995, but not significantly (Cunningham et al., 2015). U.S. fourth-graders students had ranked eighth participating countries. U.S. eighth-grade students' average science score had increased each year from 1995, 1999, 2007, to 2015 but, not between 2007 and 2015 (Cunningham et al., 2015). U.S. fourth-grade students' average score had increased but not significantly between the 2007 and 2015 scores (Cunningham et al., 2015). U.S. eighth-grade students' average mathematics score had been ninth among 34 participating countries. The U.S. eighth-grade students' mathematics scores had increased each year.

Students who had negative perceptions about mathematics and science careers such as they were unexciting, cumbersome, or too expensive to pursue, had been unlikely to pursue a STEM major or career even when confident in their abilities (Patrick, 2009). The National Education Goals had included the importance of science and mathematics and had stressed that significant progress had to be made in these areas for the U.S. to compete globally (Bae & Smith, 1997, Vinovskis, 2015). To begin to make significant gains in science and mathematics, elementary and middle school are a time to secure students' STEM interest and academic performance to ensure their success in STEM later in life.

Academic achievement has not been the only predictor of success in a STEM career. Students' career choices have been influenced mostly by good teachers, parents, siblings, and peers (Cerinsek, Hribar, Glodez, & Dolinsek, 2013). In addition, parents and teachers have limited STEM knowledge, something that negatively impacted the students' interest in pursuing STEM careers (Hall, Dickerson, Batts, Kauffmann, and Bosse, 2011). Additionally, parents' and teachers' limited STEM knowledge could have been due to generational differences in courses taken while in school (i.e., algebra, calculus, and engineering). Similar studies have supported the notion that students' career interests were influenced significantly by their personal interests, parents, and teachers (Bottia et al., 2018; Gross, 1988; Malgwi, Howe, & Burnaby, 2005). There have been direct relationships between students whose parents were in STEM careers and those students' success in STEM education (Astin & Astin, 1992; Grandy, 1994). In addition, schools who have included parents and provided them with STEM materials promotes students' STEM preparedness and careers (Rozek et al., 2017). Furthermore, students whose parents supported and followed their STEM academic journey were more likely to enter STEM pathways and careers (Craig, Verma, Stokes, Evans, & Abrol, 2018). Parental influence had positively or negatively impacted students' academic achievement and interests which has influenced their pathway and career choices.

To enhance students' interest in STEM careers and better ensure equal opportunity for all students, students need to be exposed to STEM education at an early age (DeJarnette, 2012). Thus, it is critical that K-12 schools provide students with technology, science, and critical thinking skills (Partnership for 21st Century Skills, 2009). In 2001, the U.S. Department of Education enacted the *No Child Left Behind Act* (*No Child Left Behind Act*; NCLB), which required schools and districts to implement technology into the curriculum and provide research-based instruction; institute professional development for teachers to integrate technology into the classroom; and analyze the circumstances where technology improved student achievement and performance of teachers (NCLB, 2001).

A strong STEM foundation will help secure the U.S. position as a world leader in innovation. Early positive experiences with mathematics and science careers can help retain students in STEM courses in high school and college and increase their success rate in STEM careers (Museus, Palmer, Davis, & Maramba, 2011). Early interest in STEM concepts is the foundation for creating a competitive STEM workforce that is prepared to meet the challenges of the rapid development of scientific and technological innovations (Tanenbaum, 2016).

Research Problem

The science, technology, engineering, and mathematics (STEM) workforce is expected to increase by over 1 million STEM workers over the next 10 years, but U.S. students may not have acquired the necessary skills and knowledge base to fill those jobs (Olson & Riodan, 2012). Inadequate research and educational systems have been blamed for U.S. students' lack of preparedness to fill STEM workforce gaps (Augustine, 2005). The U.S. is in a national crisis and in danger of losing its global leadership and competitiveness in technology, and this will affect the future of our students (Augustine, 2005). Reich (2010) states efforts to keep the U.S. competitive globally have been unsuccessful because funding for basic scientific research and education does not have consistent support for research. Lack of science and technology components and of human capital affect the nation's economy, security, and role as a world leader.

Furthermore, advancements in technology require U.S. students to obtain the STEM skills necessary to compete economically and innovatively in the future. The lack of student progress in mathematics and science could be detrimental to the U.S.' future STEM workforce (Allen-Ramdial & Campbell, 2014).

U.S. students need to be prepared to create solutions to solve problems that arise due to the rapid advancement of technology. STEM education is perceived as the solution to this problem (Atkinson & Mayo, 2010). However, a significant limitation to using STEM education to keep the U.S. competitive in the global market is the lack of a universally agreed upon definition for STEM education and how to integrate it (NRC, 2014). The discrepancies regarding defining STEM education and what is needed to prepare students to meet the needs of the 21st century STEM skilled workforce creates challenges for educators. Since there is not an agreed upon definition of STEM, it is difficult for educators, policymakers, and stakeholders to agree exactly how to increase STEM education in the U.S. (Schneider et al., 2016).

Early interest in STEM concepts is the foundation for creating a competitive STEM workforce prepared to meet the challenges of the rapid development of scientific and technological innovations (Tanenbaum, 2016). At an early age, students must be interested, encouraged, and motivated in STEM education and academic performance as well as given the vision for a possible STEM career. According to Tanenbaum, "introducing students to STEM early in their education, in both informal and formal learning settings, capitalizes on children's innate interest in the world around them" (p. 44). K-5 STEM education is a necessary component in building students' interest, curiosity, and foundation in different STEM areas in order to supply the future STEM workforce with properly skilled employees.

Significance of the Study

Lack of science and technology components such as STEM literacy and human capital affect the nation's economy, security, and role as a world leader. U.S. students need to be better prepared to take advantage of exploding STEM fields, where 1 million STEM professionals will be needed (Olson & Riodan, 2012). When compared to all other occupations, the science and engineering workforce is projected to have the highest projected growth rate from 7.3 million to 8.2 million jobs between 2016 and 2026 (Fayer, Lacey, & Watson, 2017; Sargent, 2017). When meeting with congress, Augustine (2006) addressed the difficulty of a country recovering the lead in science and technology once it is lost. He testified before the Committee on Science and stated that the U.S. research and educational systems are insufficient and pose a greater danger to the U.S. national security than a conventional war. The U.S. is in danger of losing its global leadership in technology and economic competitiveness; this can affect the future of U.S. students to be able to obtain jobs in the STEM workforce globally.

Advancements in technology require U.S. students to obtain the necessary STEM skills to compete economically and innovatively in the future (Holt, Colburn, & Leverty, 2012). Thus, U.S. students must to be taught to solve problems that arise due to the rapid advancement of technology. STEM education is perceived as the answer to scientific and rapid technological development. However, inconsistencies around defining STEM education and what is needed to prepare students to meet the needs of the 21st century STEM-skilled workforce creates challenges for educators (Atkinson & Mayo, 2010). The researcher wondered how different stakeholders (i.e., education, industry, and policymakers) could impact K-12 STEM educational systems, and particularly how they could do that if they have a different understanding of STEM education and its purpose.

She then switched her focus to identifying K-5 teachers' perceptions of STEM and identifying key components of a STEM school.

The researcher sought to determine if the integration of STEM education into an elementary school would impact State of Texas Assessment of Academic Readiness (STAAR) scores for reading and mathematics in grades 3-5 and science in grade 5, identify K-5 STEM educators' perceptions regarding STEM education, identify the key components of STEM schools, and identify how an engineering laboratory supports STEM education. During intermediate and high school, students begin to select courses at these grade levels which support STEM knowledge and fields. This research is significant because of the need for educators to interest elementary school students in STEM possibilities prior to when students have so many other options bidding for their time and interest.

Research Purpose and Questions

The purpose of this study was to determine if integrating STEM (science, technology, engineering, and mathematics) into an elementary school would increase student achievement as measured by the State of Texas Assessments of Academic Readiness (STAAR) scores. In addition, this study sought to identify K-5 educators' perceptions of STEM education, key components of a STEM school, and how the use of an engineering laboratory supports STEM education. The current study addressed the following research questions:

Research Question 1: Does integrating STEM curricula into an elementary school increase students' Grades 3-5 Reading and Mathematics and Grade 5 Science STAAR scores?

Research Question 2: What are K-5 STEM educators' perceptions of STEM education and key components of a successful STEM elementary school?

Definition of Key Terms

Blended Learning: Blended learning occurs when students learn partly in a brick-and-mortar site *supervised by an educator* and partly through online resources, in which they control their time and pace (Horn & Staker, 2011).

Elementary School: An elementary school in this study refers to a public school with kindergarden through fifth grade.

Engineering Laboratory: An engineering laboratory for this study refers to a weeklong engineering design project that is conducted with the science teachers once every nine weeks.

Inplementation: Implementation is “an act or instance of implementing something : the process of making something active or effective” (Merriam-Webster, 2018).

Integration: Integration is the process to organize or merge into a functioning system (Merriam-Webster, 2018).

Learning Management System (LMS): A learning management system (LMS) is defined as a software application used to help facilitate communication among educators, students, and parents, organize and distribute digital materials, assignments, and assessments, and which can track and record student data and grades (Dictionary.com, 2017).

One-to-One Technology: One-to-one technology for this study refers to the school district providing fourth- and fifth-grade students with their own tablet to use at school and home.

Professional Learning Community (PLC): Professional Learning Communities (PLCs) are groups of educators who share a common vision and participate in regular collaborative meetings that focus on the improvement of pedagogical strategies and the academic performance of students (Dogan, Pringle, & Mesa, 2016; Hidden Curriculum, 2014).

Project-Based Learning (PBL): Project-based learning (PBL) is an instructional technique that allows students to acquire knowledge and skills through authentic projects that solve complex, real-world problems or challenges (Buck Institute for Education, 2018).

State of Texas Assessments of Academic Readiness (STAAR): State of Texas Assessments of Academic Readiness (STAAR) is

> a series of state-mandated standardized tests given to Texas public school students in grades 3-8 and those enrolled in five specific high school courses. First given in spring 2012, STAAR is based on the state's curriculum standards called the Texas Essential Knowledge and Skills. (TEA, 2017)

STEM: STEM refers to courses in science, technology, engineering, and mathematics (DOE, n.d.).

STEM Curriculum: For the purpose of this study, STEM curriulum is defined as the purposeful integration of two or more STEM content areas into classroom activitites and lessons.

STEM Literacy: STEM literacy is the

> ability to adapt to and accept changes driven by new technology work, to anticipate the multilevel impacts of their actions, to communicate complex ideas effectively to a variety of audiences, and perhaps most importantly, to find measured, yet creative, solutions to problems that are today unimaginable. (Zollman, 2012, p.15)

Student Achievement: For the purpose of this study, student achievement is defined according to TEA and measured using the State of Texas Assessments of Academic Readiness (STAAR) Performance Indicator Index 1: Student Achievment (TEA, 2012).

Texas Educational Agency (TEA): The Texas agency that offers leadership, guidance, and resources to assist schools in obtaining the educational needs of all students (TEA, 2017).

Texas Essential Knowledge and Skills (TEKS): Texas educational standards detailing what kindergarten through high school students should know and be able accomplish at the end of each academic year (TEA, 2017).

Conclusion

This chapter has provided a context of science, technology, engineering, and mathematics (STEM) education in the U.S., an overview of the need for the study, the research problem, the significance of the study, the research purpose and questions, and the key definitions pertaining to this study. The present study will contribute to current research by seeking to provide a qualitative face to STEM education. The next chapter will be a literature review of the major constructs of this study.

CHAPTER II:

REVIEW OF LITERATURE

The purpose of this study was to determine if implementing integrated science, technology, engineering, and mathematics (STEM) curricula into an elementary school would impact student achievement for students in the STEM elementary school as measured by the State of Texas Assessments of Academic Readiness (STAAR) scores. In addition, the researcher sought to identify K-5 STEM educators' perceptions of STEM education and key components of a successful STEM school.

Historic Perspective of STEM in the United States

The U.S. has addressed the problem of staying competitive globally and the rise of STEM needs. In the early 1970s, the U.S. began falling behind other industrialized nations, and policymakers, experts, and professors looked for ways to make the nation more competitive in the global marketplace (Duke, 2014). Ten years later, the Secretary of Education published *A Nation at Risk: The Imperative for Education Reform*, which highlighted the failure of the public-school system to create a competitive workforce (Gardner, 1983). Additional reports indicated the need for a greater focus and inclusion on low-socioeconomic, minority, and struggling students (Duke, 2014). President George W. Bush signed the *No Child Left Behind Act* (NCLB) in 2002, which required subpopulations (i.e., English-language learners, students in special education, and poor and minority children) to attain the same achievement goals as their peers. Additionally, in 2007, President Bush signed the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (COMPETES) to improve skills of qualified teachers in STEM courses to increase the number of Advanced Placement (AP) and International Baccalaureate (IB) teachers by 700,000 in science, technology, engineering, and mathematics (STEM) subjects by 2008 (Duke, 2014; Furman, 2013). President Obama reiterated President Bush's concerns and began new initiatives to motivate and inspire students to excel in science and mathematics (Duke, 2014).

What is STEM Education?

Science, technology, engineering, and mathematics (STEM) education has been in a constant state of evolution since the early 1990s, when it was known as SMET (science, mathematics, engineering, and technology). According to Denning (1983), the future of our country is in jeopardy and massive changes in its educational system need to take place. Science, mathematics, engineering, and technology (SMET) became the nation's focus in the early 1990's. In 1995, the National Science Foundation (NSF) created the National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) to assist the efforts toward improving and advancing SMET education (Zia, 2002). The NSF changed SMET to STEM (science, technology, engineering, and mathematics) in the early 2000s (Dugger, 2010). With our nation at risk, more rigorous educational methods should be applied to K-12 academics (Denning, 1983).

According to Wang, Moore, Roehrig, and Park (2011), STEM education can be approached by either multidisciplinary or interdisciplinary integration. Gonzales and Kuenzi (2012) referred to STEM education as formal and informal educational environments where teaching and learning of different fields and activities of science, technology, engineering, and mathematics takes place for preschool to postdoctorate students. Teachers guide students and encourage students to make STEM connections in the content-specific classrooms (Wang et al., 2011). Without universally accepted definitions and common language regarding STEM education, it is difficult for educators, policymakers, and stakeholders to agree exactly how to implement STEM education in the U.S. (NRC, 2014; Schneider et al., 2016). The method in which STEM education is implemented and viewed in K-12 education has not been defined since its infancy stages. Furthermore, inconsistencies in how to integrate STEM into K-12 educational systems create problems of comparing what pedagogical approaches best support learning and how results compare among disciplines (NRC, 2014). These inconsistencies add to the difficulty of making connections among STEM subjects and courses, so students may fail to understand how integration of these subjects applies to real-world applications (Breiner, Harkness, Johnson, & Koehler, 2012).

There are several ways STEM is taught in K-12 schools. One approach to teaching STEM is to teach science, technology, engineering, and mathematics as separate entities, also known a silo approach. Dugger (2010) notes that students do not always see the connections among STEM subjects when they are taught in silos. In many instances, STEM is taught with an emphasis on two subjects, such as science and mathematics (SteM), being taught in unison with little engineering and technology integration (Dugger, 2010). A third approach consists of one subject such as engineering being integrated into the separate science, technology, and mathematics courses (Dugger, 2010). Another way, three disciplines would be taught in the fourth discipline. For example, a science teacher could integrate technology, engineering, and mathematics into the classroom content. The last approach is one in which the STEM disciplines are fully integrated and learned in unison together.

Teaching STEM subjects as one unit is referred to as an integrated approach (Breiner et al., 2012; Morrison & Bartlett, 2009). Motivating students to study STEM and integrating all four disciplines of STEM as one entity might be a better way of obtaining that goal and may develop their interest and performance in STEM courses (Stohlmann, Moore, & Roehrig, 2012).

An interdisciplinary integration requires the focus on a real-world problem and the use of 21st century skills (i.e., critical thinking, problem solving, and content knowledge) to solve a problem (Wang et al., 2011). Sanders and Wells (2006) noted that integrative STEM education intentionally integrated concepts and practices of SteM (science and/or math) and applied them to technological/engineering design-based learning that enhanced additional integration with other school content areas. English (2016) noted that an integrated, interdisciplinary STEM approach is vital for students to fully conceptualize how the content areas are connected and to advance STEM integration. Since there are multiple perspectives of what STEM entails and means, there will be a variance in how school districts implemented STEM curricula, programs, and initiatives which produced different outcomes, and this may positively or negatively impact stakeholders such as STEM industries (Bybee, 2013). Clarifying what STEM means and providing the different perspectives of what STEM entails is necessary as policymakers consider education reform.

Why Is STEM Education Important?

The objectives of STEM education for all U.S. students are to increase STEM training and careers, develop a skilled STEM workforce, and increase science literacy among citizens (National Research Council, 2011). Over the past decade an increase in discussion concerning STEM education, pertaining to the concern over a shortage of prepared STEM workers and educators worldwide, has been prompted by a dynamic global economy and workforce (Kennedy & Odell, 2014; Sargent, 2017). Bybee (2013) noted that educating the U.S. population in STEM literacy is the purpose of STEM education since many jobs will require elements of STEM.

STEM Workforce

According to the U.S. Department of Labor, most of the top jobs in the U.S. will require considerable science or mathematics training by 2018 (Beede et al., 2011). The 2010-2020 projections from the U.S. Department of Labor (2012) state computer and mathematical occupations are the sixth fastest growing group. The U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics; BLS) data indicates a rapid growth in all STEM jobs but more so in technology, mathematics, and engineering between 2012 and 2022 (Vilorio, 2014). The BLS projects that the science and engineering workforce will increase by almost 900,000 jobs from 2016 to 2026 (Sargent, 2017). Such STEM concepts as how the world works, and problem solving, are agreed upon by STEM workers who utilize different technologies (Vilorio, 2014). Technology skills are important to acquire early on so that people become proficient in the STEM careers and in their daily lives. Mathematics and technology skills are becoming connected to successful employment for different careers (Fuchs, Fuchs, & Karns, 2001).

Baker (2013) stated people outside a STEM field are at an economic disadvantage because they are not taking advantage of the 26% STEM job growth, and people in STEM careers typically make three times the salary of those in non-STEM careers. To take advantage of future job growth and triple-salary possibilities, K-12 schools must interest students in STEM before they must choose career paths in early high school. It is important to encourage students to enroll in critical STEM high school courses, that is. algebra I & II, calculus, and physics, so they develop an interest in STEM and the necessary skill set to make STEM career choices (DOE, 2012). Students will need to acquire significant training in STEM educational pathways to pursue a STEM career and ensure a job in the future STEM workforce (Metcalf, 2010).

U.S. Student Academic Achievement

The lack of student progress in mathematics and science could be detrimental to the U.S.' future STEM workforce (Allen-Ramdial & Campbell, 2014). In 2009, according to the Program for International Student Assessment (PISA) tests, U.S. students were ranked 31st in mathematics and 23rd in science (Bybee, McCrea, & Laurie, 2009). During the same year, the National Assessment for Educational Progress (NAEP) tests indicated that only 21% of high school U.S. seniors were reported to have scored at the proficient level (Banchero, 2011; Duke, 2014). It is therefore essential to develop the knowledge and skills that will bolster academic progress of students in STEM courses.

Nationally, American students' academic knowledge and skills are assessed by NAEP, which has been used for students ages 9, 13, and 17 (NCES, 2000). According to the Nation's Report Card from NAEP (2011), eighth-grade male students outperformed eighth-grade female students in 2009 and 2011 by 4 points and 5 points, respectively. According to the U.S. Department of Education (NCES, 2015), females received more credit than males in algebra II, advanced biology, chemistry, and health science/technologies in 2009, whereas their male counterparts earned more credit in physics, engineering, science technologies, and computer information science. Males, however, outperformed females in NAEP mathematics and NAEP science, especially those who took advanced mathematics and advanced science courses (NCES, 2015).

The National Center for Educational Statistics (NCES) data indicates that the gender gap has been removed or significantly decreased in education, but that the gap continues in science and mathematics achievement (NCES, 2000). Females are taking similar high school science and mathematics courses compared as males except for physics (NCES, 2004). Male students are more likely to receive college credit, scoring a 3 or higher on an AP test. Female students, however, are more likely to receive college credit in English and foreign languages (NCES, 2000). If females are less likely to have an interest in and receive credit for higher level sciences, they are more likely to be underrepresented for the master and doctoral programs, which might contribute to their underrepresentation in STEM careers (NCES, 2000).

According to NAEP, on a 300-point scale, eighth-grade science scores increased two points from 2009 to 2011—150 to 152—but still fall below the 170 needed to obtain science proficiency for U.S. students (NCES, 2012; Sparks, 2012). Nationally, males continued to score higher than females in 2011 (5 points) compared with 2009 (4 points), but not by a significant difference (Carlone, 2015; NCES, 2012). Males in 48 of the 50 states outscored females on the 2011 NAEP eighth-grade science exam and scored the same as females in Delaware and Maryland, and females who attend overseas schools and participate in the Department of Defense Education Activity (DoDEA) outscored males (NCES, 2012). When comparing states with similar ethnicities, California (White 26%, Black 7%, Hispanic 51%, and Asian 14%), Florida (White 45%, Black 22%, Hispanic 27%, and Asian 3%), New York (White 51%, Black 19%, Hispanic 21%, and Asian 8%), and Texas (White 31%, Black 13%, Hispanic 50%, and Asian 4%), a higher percentage of males not only scored at or above basic level but also at or above proficient (NCES, 2012). Texas, specifically, has 69% of males and 65% of females scoring at or above basic level and 35% of males and 29% of females scoring at or above proficient level. Only 2% of males and 1% of females scored at an advanced level (NCES, 2012). Females in Texas, like many other states that participated in the NAEP eighth-grade science test need to begin closing the gender gap.

Underrepresented Groups in STEM

According to the President’s Council of Advisors on Science and Technology (PCAST), the projected growth for science and technology jobs is unprecedented, with 1 million science, technology, engineering, and mathematics (STEM) professionals needed within the next decade (Olson & Riodan, 2012). To meet America’s need to stay competitive in the global market, more people must enter and remain in STEM careers. Yet underrepresented groups such as females and minorities typically do not finish STEM majors in college and are less likely to enter STEM careers. President Barack Obama noted, “we’ve got half the population that is way underrepresented in those [STEM] fields” and issued an Executive Order establishing the White House Council for Women and Girls in March 2009 to help address the problem (Office of Science and Technology Policy, 2013).

According to the President’s Council of Advisors on Science and Technology report (2012), the U.S. needs to produce more scientists and engineers over the next decade to cover the 0.3% growth in STEM jobs, which equates to a 1,000,000 deficit in STEM workers (Carnevale, Smith, & Strohl, 2010; Carnevale, Smith, Melton, 2011; Moss-Racusin, Dovidio, Brescoll, Grahm, & Handelsman, 2012). According to Pearsall (2015), women represent 12% of engineers and 26% of computer professionals, and African-American females represent 1% and 3%, respectively, of those fields. The technology could possibly impact the number of underrepresented populations in STEM fields. Underrepresented groups face barriers, such as a lack of access to technology, that a one-to-one initiative could address and improve (Hew & Brush, 2006).

Expanding participation in the U.S. scientific workforce will need intentional and deliberate involvement in STEM-related educational fields (Jackson, Charleston, George, & Gilbert, 2012; Moore, 2006; Pearson, 2002). Underrepresented student achievement in mathematics and science are of interest due to the limited numbers of such students in

STEM fields. The lack of students, especially underrepresented groups, entering STEM fields not only hurts the U.S.' ability to be a global leader but also affects its ability to be competitive.

Gender gap. Gender gaps in STEM careers continue to be problematic, and females need to take an active role to advance academically in STEM. In 2012, females received only 19% of all engineering degrees (National Science Board, 2012). In science and technology careers, females have a greater attrition rate than do their male counterparts (Cooper & Weaver, 2003; Dunleavy & Heinecke, 2007). According to the President's Council of Advisors on Science and Technology report (2012), females make up 70% of college students but only 45% are receiving a STEM undergraduate degree; females need to enter STEM fields to decrease the deficit in scientists and engineers over the next decade.

English Language Learners. As ELL students learn a new language, technology can have a valuable role in providing them with multiple options and opportunities to increase their skills in mathematics and science. According to Brescia, Kissinger, and Lee (2009), ELL mathematics test scores were higher because of the amount and daily use of technology in the classroom and at home. However, ELLs may not use the available technology appropriately to motivate them to increase scores (Binnur, 2009), and the results stated that while technology improved test scores, it should not be used by teachers as the only way to positively engage and motivate ELL students. According to the U.S. Bureau of Labor Statistics (2014), 8.2% of Hispanics (Latinos) are in architecture and engineering careers. Thus, the need to equip ELL students with the proper technological use and training to provide them with the necessary technology skills needed to advance in STEM careers.

According to the Nation’s Report Card (2015), 33% of fourth-grade students were proficient and 7% advanced in mathematics, with 24% Hispanic students scoring at the proficient and 3% at the advanced level (NCES, 2015). Twenty-one percent of Hispanic fourth-graders scored at or above Proficient on reading. The NCES report *Status and Trends in the Education of Racial and Ethnic Groups* stated the 1992 White-Hispanic reading gap was not measurably different than the 2013 gap (25 points) for fourth-grade students (Musu-Gillette et al., 2016). In eighth grade, the reading gap decreased five points (from 26 points to 21 points) between 1992 and 2013 (Musu-Gillette et al., 2016). There was also no measurable difference between the White-Hispanic gaps for fourth- and eighth-grade mathematics.

African Americans. According to the U.S. Census Bureau, African Americans make up 11% of the workforce and 6% of the STEM workforce (Landivar, 2013). As with females and ELLs, Charleston and Jackson (2011) noted, when pursuing a STEM career, African Americans face many challenges. For example, within K-12 education, many African Americans do not acquire the important STEM knowledge and skills in mathematics and science which allows them to progress at a collegiate level in STEM courses (Charleston & Jackson, 2011). The study by Jackson, Charleston, Lewis, Gilbert, and Parrish (2017) indicated a positive relationship among African Americans considering a STEM major and a career, suggesting that African Americans need to be exposed to STEM opportunities and intervention programs that lead into STEM majors and careers.

According to the Nation’s Report Card (2015), 33% of fourth-grade students were proficient and 7% advanced in mathematics, with 17% of Black students scoring at the proficient and 1% at the advanced level (NCES, 2015). Eighteen percent of Black fourth-graders scored at or above Proficient on reading (NCES, 2015). According to the NCES report *Status and Trends in the Education of Racial and Ethnic Groups*, the 1992 White-Black reading gap decreased six points (from 32 points to 26 points) between 1992 and 2013 gap for fourth-grade students (Musu-Gillette et al., 2016). In eighth grade, there was not a measurable difference between 1992 and 2013 (Musu-Gillette et al., 2016). The White-Black achievement gap in mathematics decreased six points (from 32 points to 26 points) between 1990 and 2013 (Musu-Gillette et al., 2016). In 2013 there was not a measurable difference from the mathematics gap in 1990 for eighth-graders (Musu-Gillette et al., 2016).

Integration of STEM Education

Since STEM education is a relatively new approach, the Academic Competitiveness Council (ACC) was charged with evaluating federal STEM programs and reported “there is a general dearth of evidence of effective practices and activities in STEM education” (Kuenzi, 2008, p. 2). Advocates of integrated STEM education argue it is important to teach STEM across disciplines in a connected approach so that students and teachers develop an awareness of how to make connections between real-world problems and improve learning (Honey, Pearson, & Schweingruber, 2014; Subramanian, 2016). Outcomes such as increasing student motivation, interest, academic achievement, and perseverance in learning will increase the number of students who are college-ready and enter the STEM workforce (Subramanian, 2016). According to Tsupros, Kohler, and Hallinen (2009), the best strategy for students to learn about real-world issues and situations would be to utilize an integrated STEM approach in education.

STEM integration helps determine how things work and how technologies are created and provides students with authentic learning experiences, including problem solving, innovation and design, three themes with high priorities on every nation’s agenda (Hernandez et al., 2014). Engineering is an important part of U.S. innovation and applies mathematical, scientific, and technological concepts; therefore, students should be exposed to the engineering design process in K-12 educational systems (Hernandez et al., 2014). “Engineering is a natural integrator” and can offer a way to purposefully integrate STEM across disciplines, increasing the connections students make in mathematics, science, and technology (Honey, Pearson, & Schweingruber, 2014; Moore et al., 2014, p. 2).

Key Components of STEM Education

STEM education continues to evolve in U.S. educational systems. Different goals, outcomes, nature of integration, and implementation of STEM curricula often impact the level of effective STEM integration (Honey, Pearson, & Schweingruber, 2014). When trying to implement new and/or schoolwide initiatives relating to STEM education, classroom teachers need to be provided with appropriate professional development. How the teachers receive such knowledge in both pedogological approaches and STEM knowledge can vary. Thus, identifying key components, such as implementation of professional development, professional learning communities, technology integration, project-based learning, and engineering integration, will help identify common practices and vocabulary within STEM education.

Implementation of Professional Development

Prior to conducting professional development on a new schoolwide initiative, it is important for at least two members from each department to attend a conference and discuss key points with district, school administrators, and department faculty (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). The team should meet to create a plan of action for their campus professional development to determine a clear purpose and understand how it benefits teachers and students. During this time, it should be determined whether the campus will focus on site-based professional development or curriculum-linked professional development. According to Penuel et al. (2007), curriculum-linked professional development is more effective because it promotes a change in teacher pedagogy by training the teachers how to use new strategies, materials, and assessments instead of just coaching like a site-based professional development. Hollingworth, Olsen, Asikin-Garmager, and Winn (2017) noted that teacher buy-in is created when principals cultivate relationships that empower teachers to participate in the exploratory process. Thus, implementation of new initiatives and professional development are more widely accepted. To enhance the implementation of a professional development workshop, it would be helpful if some of the teachers were already on board by attending a conference. Giving them opportunity to perhaps share with other teachers also might be helpful, as well as determining what kind of campus professional development would be needed. These preliminary steps might aid in acceptance of the new initiative on a campus and in the district.

Research indicates that educators do not learn enough content and ways to implement it in a one-shot professional development; therefore, such training of sufficient length will provide the learning opportunities essential for educators to incorporate the knowledge into practice (Hollingworth, Olsen, Asikin-Garmager, & Winn, 2017; Penuel et al., 2007; Tate, 2009). Once teachers recognize their acceptance of the new initiative, they can take an active role in their professional development. According to Beavers (2009), teachers should take part in planning their professional development because their involvement and choice will greatly increase the success of educators.

Future professional development in general needs to focus on several areas. Beavers (2009) states that the “most successful adult learning takes place in a collaborative setting” (p. 27), in which the atmosphere for educators is to develop ideas and problem-solve to create solutions and shape a community environment of trust and gratitude that allows colleagues to learn from each other after the professional development has ended. To have an effective initiative, rational trust must be developed. According to Thornton and Cherrington (2014), rational trust provides authentic reflection and great communication, which is necessary for educators who support each other. The development of trust in conjunction with long-term professional development will aid in the acceptance and implantation of a new initiative such as implementing Professional Learning Communities (PLCs) in STEM schools.

Professional Learning Communities

Professional Learning Communities (PLCs) are groups of educators who, sharing a common vision, participate in regular collaborative meetings that focus on the improvement of pedagogical strategies and the academic performance of students (Dogan, Pringle, & Mesa, 2016; Hidden Curriculum, 2014). Educators in the PLC work together to examine student work, review assessment data, reflect, discuss, and share strategies for how to improve student learning and teacher practice. Participation in PLCs suggested improvement in reform-based teaching pedagogy that includes teacher facilitation of student-centered classrooms and scaffolding inquiry to ensure learning by students (Dogan, Pringle, & Mesa, 2016; Hord, (1997). The greatest impacts of a PLC are the creation of common formative assessments and lesson design (Hord, 1997). As PLCs become more prevalent in schools, new challenges and ways to address the challenges begin to form. Fulton and Britton (2011) stated that there is convincing evidence indicating that teachers who participate in a PLC, which supports teacher improvements and increases student learning, create a successful school environment. However, the term *professional learning community* has been used so commonly that it has lost much of its meaning (DuFour & DuFour, 2007). Thus, there are several potential challenges regarding conducting professional development and working in a professional learning community (PLC).

To overcome these challenges, planning is necessary to create a sound professional learning community. According to Dufour and Dufour (2013), leaders need to orchestrate a guiding coalition of key staff members in the school (e.g., educators from different committees and department chairs) and begin creating “allies before engaging the entire faculty” (p. 21). Similar to implementing new professional development, the formation of the guiding coalition will help increase teacher acceptance (Dufour & Dufour, 2013; Penuel et al., 2007). The application of PLCs in education is to develop shared values and a common culture among teachers so they feel a shared responsibility for all students, not just their own. Educators must create norms where differences and disagreements are debated and regarded as the groundwork of improvement (Stoll, Bolam, McMahon, Wallace, & Thomas, 2006). Mike Mattos, a former principal of Pioneer Middle School, in Tustin, California, stated that most teachers joined the profession to help others and realized “collaboration is good not just for the children, but for teachers as well” (Honawar, 2008, p. 8).

In a STEM school, teachers share ideas and learning experiences in their PLC. STEM teachers and coaches facilitate the PLC and share their classroom practice and pedagogy, “diagnosing areas that might limit student opportunity to learn important STEM content and developing strategies to address designated needs” (Vance, Salvaterra, Michelsen, & Newhouse, 2016, p. 7). In a more open and less judging atmosphere, educators may become less defensive and ready to develop leadership roles and commit to work together to develop lessons, share examples of exemplar student work, and determine what steps are needed to take which address the needs of all students. Additionally, providing teachers with leadership opportunities such as facilitating the

PLC meetings helps them build the experience and management skills needed to retain STEM teachers (Vance et al., 2016).

Technology Integration

Since the time that printed books were made available to the public, educators have sought to use current technologies as tools to make learning more relevant. Technology has come a long way since the chalkboard was introduced in late 1700s (Lee & Wizenreid, 2009). The key to adoption of innovative tools is their seamless integration into teaching and learning (Cuban, 1986; Lee & Wizenreid, 2009). From the chalkboard to computers, technology use in education has increased exponentially for administrators and teachers, as well as for students.

With the advent of the digital information age, identified by Vastag (2011), students are provided with instructional technologies, such as media centers, computer labs, interactive whiteboards, mobile devices, and laptops (Gray, Thomas, & Lewis, 2010; Johnson, Levine, & Smith, 2009). In the U.S., the federal government has devoted a significant amount of its budget to support technology in education (Hew & Brush, 2006). Increasingly, school districts can equip students with technology, and now they should switch their focus to best practices for technology integration. It is important for schools to educate students with the technology and critical thinking skills of the 21st century (Partnership for 21st Century Skills, 2009). This will pave the way for technology to be integrated easily into STEM areas.

Purposeful integration of technology into STEM curricula, teacher pedagogy, and daily classroom procedures creates a STEM school culture that will “enhance learning and provide relevance” (Kennedy & Odell, 2014, p. 254). When technology is integrated into the classroom and used effectively with a learning management system (LMS), face-to-face instruction, performance-based assessments, and project-based learning (PBL), students receive personalized instruction that increases their engagement and achievement (Daro, Dieckmann, Martin, Benner, Schultz, & Wei, 2015). Students use technology to create and analyze models, conduct simulation, and participate in web-based exercises, which strengthens their STEM education learning experiences in a blended-learning environment (Kennedy & Odell, 2014).

Blended learning. In 2001, the U.S. Department of Education enacted the *No Child Left Behind* (NCLB) Act, requiring school districts to implement technology into curriculum and instruction (U.S. DOE, 2001). Technology has rapidly reformed education in the way that teachers teach, and students learn (Seakhoa-King, Nehme, & Ali, 2015), thus allowing blended learning to emerge. According to Horn and Staker (2011), blended learning is defined as occurring when students learn partly in a brick-and-mortar site supervised by an educator and partly through online resources, in which they control their time and pace. Other researchers define blended learning as using the strengths of both face-to-face teacher and student interactions with online learning environments (Delialioglu, 2012; Delialioglu & Yildirim, 2007; Osguthorpe & Graham, 2003). According to Picciano, Seaman, Shea, and Swan (2012), the use of blended learning in K-12 education increased by 47% in the 2005-2006 and 2007-2008 academic school years and is expected to continue to increase. Blended learning, also known as hybrid learning, technology-mediated learning enhanced instruction, web-enhanced instruction, and web-assisted instruction (Delialioglu, 2012), often uses technology in the classroom as an instructional tool. There are many variations on definitions for hybrid and blended learning. According to Scida and Saury (2006), hybrid learning consists of "classes in which instruction takes place in a traditional classroom setting augmented by computer-based or online activities which can replace classroom seat time" (p. 518).

Student engagement increases in the classroom when technology is implemented into a blended learning model. According to the “Seven Principles for Good Practice in Undergraduate Education,” a framework set forth by Chickering and Gameson (1987), student engagement is increased when student and faculty have increased contacts, students work in cooperative environments, students are actively learning, educators provide timely feedback, students remain on task, teachers communicate high expectations, and teachers differentiate and learn to accommodate diverse populations. This framework is instrumental in most blended-learning environments that use face-to-face interactions coupled with chances for students to participate online, allowing teachers to provide immediate feedback and support (Castle & McGuire, 2010; Owston, York, & Murtha, 2012).

According to Kuh (2001), increasing student engagement though decisive activities is an important factor in improving students’ academic success and their personal development. Researchers define engagement based on students’ motivation to learn and participate emotionally (Fredricks & McColskey, 2012) and the magnitude and excellence of cognitive and emotional involvement in the learning process (Henrie, Bodily, Mawaring, & Graham, 2015). Student engagement in a blended-learning environment has been studied through these self-reports by college students in the National Survey of Student Engagement (NSSE). Results indicated that student engagement could help define where collegiate institutions needed to improve (Kuh, 2001). According to Figg and Jamani (2011), the two most significant strategies teachers can use to increase student engagement are to provide short handouts and integrate technology skills incrementally. E-Learning systems, however, provide trackable, quantifiable data that can enable one to identify whether students are engaged or disengaged while using these systems (Cocea & Weibelzahl, 2011).

Learning Management Systems (LMS) are additional tools used in blended learning environments. An LMS is defined as a software application used to help facilitate communication among educators, students, and parents, organize and distribute digital materials, assignments, and assessments, and can track and record student data and grades (Dictionary.com, 2017). According to Henrie, Bodily, Marwaring, and Graham (2015), student engagement can be increased by taking the time to help students become familiar with the LMS but still incorporate face-to-face instruction.

One-to-one technology. To boost students' technology skills, school districts are implementing one-to-one technology (i.e., school districts providing students with their own technological device, such as an IPad, Google Chomebook, or laptop) using different types of devices. In 1990, the historical foundation of one-to-one technology started at Ladies Methodist College, in Melbourne, Australia, which was one of the first institutions to provide laptops for students in grades 5-12 (Johnstone, 2003). Recently, the lower cost of mobile technology has made one-to-one initiatives possible for school districts in the U.S. to implement. The state of Maine has one of the largest one-to-one technology initiatives, which started in the spring of 2002 with the signing of a $37 million contract that provided iBook laptops to 34,000 students and 3,000 teachers (Silvernail, 2004). Even though one-to-one technologies are rising in attractiveness, they are still a new intervention for instruction. Many researchers proposed that the effective use of the technology on a one-to-one campus is more critical to students than the quantity of time students spend using these devices in or out of the classroom environment (Nordin, Embi, & Yunus, 2010; Banister, 2010; Mang & Wardley, 2012; Kposowa & Valdez, 2013; Lei & Zhao, 2008).

Prior research has indicated that there are benefits to using technology if the usage is regular and effective while teaching and learning (Lowther, Inan, Ross, & Strahl, 2012;

Lei & Zhao, 2008; Oliver & Corn, 2008). One advantage of one-to-one technology is the increase in personalized learning. Teachers can administer online assessments easier when the data can be analyzed to make data-driven decisions to customize and improve instruction (Anastos & LaGace, 2007). Furthermore, teachers can differentiate instruction to each student based on needs. Ross, Lowther, and Morrison (2001) discovered that more teachers used student-centered models in their first year of having one-to-one technology. Many researchers agree that it takes teachers time to gradually adapt to one-to-one technology where they can implement student-centered lessons (Rockman, 1998, 2000; Ross et al., 2001; Russell, Bebell, & Higgins, 2004). Also, researchers have revealed that one-to-one technology will increase research, analytical, and writing skills (Rockman, 1998, 2000; Ross et al., 2001; Russell et al., 2004).

Students who can take their laptops home have better attitudes about school, self-concept, and computer skills compared with students who must leave them at school (Knezek & Christensen, 2004; Muir, Knezek, & Christensen, 2004b). Researchers found that when comparing Maine's laptop initiatives against schools who did not have those initiatives, there were moderate to small gains on the end-of-course assessments of nine middle schools in science, mathematics, and visual (performing) arts over two years (Muir, Knezek, & Christensen, 2004a). This amount of gain is equal to four months of extra classes for science and two months of extra classes for mathematics and visual (performing) arts over the two years, the researchers indicated.

The *No Child Left Behind Act* (U. S. DOE, 2001) requires each state in the U.S. to develop an annual assessment to measure school and student progress. Mandinach, Rivas, Light, & Honey (2006) explained that one of the main issues is the accountability needed to achieve performance directives mandated by the state. In the state of Texas, for example, many school districts are implementing one-to-one to facilitate instruction to create a student-centered learning environment. Lowther et al. (2012) found that a subtle implementation of one-to-one technology and the influence of the teachers' technical skills can have an impact on students' outcomes.

Conflicting results using one-to-one. According to the National Center for Educational Statistics (NCES, 2001), technology used in the classroom has a positive outcome on students' mathematics and science achievement. However, there is a gap in mathematical skills nationwide when comparing U.S. students with students in other technology-advanced countries (Burns, Klingbeil, & Ysseldyke, 2010). According to researchers, students demonstrated moderate to small increases in mathematics skills when technology was used in one-to-one mathematics classes (Muir, Knezek, Christensen, 2004a; 2014; Gulek & Demirtas, 2005). Some researchers found, however, that the use of technology in mathematics classes did not impact student achievement (Eyyam & Yaratan, 2014; Protheroe, 2005).

Not only are there inconsistent results in mathematics student achievement, but students' performance in science is also inconsistent. Notten and Kraaykamp (2009) stated that science performance increased by using computers at school and at home. However, the results obtained from Waight and Abd-El-Khalick (2007) indicated that technology hindered science inquiry instead of increasing science achievement. Therefore, the type of mobile technology used in school districts needs to be further explored to determine its impact on student achievement.

Project-Based Learning

Technology integration into the classroom coupled with an effective LMS has provided a way for teachers to implement project-based learning (PBL) and the engineering design process (EDP). According to the Buck Institute for Education (2018), project-based learning engages students and requires them to investigate and respond to authentic, real-world problems and obtain knowledge and skills by working through the complex problems and questions. When an authentic, challenging problem is integrated into the curriculum, students acquire cognitive and social skills that prepare them for life outside of school. According to Larmer (2016), when PBL is not just incorporated in the curricula of one class but used throughout students' educational careers, it better equips them to become responsible college and career-ready adults. This empowers the students and makes them responsible for their own learning, which increases their classroom engagement. The goal is to create students with problem-solving and critical thinking skills that will transfer into all disciplines and everyday situations.

Engineering Integration

To compete in the global 21st century market, the International Technology and Engineering Educators Association (ITEEA) created the Engineering by Design (EbD) program to integrate science, technology, and mathematics into the engineering design process to better prepare today's students for tomorrow's advancements in technology and engineering (Strimel, 2012). EbD was developed because the U.S. does not currently have a STEM education model to follow and students need to acquire a skill set to be successful in a STEM career. Students can collaborate while increasing their critical thinking, creativity, and communication skills while solving a real-world problem. The engineering design process (EDP) emphasizes that all activities (i.e., researching, calculations, budgeting, creating, and testing) should be contextualized around the design challenge (Strimel, 2012). For example, many engineers must work under specific constraints such as budget constraints which can limit the design by eliminating different possibilities (Dym, Little, Orwin, & Spjut, 2009). The goal is to engross students in such a significant way that they learn the engineering design process while learning other content areas.

To have effective implementation of STEM curricula and to become an EbD school, schools need to adhere to the Next Generation Science Standards, Common Core Science Standards, or other science standards used by states. STEM schools should offer professional development and online tools and collaboration for educators. Additionally, data should be analyzed to help educators prepare and modify STEM units.

Engineering by Design (EbD)'s primary focus is to have students become critical thinkers, problem solvers, and effective communicators in a global economy. Therefore, the curriculum is designed to allow students to solve real-world problems while integrating all four components of STEM. For example, one lesson would begin with engaging students by showing them the Design Squad Nation paper tower video and having them discuss the steps they had to use to solve the problem. During the exploration and explanation phases, students research the engineering design process and explain what is meant in each step. Students complete the Crane Strain Problem Brief to apply their knowledge of the engineering process. Using the rubrics provided, students then evaluate their knowledge and performance. The final step allows students to use advanced truss math calculations to decide design flaws in their crane.

Teachers using the EbD curriculum assess students using an online preassessment, hands-on design challenge, online follow-up to the design challenge, and post assessment. Results are compiled and analyzed to make any modifications necessary to EbD, and teachers receive continued professional development according to the current data. Data suggested teachers need more time to plan for STEM curricula, successful strategies, and more time devoted to the content of STEM courses. Students were evaluated and asked how likely they were to choose a STEM career and how applicable the math and science content was to the course. Data indicated there is still a lack of interest in STEM careers for underrepresented groups (Strimel, 2012). Additionally, student data suggested that math and science concepts were important or very important throughout the STEM course.

Engineering by Design's goal is to integrate science, technology, engineering, and mathematics to achieve engineering and technology literacy for all participants. Additionally, students would acquire the skill set to apply their knowledge and skills to real-world problems and become the nation's future innovators. An advantage to using EbD is that it provides ongoing professional development for teachers and vast networking capabilities for educators.

Many schools are beginning to stress the integration of all areas of STEM, where students will use the engineering design process to apply key concepts in their math and science courses. Since there is confusion as to what to teach and no clear national engineering standards have been created, the National Academies called for a clear focus on the integration of STEM education. The recent K-12 engineering framework expects educators to focus on design and problem solving while incorporating STEM concepts (Strimel, 2012). In addition, educators should "promote engineering habits of mind" (Berland, 2013, p. 22). Similarly, the recent K-12 science education standards incorporate STEM (mainly science) into engineering design challenges. Thus, the problem is that the focus is on learning science concepts and not promoting and instilling engineering habits. Focusing the utilization of an interdisciplinary approach while brainstorming possible solutions will allow for students to increase their creativity and ingenuity similarly as engineers do in the real-world (Gormley & Boland, 2017; Marcos-Jorquera, Pertegal-Felices, Jimeno-Morenilla, & Gilar-Corbi, 2016). Furthermore, modeling a "think tank" environment to "learn and adapt to innovate solutions to new problems" provides students with the opportunity to demonstrate their ability to work together like engineering teams (Larson, Lande, Jordan, & Weiner, 2017, p. 2). The development of these engineering habits is essential to instill in students at an early age.

Berland (2013) reported on the instructional design principles that will modify Engineer Your World, an innovative, student-centered curriculum that provided students with engineering principles and authentic engineering experiences. The goals for redesigning Engineer Your World focused on how usable it was in public high schools with a vast number of resources, variety of class schedules and sizes, and the interest level of the students, and how to transfer and apply engineering design strategies to science concepts. Specific criteria were identified and used by teachers and designers to determine the appropriate learning objective to focus on.

According to Berland (2013), incorporating engineering into science is a great idea but teachers' pedagogical method and classroom philosophy may not be conducive to integrating the EDP. Secondly, engineering education accentuates engineering habits of the mind and most science classrooms need to focus on science curricula, not the engineering process. An important different to note is that scientific inquiry focuses on gathering empirical data which supports a hypothesis and explains why something is occurring, whereas the EDP has students create a project or solve a problem using constraints and specifications (Nadelson, Pyke, Callahan, Hay, Pfiester, & Emmet, 2011). Therefore, learning goals focusing on engineering objectives instead of math and science knowledge and skills should be implemented in classrooms when working on the EDP.

Impact of STEM Education

Erdogan and Stuessy's (2015) findings suggest that all ethnicities of students who attend STEM schools benefit, even though they may not pursue a STEM career in college. Additionally, students from these schools were more likely to understand college goals when compared with their peers.

In 2013 in Texas, there were 65 T-STEM (Texas STEM) academies that were awarded a STEM Designation from the Texas Education Agency (TEA) if they focused on and enrolled students who were at-risk for dropping out, provided open enrollment with no requirements (i.e., test scores and essays), were open for grades 6-12 or grades 9-12, created a relationship with schools in their feeder pattern, and implemented and showed progress on the T-STEM Blueprint (Kennedy & Odell, 2014). When compared with students from schools with similar demographics, T-STEM academy students outperformed those students (Kennedy & Odell, 2014). On average, students in T-STEM schools scored 3.3% higher than the average state scores on Mathematics Texas Assessment of Knowledge and Skills (TAKS) and 3.3% higher than students who took the science TAKS (Kennedy & Odell, 2014). Students attending T-STEM schools also had higher attendance rates and fewer office referrals for inappropriate behaviors as compared with students in the comparison schools (Kennedy & Odell, 2014).

Theoretical Framework

This study was framed under the Descriptive Framework set forth by the report *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*, from the National Academy of Engineering and Board on Science Education of the National Research Council (Honey, Pearson, & Schweingruber, 2014). The purpose of this framework was to identify, discuss, and investigate integrated STEM initiatives in the U.S. K-12 educational systems and provide common perspectives and vocabulary that researchers and practitioners could utilize. The framework consisted of four high-level features: goals, outcomes, nature of integration, and implementation.

Table 2.1

High-Level Features of STEM Integration in K-12 Education

General Features	Subcomponents
Goals	Student Goals • STEM literacy • 21st century competencies • STEM workforce readiness • Interest and engagement • Making connections Educator Goals • Increased STEM content knowledge • Increased pedagogical content knowledge
Outcomes	Student Outcomes • Learning and achievement • 21st century competencies • STEM course taking, educational persistence, and graduation rates • STEM-related employment • STEM interest • Development of STEM identity • Ability to make connections among STEM disciplines Educator Outcomes • Changes in practice • Increased STEM content and pedagogical content knowledge
Nature and Scope of Integration	Type of STEM connections Disciplinary emphasis Duration, size, and complexity of initiative
Implementation	Instructional design Educator supports Adjustments to the learning environment

(Honey, Pearson, & Schweingruber, 2014)

Conclusion

This chapter has presented a review of literature relating to the purpose of this study, which was to determine if integrating science, technology, engineering, and mathematics (STEM) into an elementary school would increase student achievement for students in the STEM elementary school, as measured by the State of Texas Assessments of Academic Readiness (STAAR) scores, and identify K-5 educators' perceptions of STEM education, key components of a STEM school, and how the use of an engineering laboratory supports STEM education. The researcher utilized the descriptive framework, STEM Integration in K-12 Education. The focus of the next chapter presents the researcher's methodology for this dissertation.

CHAPTER III:

METHODOLOGY

The purpose of this study was to determine if integrating STEM (science, technology, engineering, and mathematics) into an elementary school will increase student achievement as measured by the State of Texas Assessments of Academic Readiness (STAAR) scores. In addition, the researcher sought to identify K-5 educators' perceptions of STEM education and key components of a successful STEM elementary school.

Overview of Research Problem

The STEM job field is exploding, but American students may not be able to take advantage of it. According to the President's Council of Advisors on Science and Technology (PCAST), the projected growth for science and technology jobs is unprecedented and 1 million STEM professionals will be needed by 2022 (Olson & Riodan, 2012; Vilorio, 2014). New labor projections from the BLS indicate the science and engineering workforce will increase by approximately 900,000 jobs between 2016 and 2026 (Sargent, 2017). When testifying before the Committee on Science, Norman R. Augustine (2005) compared the U.S. lack of preparedness of students unfavorably to a state of war regarding our nation's security: "the inadequacies of our system of research and education pose a greater threat to the U.S. national security over the next quarter century than any potential conventional war that we might imagine" (p. 8). The seminal Rising Above the Gathering Storm (2007) report concurs: "We fear the abruptness with which a lead in science and technology can be lost—and the difficulty of recovering a lead once lost, if indeed, it can be gained at all" (p. 4). This report indicated the U.S. was in a national crisis and in danger of losing its global leadership in technology, which would affect the future of our students and U.S. economy. Reich (2010) stated that efforts to keep the U.S. competitive globally have been unsuccessful because funding for basic scientific research and education do not have consistent support, which allows for unstable investments. Lack of science and technology components and human capital affect the nation's economy, security, and role as a world leader. Thus, the need to remain a global leader had propelled the STEM movement in the U.S. to the next level.

STEM education is a fairly new approach to teaching (Sanders, 2009); collecting data on the influence of a STEM school on state test scores may support the efforts of implementing more STEM schools. As the STEM movement progresses, students need an environment that is conducive to the application of science and mathematics in authentic Engineering Design Process (EDP) which utilizes technology and provides a solution to a problem (Kennedy & Odell, 2014). Identifying key components of successful STEM schools is essential to the development of STEM curricula and programs nationwide.

U.S. students need to be prepared by the education system to create solutions to problems that arise due to the rapid advancement of technology. STEM education is perceived as the solution to the lack of preparedness and competitive scores of U.S. students could help increase the future science and engineering workforce (Atkinson & Mayo, 2010; Sargent, 2017). As discussed in the literature review, the disagreements regarding what is STEM education and what is needed to prepare students to meet the needs of the 21st century STEM skilled workforce creates challenges for K-12 educators. Furthermore, advancements in technology require U.S. students to obtain the necessary STEM skills to compete economically and innovatively in the future. STEM schools may be the answer.

Operationalization of Theoretical Constructs

This study consisted of one construct: student achievement. Student achievement was measured by the mean percent score on the Texas state-mandated test, STAAR, for third, fourth, and fifth-grade STAAR reading and mathematics and the fifth-grade STAAR science.

Research Purpose and Questions

The purpose of this study was to determine if the implementation of integrated STEM (science, technology, engineering, and mathematics) curricula into an elementary school would increase student achievement as measured by STAAR scores. In addition, the researcher sought to identify K-5 STEM educators' perceptions of STEM education and identify key components of a successful STEM elementary school. The current study addressed the following research questions:

Research Question 1: Does integrating STEM curricula into an elementary school increase students' Grades 3-5 Reading and Mathematics and Grade 5 Science STAAR scores?

Research Question 2: What are K-5 STEM educators' perceptions of STEM education and key components of a successful STEM elementary school?

Research Design

This was an exploratory case study using a mixed-methods research approach (QUAL-quant) that examined K-5 educators' perceptions of STEM education and STEM schools. The advantage of a mixed-methods design is that it provides both breadth and depth of data (Creswell, 2003). This study provided an in-depth, multifaceted exploration of one elementary school's K-5 STEM educators' perceptions of the implementation of integrated STEM curricula into their school. It is therefore considered a case study using mixed methods (Creswell, 2007; Lichtman, 2010).

Texas teachers administer state exams, STAAR, annually to provide benchmark data to measure achievement individually, holistically and within subpopulations. Upon the release of the 2017 Texas STAAR data, the researcher gathered quantitative data to compare reading, mathematics, and science STAAR scores from the years 2012-2017 to look for trends in student achievement prior to the integration of STEM curriculum in the elementary school to the present. The researcher sent a survey to all K-5 educators at the site, and conducted interviews with the principal, content specialists, and the librarian. In addition, the researcher conducted interviews with teachers and collected observational data from the engineering laboratory. Once data collection was completed, the interview data was transcribed using Rev.com and the accuracy of the transcripts was reviewed by the researcher.

Site

A suburban elementary school in Texas was selected for this study because it implemented an integrated STEM education program into the school during the 2014-2015 academic school year. This allowed the researcher to use the 2012-2013 and 2013-2014 academic school year STAAR data as a comparison for this study. In addition, this study site was purposefully selected and chosen out of convenience because the researcher was studying STEM education and it is one of the few STEM schools in the area.

The elementary school was built in the 1960s and is one of over 25 elementary schools in a Texas school district. It has a rich history of STEM ideals, originating with the enthusiasm of the “space race” and late President John F. Kennedy’s speech at Rice University in 1962. President Kennedy inspired the nation when he said, “We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard” (John F. Kennedy Presidential Library and Museum, paragraph one, n.d.). The implementation of STEM curricula began in the fall of 2014, when kindergarten through fifth-grade students were expected to participate in 21st century STEM skills, including critical thinking and solving real-world problems. It was chosen to be a STEM school because the principal wanted to create a program that would increase the school's attendance, which had declined because of rezoning in the school district. In addition, the focus was to prepare students for a competitive workforce where critical thinking, problem-solving, communication, and technology skills are imperative to their success. Thus, the idea of a STEM school was created.

Population and Sample

In this study, the population consisted of a purposeful sample of students that took the Grades 3-5 Mathematics, Grades 3-5 Reading, and Grade 5 Science STAAR during 2012-2017 academic school years in a public school district in Texas. The researcher used purposeful sampling and included participants based on their attendance and participation in the 2012, 2013, 2014, 2015, 2016, and 2017 STAAR at an elementary school in Texas. The researcher used annual TEA STAAR score reports from the TEA website that is accessible to the public (TEA, 2018). The sample consisted of the total number of third, fourth, and fifth-grade students at an elementary school who took the Grade 3 Mathematics and Reading, Grade 4 Mathematics and Reading, and Grade 5 Mathematics, Reading, and Science STAAR during the 2012-2017 STAAR administrations. Student populations who took STAAR between 2012 and 2017 have fluctuated over the six years. Sample population demographic data are shown in Tables 3.1 and 3.2.

Table 3.1

Sample Population Ethnic Distribution Data
Source: TEA Texas Academic Performance Report

STAAR Administration	Total Number of Students	*African American*	*Hispanic*	*White*	*American Indian*	*Asian*	*Pacific Islander*	*Two or More Races*
2012*	461	18	96	297	5	19	0	26
2013	440	16	97	288	0	16	0	23
2014	465	17	111	303	1	15	0	18
2015	492	14	96	328	2	24	1	27
2016	519	11	120	328	2	29	0	29
2017	599	18	142	369	1	33	0	36

**TEA Academic Excellence Indicator System*

Table 3.2

Student Demographic Data

STAAR Administration	Total Number of Students	*Economically Disadvantaged*	*Non-Educationally Disadvantaged*	*English Language Learners (ELL)*	*At-Risk*
2012*	461	94	367	9**	111
2013	440	63	377	6	76
2014	465	78	387	7	141
2015	492	74	418	19	125
2016	519	69	450	25	128
2017	599	91	508	29	204

Source: TEA Texas Academic Performance Report

**TEA Academic Excellence Indicator System; **Limited English Proficient (LEP)*

Participant Selection

The researcher selected the participants based on their roles (i.e., administrators, content specialists, librarian; and K-5 teachers) and years of experience (Table 3.3) at the elementary school. The administration, specialists, and librarian were recruited to participate in this study because of their leadership positions and their in-depth knowledge of the implementation of STEM into the elementary school. The teachers were selected for this study because they teach at an elementary school that implements integrated STEM curricula.

Table 3.3

Teacher Years of Experience

Academic School Year	Total Number of Teachers	*Beginning Teachers*	*1-5 Years Experience*	*6-10 Years Experience*	*11-20 Years Experience*	*Over 20 Years Experience*
2011-2012*	28	1.0	4.0	7.0	11.0	5.0
2012-2013	25.7	0.0	5.0	6.8	7.9	6.0
2013-2014	29.5	1.0	6.0	6.9	10.7	5.0
2014-2015	31.0	0.0	7.0	7.0	11.0	6.0
2015-2016	31.0	0.0	9.0	7.0	10.0	5.0
2016-2017	33.0	0.0	7.0	9.0	13.0	4.0

*Source: TEA Texas Academic Performance Report; *TEA Academic Excellence Indicator System*

Instrumentation

In this study, mean percent data was collected using Mathematics STAAR and Reading STAAR for grades 3-5 and Grade 5 Science STAAR. Texas relies on the results of these annual exams to capture student performance to indicate the overall impact of student learning on student achievement at the state and local levels. The Texas Education Agency (TEA) adheres to a strict process to develop and field test items on state assessments to ensure that the instruments are valid and reliable. According to TEA, the STAAR assessment is regarded as a reliable and valid instrument (Texas Education Agency, 2010). Texas and the federal government approved it as the standard to be used to test for student achievement. The STAAR was first administered during the 2011-2012 school year.

Table 3.4

Total Content Alignment and Blueprint Consistency Results

Subject	Grade	Blueprint # Questions	Form # Questions	Average Percentage of Items Rated Fully Aligned to Expectation among Reviewers	Average Percentage of Items Rated Partially Aligned to Expectation among Reviewers	Number of Items Rated as Partially Aligned by One or More Reviewer	Average Percentage of Items Rated Not Aligned to Expectation among Reviewers	Number of Items Rated as Not Aligned by One or More Reviewer
Mathematics	3	46	46	97.8%	2.2%	Three items	0.0%	
Mathematics	4	48	48	96.5%	3.5%	Five items	0.0%	
Mathematics	5	50	50	98.5%	1.5%	Three items	0.0%	
Reading	3	40	40	86.2%	12.5%	16 items	1.2%	Two items
Reading	4	44	44	91.5%	7.4%	10 items	1.2%	Two items
Reading	5	46	46	88.6%	8.7%	13 items	2.7%	Five items
Science	5	44	44	98.3%	1.1%	Two items	0.6%	One item

Adopted from Independent Evaluation of the Validity and Reliability of STAAR Grades 3-8 Assessment Sores: Part 2, available at https://tea.texas.gov/staar/vldstd.aspx

An independent evaluation organization, Human Resources Research Organization (HumRRO), was contracted by TEA to provide information on the validity and reliability of the STAAR scores (i.e., grades 3-8 reading and mathematics, grades 4 and 7 writing, grades 5 and 8 science, and grade 8 social studies). HumRRO's review (Table 3.4) process consisted of three tasks: Task 1 identified the content validity of the assessments; Task 2 provided empirical evidence of the projected reliability and standard error of measurement (SEM); and Task 3 reviewed documentation of the test construction and scoring processes. When examining content validity of the 2016 forms, HumRRO found that the blueprints and majority of items aligned with the Texas Essential Knowledge and Skills (TEKS) expectations for grades 3-5 mathematics and reading and grade 5 science. Thus, HumRRO's findings support STAAR's content validity. Projected reliability and conditional standard error of measurement (CSEM) estimates were acceptable (Table 3.5). In addition, they concluded that the test construction and scoring process were consistent with industry standards and the test measures the knowledge and skills provided in the TEKS and test blueprint, therefore, providing the development of tests that produce valid and reliable assessment scores.

Table 3.5

Projected Reliability and SEM Estimates

Subject	Grade	KZH Projected Reliability	KZH Projected SEM
Mathematics	3	0.918	2.77
Mathematics	4	0.916	2.80
Mathematics	5	0.913	3.09
Reading	3	0.890	2.65
Reading	4	0.913	2.71
Reading	5	0.908	2.75
Science	5	0.883	2.74

Source: The Texas Education Agency reporting website, https://tea.texas.gov/staar/vldstd.aspx

Data Collection Procedures

Quantitative

After receiving approval from the Committee for the Protection of Human Subjects (CPHS) at the University of Houston-Clear Lake and from the participating school district, the researcher collected publicly available archival STAAR quantitative data from the TEA for the 2012-2017 academic school years. These data were used to evaluate student achievement trends in reading and mathematics for grades 3-5 and science for grade 5 for an elementary school in Texas.

Qualitative

Survey and interview data were collected to identify educators' perspectives on STEM education and key components of a STEM school. The observational data collected allowed the researcher to see the integration of STEM during the engineering laboratory. The following sections consists of survey, interview, and observational methodologies.

Survey. The researcher created the K-5 Educators' Perception Survey using Qualtrics software. The survey consisted of a cover letter containing implied consent by participants taking the survey, 15 open-ended items, four dichotomous items (three yes/no items and one gender), and 10 nominal items which included demographic questions. The survey was emailed to the STEM content specialist at the site. The STEM content specialist forwarded the email containing the cover letter and link to the survey to 44 staff members at the site. When participants first clicked on the survey, they saw a page with the informed consent letter. By clicking "I agree," they indicated their consent. Those who did not agree were exited from the survey. The anonymous online survey took an average of 14 minutes to complete. The researcher-designed questions focused on how teachers perceive STEM education, professional development opportunities, professional learning communities (PLC), lesson plan development, and key components of a STEM school.

Interviews. During December 2017, the researcher conducted semi-structured face-to-face interviews with the STEM specialist, librarian, and teachers. In the spring of 2018, the researcher conducted a semi-structured telephone interview with the principal, two face-to-face follow-up interviews with two teachers, and in the summer of 2018 conducted a follow-up telephone interview with the librarian. The researcher also emailed the principal and librarian follow-up questions during the summer of 2018.

The researcher emailed the interview protocol and questions to the STEM specialist and she forwarded them to the K-5 teachers and librarian prior to the interviews to allow them time to process the question and formulate their answers. Preceding the interviews, the participants were asked to complete a consent form if the interview was in person or to verbally consent if it was a phone interview. The participants were also notified that the interview was being audio recorded. Once they agreed, the interviews lasted approximately 20-40 minutes. The researcher took minimal notes in her field journal as the interviews took place.

School leadership interviews. The principal interview focused on why this elementary school was chosen to be a STEM school, steps the principal has taken to ensure it is successful, and the principal's perception of key components of a STEM school. In addition, the researcher asked the STEM specialist and librarian to share their roles in developing Gemini Elementary as a STEM school, their perspectives on what are key components of a successful STEM school, and what 21st century skills do students acquire at their school. The Gemini leadership team guided innovative changes within the school platform, and the principal was seen as the visionary for the implementation of the integrated STEM movement in their school.

Teacher interviews. Teachers were asked to participate in interviews during their lunch period, per the principal's and STEM specialist's request. The interviews addressed one to three participants per interview. After a participant answered the interview question, the researcher thanked them by name. This helped the researcher keep track of specific data from the participants when the interview data was transcribed. Most interview groups consisted of teachers who taught the same grade level, but some were made up of teachers of different grade levels. The interviews addressed the K-5 teachers who volunteered to participate during their lunch period.

The purpose of the teacher interviews was to collect qualitative data pertaining to the implementation of integrated STEM at Gemini Elementary school. The researcher asked participants' perspectives on how STEM education was approached at their school, key components of a successful STEM school, and what 21st century skills students acquired at Gemini Elementary. Additionally, participants who worked at the elementary school prior to the implementation of STEM were asked about differences prior to and after the implementation of the integrated STEM curriculum.

Before participants left, the researcher asked participants if they would be willing to participate in an additional follow-up interview off-site. Interested participants completed a form for the researcher to contact them when the follow-up interviews would take place. The researcher emailed the eight participants and four of these participants agreed to participate in the follow-up interviews. Due to unforeseen weather conditions, only two teachers were able to participate. The researcher analyzed the initial survey and interview data and created follow-up teacher interview questions based on the initial data and the theoretical framework; these questions were used during the second teacher interviews in February 2018.

Observations. Engineering laboratory observations took place when the principal and STEM content specialist had evaluated the teacher curriculum and students were participating in the engineering laboratory in December 2017. The purpose of the observations was to collect qualitative data pertaining to how the integration of STEM was utilized during the EDP in the engineering laboratory. The researcher focused on how students were using the EDP and 21st century skills to support STEM education. The STEM specialist provided the researcher with two EDP options to observe; one was the week after Thanksgiving and the other was during mid-December. The researcher observed a fourth-grade class constructing Cargo Boats during the weeklong engineering laboratory in mid-December 2017. The researcher selected this time because it was at the closure of a unit that provided students with the opportunity to synthesize the knowledge they learned in science and history and apply it to a real-world problem.

Prior to the initial observations, the researcher provided the specialist with two Flip cameras with tripods to set up; this was to conduct the recordings of the engineering laboratory. To reduce the impact of the researcher at the site, the STEM specialist and principal determined that video recording three of the four observation days would be best for their teachers and students. The researcher observed and recorded the EDP lesson on the Tuesday students were designing and beginning to construct their cargo boats. Monday, Wednesday, and Thursday were recorded by the STEM specialist. The researcher picked up the observation data from the specialist. The researcher viewed Monday's video to take notes and sketch diagrams in her field journal of the Cargo Boat EDP. When the researcher began to review Wednesday's and Thursday's video-recorded observations to take notes in her field journal, she noticed the observations were not recorded. She contacted the STEM specialist via email. Since the Cargo Boat EDP had already passed, the researcher could not collect additional observational data from this EDP. The STEM specialist emailed pictures of the students' final Cargo Boats to the researcher.

Data Analysis

Quantitative

Data were collected from TEA's Texas Academic Performance Reports (TAPR) from the years 2012-2017 to answer the following research question: Does integrating STEM into an elementary school increase that school's Grade 3 STAAR, Grade 4 STAAR, and Grade 5 STAAR reading and mathematics scores and Grade 5 science STAAR scores?

For this study, the 2012-2013 and 2013-2014 academic school years prior to the integration of STEM into the elementary school served as the comparison group prior to the 2014-2015 implementation year. Data were analyzed in SPSS using descriptive statistics to compare the mean scores of Grade 3-5 Mathematics STAAR, Grades 3-5 Reading STAAR, and Grade 5 Science STAAR scores.

Qualitative

After all data were collected, the researcher sent the audio files to Rev.com to be transcribed. Once the researcher reviewed the transcriptions for accuracy, they were imported into QSR International's NVivo 10 qualitative data analysis Software. Survey data were also uploaded to NVivo. The data were divided into meaningful units and a priori and emergent codes were assigned. Text was coded manually by the researcher and auto-coded based on patterns and queries. Manual codes were compared with the auto-codes to look for additional codes. Each code was assigned a different color and stored as nodes. The coded data were used to look for trends and analyzed for modifications to the codes or emerging themes.

Once themes were decided upon, the researcher reviewed the theoretical framework and noticed that many of the themes and subthemes fell into categories like those of the framework. The researcher reorganized the themes accordingly. Then the researcher noticed common themes within different sections of the framework and decided to reorganize the themes by key components. Two experts reviewed the qualitative results and feedback was utilized to add support and strengthen the themes.

Qualitative Validity

Validity was established throughout this study. First, open-ended survey and interview questions were reviewed by colleagues, STEM content experts, and qualitative research experts. The K-5 Teachers' STEM Perceptions survey was reviewed by three STEM experts. Feedback from the suggestions and modifications allowed the researcher to modify the survey questions to encompass different perspectives. The survey was sent to two STEM content specialists and a research expert to look for inconsistencies and to suggest modifications to the wording of the questions. Thus, face and content validity were established prior to sending the participants the K-5 Teachers' STEM Perspective survey.

Validity was also established through making connections between quantitative and qualitative data by triangulation. The researcher compared the quantitative data with the qualitative data from the K-5 Teachers' STEM Perception survey and interview data to determine if the teachers' perceptions of implementation of integrated STEM curricula affected test scores. Furthermore, the responses of participants who completed the survey and participated in the interviews were analyzed for consistency in responding to similar questions. In addition, she then used the observational data to see what the implementation of integrated STEM curricula looked like, so she could triangulate it across interview and survey data. Since the researcher triangulated the quantitative and qualitative data, validity was established in this mixed-methods study.

Researcher Identity

This is the researcher's 18th year teaching science. She has taught sixth through eighth grade, regular and pre-AP (advanced placement), and in traditional and personalized learning classroom that focus on project-based learning. A few years after she began teaching, she noticed she lacked the knowledge and skill set needed to teach geology to her sixth-grade students. Instead of looking in her school district for professional development, the researcher decided to attend geology classes to acquire the knowledge she lacked. She began attending a series of geology courses (i.e., historical geology, physical geology, environmental geology, planetary geology, and research seminar) at Rice University in Houston, Texas, over a two-year period. At the end of two years, the courses cycled, and the participants could take them again. She found these courses and the classroom activities presented in them invaluable and continued taking the courses past the original two years. Her geology professor encouraged her to apply for the Master of Science Teaching program at Rice University. She applied and was accepted.

In additional to the geology courses taken (for the second time), the researcher began taking astronomy and physics courses with another professor. During this time, the astronomy and physics professor encouraged her masters' students to participate in the National Science Teachers Association (NSTA) conference in Philadelphia and San Francisco. At the NSTA conferences, she helped provide information about the Discovery Dome, a portable planetarium, and how it works. She did not realize at the time that participation at the conferences sparked the researchers' interest to set the researcher up for presenting at conferences in her future. She graduated from Rice University in May 2011 with a Master of Science Teaching in Physics.

After obtaining her degree, the researcher looked for doctorate degrees to continue her education but did not come across any programs that sparked her interest. She continued to teach eighth-grade science. In November 2012, she had her son and her advancement of her education was put on hold. During this time, she attended and led several science professional development trainings. One training, the Sustainable Trainer Engagement Program (STEP), through the Lunar and Planetary Institute (LPI), helped the researcher learn the necessary content to begin presenting Texas Essential Knowledge and Skills (TEKS) content at the Harris County Department of Education (HCDE) in Houston and LPI in Clear Lake, TX. During this time, the researcher honed her presentation skills. She began presenting relevant TEKS content at state conferences such as CAST and the National Science Teachers Association (NSTA) Regional conferences and NSTA STEM symposiums. She then started presenting TEK specific for her home school district in focus meeting trainings.

In the fall of 2014, a close colleague encouraged her to apply for the new doctorate program, Ed.D. in Curriculum and Instruction with a STEM focus, at the University of Houston-Clear Lake. This was the perfect opportunity she was looking for. She was working with an all-female STEM group of eighth-grade teachers at her school and thought this doctorate would help her highlight the need for females in STEM careers. After a few years in the program, she realized there are many different definitions or perceptions of STEM and STEM education. She wondered how different stakeholders (i.e., education, industry, and policymakers) could impact STEM curricula, programs, and initiatives. She was particularly interested in how different perceptions of STEM education could impact K-12 students early in their educational careers. She then switched her focus to identifying K-5 teachers' perceptions of STEM and identifying key components of a successful STEM elementary school.

Privacy and Ethical Considerations

CPHS approval was obtained from the University of Houston-Clear Lake's CPHS and the participating school district prior to the beginning of this study. For the quantitative component of the study, archival data were used, and students' personal information was not included, reducing the possibilities for ethical issues to arise during this study. Since archival data is publicly available, there was no need to obtain permission from the Texas Education Agency (TEA) to use STAAR data for the study.

For the qualitative component, educator participants received an informative letter at a faculty meeting introducing the research study. Additionally, survey participants were emailed a cover letter explaining the intent of the research prior to consent, and the cover letter appeared on the first page of the online survey prior to participants taking the survey. The cover letter stated that participation would be completely voluntary, the survey would take approximately 15-20 minutes, responses would be kept confidential, and the data was used for the researcher's dissertation.

Interview participants were given an informed consent form providing the purpose of the study, the acknowledgement that their participation was voluntary, and ensuring complete confidentiality. Phone interview participants consented to participate orally.

Participants in all sections of the qualitative study identified themselves with the last four digits of their phone numbers. This helped the researcher to track data between qualitative sections and keep the participants' identities confidential. In this dissertation, pseudonyms were used instead of the last four digits of the participants' phone numbers. Pseudonyms were used to protect the participants' identities, and personal information will be kept securely locked in a safe at the researcher's home. Thus, minimal risk to the participants was anticipated. All data will be kept on an external hard drive, locked in a safe at the researcher's home for a minimum of five years, after which it will be destroyed.

Research Design Limitations

There were several limitations that affected the planning of this study. The area in which the research site is located was severely impacted by Hurricane Harvey and the subsequent flooding and school closure. Many educators felt too busy to participate, limiting the perspectives and/or resulting in a lower number of participants. The Institutional Review Board (IRB) committee for the school district did not grant the researcher access to all K-8 teachers in their district and only approved a single study at the site with K-5 educators. At the site, participants might have been apprehensive to share their thoughts with the researcher, so the initial interviews were conducted on-site, and the follow-up interviews were conducted off-site. Additionally, the researcher was not comparatively experienced in creating surveys and collecting data, which may have affected the quality of data collected. Finally, since this was a case study, results will not be able to be generalized to other schools due to the small sample sizes.

Conclusion

The purpose of this study was to determine if implementing integrated STEM (science, technology, engineering, and mathematics) curricula into an elementary school would increase student achievement as measured by the State of Texas Assessments of Academic Readiness (STAAR) scores. Descriptive statistics were used to compare mean scores of Grade 3-5 Mathematics STAAR, Grades 3-5 Reading STAAR, and Grade 5 Science STAAR scores. In addition, the researcher sought to identify K-5 educators' perceptions of STEM education and key components of a STEM elementary school. It was the goal of the researcher to provide educators, school districts, and policymakers a QUAL-quant mixed-methods insight to educators' perceptions on STEM education.

CHAPTER IV:

RESULTS

Introduction

The purpose of this QUAL-quant mixed-methods case study was to determine if integrating STEM (science, technology, engineering, and mathematics) education into an elementary school would increase student achievement as measured by the STAAR scores. In addition, the researcher sought to identify K-5 educators' perceptions of STEM education, key components of a STEM school, and how the use of an engineering laboratory supports STEM education.

This research was important because implementing STEM curricula in elementary schools is essential for students to acquire 21st century skills such as problem-based learning and collaboration skills that are needed to be successful in future STEM workplaces (DeJarnette, 2012). Initially, many new STEM initiatives focused on middle and high school students, but more programs are beginning to focus on elementary students (DeJarnette, 2012; Vasquez, 2005). It is essential to begin STEM education before rival interests distract students from developing a broad STEM foundation so that they may have a better opportunity to take advantage of future jobs and the U.S. may have the personnel to continue as a global leader. Previous research confirmed the need to expose students to STEM education at an early age (DeJarnette, 2012); early interest in STEM concepts is considered foundational for creating a competitive workforce (Tannebaum, 2016). However, since there is a lack of agreement as to what defines STEM, it is difficult for educators, policymakers, and stakeholders to agree on exactly how to increase STEM education in the U.S. (Schneider, Bahr, Burkett, Lusth, Pressley, & VanBebbekom, 2016). Therefore, to clarify language for stakeholders and add to the knowledge base for elementary students, the researcher sought to measure testing data from an elementary school, to examine administrative and teaching personnel's perspectives, and to investigate the addition of an engineering lab to an elementary school, and thus asked the following research questions:

Research Question 1: Does integrating STEM curricula into an elementary school increase students' Grades 3-5 Reading and Mathematics and Grade 5 Science STAAR scores?

Research Question2: What are K-5 STEM educators' perceptions of STEM education and key components of a successful STEM elementary school?

The findings of this study included the comparison of STAAR testing in grades 3-5 reading and mathematics, and science grade 5 from 2012 to 2017 from an elementary school in Texas, insights from the principal, STEM specialist, and teachers, and observations of the engineering laboratory. The school implemented STEM education for all students in the fall of 2014. The K-5 Educators' STEM Perceptions Survey was sent to 44 staff members. The principal, STEM specialist, librarian, and 15 teachers were interviewed. Interviews took place from December 2017 through July 2018. Observations of the engineering laboratory took place during December 2017.

This chapter presents the findings of the quantitative and qualitative data analysis of this study. The participants' demographics of the study will be presented first and then the results for the two research questions and summary of the findings are presented.

Participant Demographics

The administration and teachers were selected to participate in the study because they worked at an elementary school during the 2017-2018 academic school year that had implemented integrated STEM education starting in 2014-2015 and continued to be a STEM campus. Participants were selected based on their willingness to take the K-5 STEM Educators' Perception Survey and/or participate in interviews. Fifty-two percent (*n*=17) of teachers and content specialists who were emailed the survey completed it. Survey participants included two content specialists, two kindergarten, two first-grade, one second-grade, three third-grade, and four fifth-grade teachers, and three teachers who reported that they taught multiple grade levels. Twelve survey participants were White, one African American, three Hispanic, and one did not report their ethnicity. The participants' ages ranged from 25 to over 55. When asked how many years they have worked at Gemini Elementary, participants responded as follows: three 0-3 years, six 4-6 years, one 7-9 years, six 10 or more years, and one participant did not respond. Nine survey participants' highest level of educated completed was a bachelor's degree, whereas six received a master's degree and one a doctorate degree. When asked what STEM courses they took while in college, almost all of the teachers reported that they had not taken any specific STEM courses. The teachers, content specialist, and librarian are all female and the principal is male. Table 4.1 presents educators' pseudonyms and demographic information of interview participants.

Table 4.1

Participant Demographics

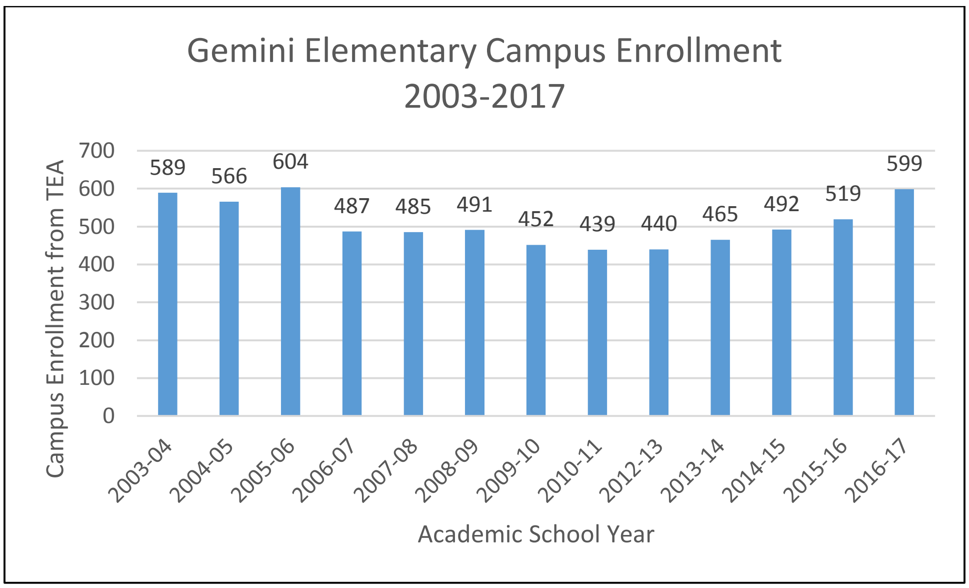
Pseudonym	Survey	*Interview*	*Grade Level/Role*	*Years' Experience in Education*	*Ethnicity*	*Age Range*
Mr. Pettit		X	Principal	26 or more	White	Over 55
Dr. Curtis	X	X	STEM Specialist	21-25	White	45-54
Ms. Jemison		X	Librarian	16-20	African American	45-54
Ms. Fernandez	X	X	Kindergarten	6-10	Hispanic	25-34
Ms. Bell	X	X	Kindergarten	26 or more	White	45-54
Ms. Lopez		X	Kindergarten	6-10	Hispanic	25-34
Ms. Anderson		X	1st Grade	6-10	White	25-34
Ms. Bowe	X	X	1st Grade	11-15	African American	45-54
Ms. Lander		X	2nd Grade	26 or more	White	Over 55
Ms. Spitz		X	2nd Grade	11-15	Multiracial	25-34
Ms. Shepard	X	X	3rd Grade	6-10	White	35-44
Ms. Kelly		X	4th Grade	11-15	White	35-44
Ms. Neil	X	X	5th Grade	6-10	White	35-44
Ms. Cooper	X	X	5th Grade	21-25	White	45-54

History of STEM Education at Gemini Elementary

Although not part of the original framework for this study, the history of how a STEM program began at Gemini Elementary School emerged as an important theme. Survey and interview data provided a reason as to why STEM education became important and was seen as a solution to Gemini Elementary school's decreasing campus enrollment (Figure 4.1). The principal at Gemini Elementary was concerned about his school's decreasing student population due to their school district's decision to change the campus's boundary, which took effect during the 2006-2007 campus enrollment. The principal became increasingly concerned as the student population continued to decrease in subsequent years. In addition, the boundary for attendance zone changes decreased the population of identified gifted students, with half of these students being shifted to a neighboring elementary school.

Figure 4.1

Gemini Elementary Campus Enrollment According to TAPR



Consequently, Gemini Elementary experienced a significant decrease in their campus enrollment. The principal decided to work with the science curriculum coordinator because his initial thoughts were to create a science magnet program at his school. He stated, "I started thinking about a magnet school because of … our school was underpopulated by students and because of recent construction nearby with another school. And so, I really looked at maybe a science magnet." The science coordinator steered the principal toward the idea of STEM and he began speaking to his staff about the idea of going in a different direction with their school. When discussing different options with the specialist, the principal recalled saying, “Let’s start thinking about how we can be different as a school and really move our students in their thinking.” During a faculty meeting, staff members brainstormed and discussed their options. “The idea of a STEM campus emerged out of that conversation with the faculty,” the principal noted. The principal and science coordinator began working together with the district assistant superintendent for elementary education and formulated more specifics about what a STEM program might look like. The principal formed an exploratory committee to investigate ways to increase campus enrollment and provide a vision to educate 21st century learners. They proposed their school be converted to a magnet school and presented that idea to the school board. The board agreed to provide them with two half-time positions for a STEM specialist to coordinate the STEM magnet program, and an instructional science coach.

When planning the STEM magnet program, the administration team decided not to have a school within a school but to provide this opportunity through a lottery system open to all students in the school district. The STEM specialist explained:

> And when we were planning the STEM program, there was nothing that we were planning that all kids couldn’t benefit from, so we didn’t understand why we couldn’t have a school, a STEM school for everyone and then the magnet to attract other kids to our school, so we went that route.

As educators at Gemini Elementary continued to explore ideas for their STEM program, they traveled to local school districts that had implemented different programs (i.e., STEM and science magnet schools) and collected ideas. They liked the science magnet program at an intermediate school. The principal recalled, “So we really kind of did a lot of research on what it [STEM] is and then really started thinking about how we could apply those ideas." The following August, the STEM magnet program began to be implemented.

When Gemini Elementary proposed adding a STEM program, their student enrollment had fallen to 467 students. One of the program objectives was to increase the student population to 510-530 students. Student enrollment surpassed the campus goal and increased to approximately 620 students during the 2017-2018 academic school year. Both the principal and STEM specialist attribute the increase in enrollment to the implementation of the integrated STEM and magnet school programs.

Research Question One

Research question one, Does implementing integrated STEM curricula into an elementary school increase Grade 3 STAAR, Grade 4 STAAR, and Grade 5 STAAR reading and mathematics scores and Grade 5 STAAR science scores?, was answered using descriptive statistics from 2012-2017 STAAR scores. Scaled STAAR score data were used to quantify "student's performance relative to the passing standards or proficiency levels" (TEA, 2018, para.1). The integrated STEM curricula were implemented into the elementary school during the 2014-2015 school year, which will refer to the 2015 STAAR in the subsequent sections. The STAAR scores for academic years 2012-2014 were used to assess pre-STEM STAAR scores for purposes of comparison. Students in Texas who take Grade 5 Reading and Mathematics STAAR are provided with retest opportunities. Therefore, the percentage of fifth-grade students who met the passing standard on the Grade 5 Reading and Mathematics STAAR may increase due to the retesting requirements. In this section, results from Reading, Mathematics, and Science STAAR data for 2012-2017 will be discussed.

Reading STAAR

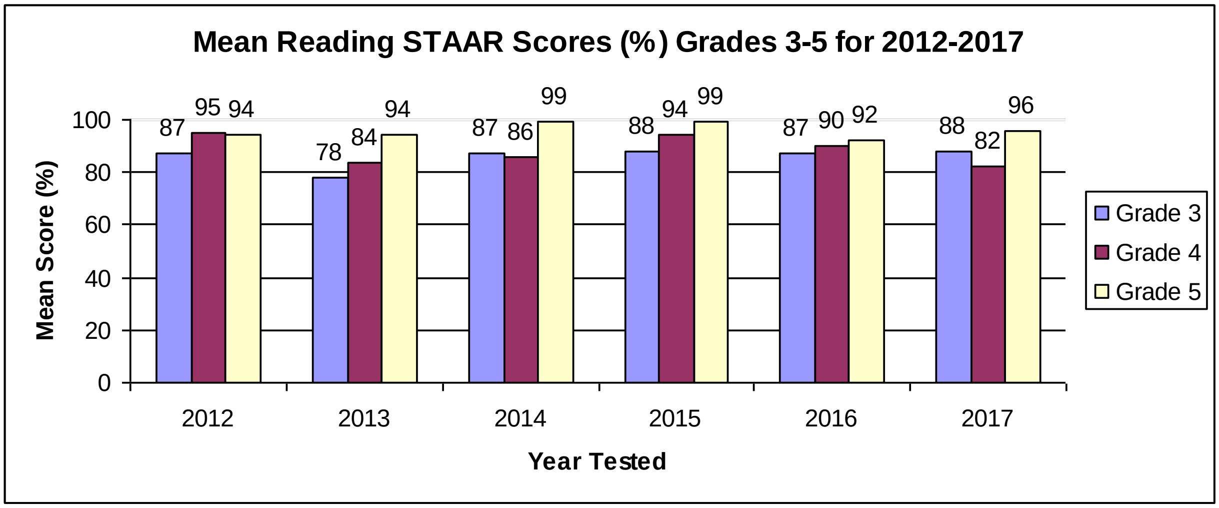
Grade 3 Reading STAAR mean scaled scores decreased nine points and then increased between the 2012 and 2014 testing years. During the implementation year, reading scores increased one percentage point. The Grade 3 Reading STAAR mean scaled scores remained relatively the same between 2015 and 2017.

Grade 4 Reading STAAR mean scores decreased 11% between 2012-2013 and 2013-2014 academic school years and increased two percentage points and then increased two percentage points during 2014. During the implementation year, reading scores increased six more percentage points in 2015. Since 2015, Grade 4 Reading STAAR mean scores have decreased to 82%. This is four percentage points lower than the implementation year and there has been a downward trend in Grade 4 Reading STAAR scores for the past two years.

Grade 5 Reading STAAR mean scores were 94% during 2012 and 2013 and then increased five percentage points to 99% during 2014. During the implementation year, the scores remained the same. In 2016, scores decreased to 92% and then increased to 96% in 2017. This is five percentage points lower than the implementation year. STEM education appears to have affected Grade 5 Reading STAAR scores for two years after implementation and then the scores have increased and then decreased over the last two years.

Figure 4.2

Mean Reading STAAR Scores for Grades 3-5



Mathematics STAAR

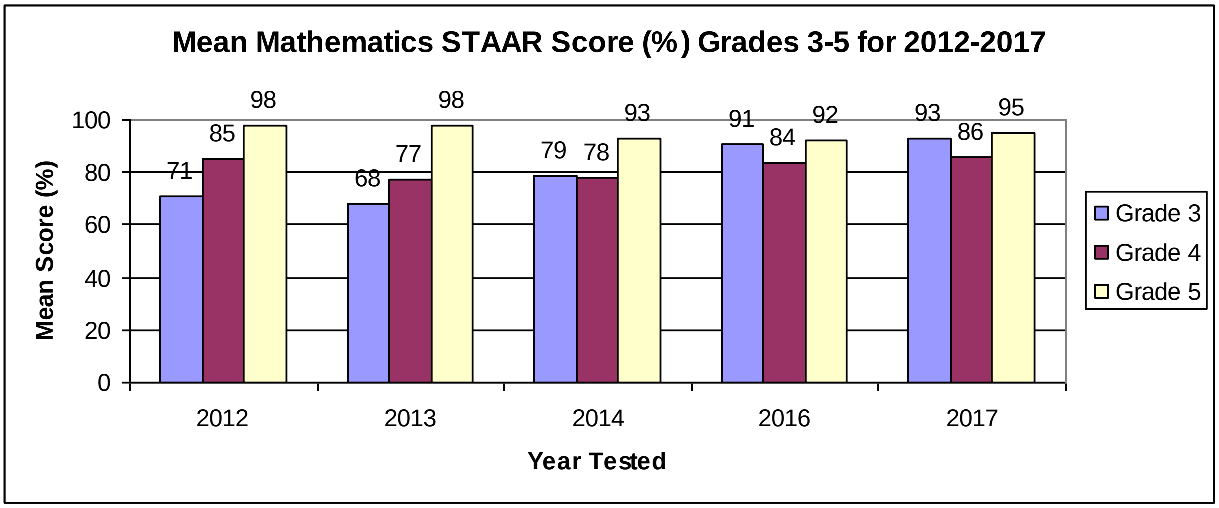
Grade 3 Mathematics mean scaled STAAR scores fluctuated prior to the implementation of STEM education. After the initial implementation phase, Grade 3 STAAR scores increased from 12% to 91% (of students passing the test) in 2016. The Grade 3 Mathematics STAAR scores continued to show a positive trend in 2017.

Grade 4 Mathematics mean STAAR scores were on a downward trend prior to the implementation of STEM education. After the initial implementation phase, Grade 4 STAAR scores increased from 6% to 84% of students passing the test in 2016. The following year, 86% of students met the passing standards.

Grade 5 Mathematics mean STAAR scores were between 93% and 98% students passing prior to the implementation of STEM education. During the implementation year, scores decreased one percentage point to 92% of students passing. In 2017, the Grade 5 Mathematics scores increased to 95% of students meeting the passing standards.

Figure 4.3

Mean Mathematics STAAR Scores for Grades 3-5



**Texas did not report Mathematic STAAR scores for 2015.*

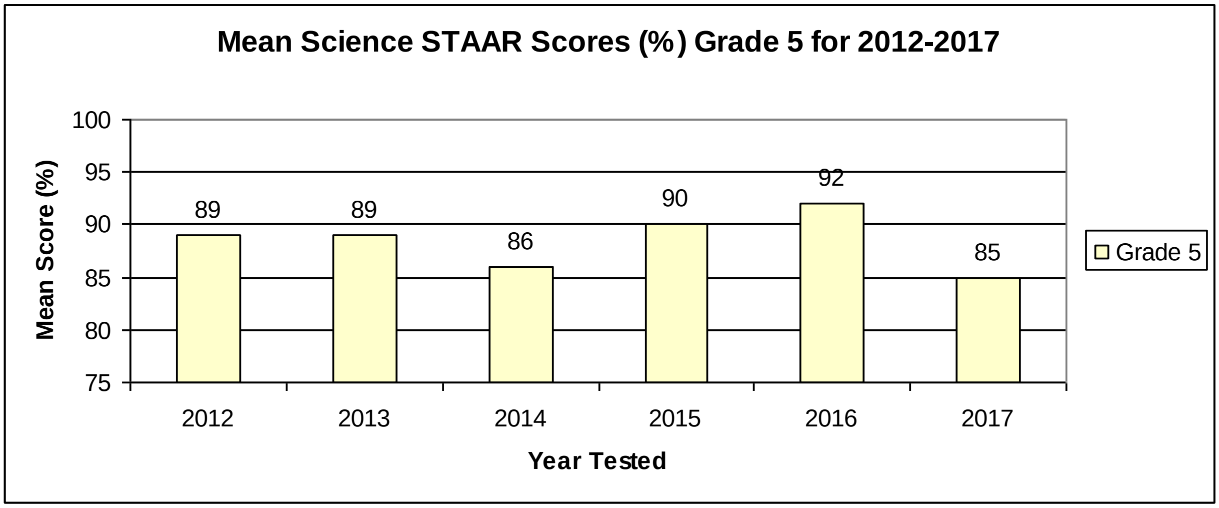
Science STAAR

Students take the Science STAAR for the first time in fifth grade, as compared with reading and mathematics, which students take annually starting in the third grade. The STEM specialist shared that prior to the 2016-2017 academic school year, the principal moved a few key science teachers to teach reading and mathematics. She believed this change impacted the 2017 Grade 5 Science STAAR results.

Grade 5 Science scaled mean STAAR scores (Figure 4.4) were between 89% and 86% prior to the implementation of STEM education. During the implementation year, scores increased four percentage points to 90% of students who met the passing standard. The scores continued to increase for one year, with 92% of students passing in 2016. In 2017, however, Grade 5 Science STAAR scores decreased seven percentage points to 85% of students who met the passing standard. The STAAR data is inconclusive whether the implementation of integrated STEM education data increases students' scores on the state assessment.

Figure 4.4

Mean Science STAAR Scores for Grades 5



Outcome for student achievement. Utilizing the lens of the framework, Gemini Elementary outcomes are closely associated with its goals (Honey, Pearson, & Schweingruber, 2014). Survey and interview data provided an insight regarding student achievement as measured by STAAR and aligns this outcome provided by the theoretical framework.

Outcomes for students. Learning and achievement is a student outcome typically measured using the State of Texas of Assessments of Academic Readiness (STAAR) within schools across Texas. As the principal and STEM specialist reflected, the implementation of integrated STEM education has not caused any "harm" in students' learning and achievement. In fact, the specialist noted, "By the time our kids get to fifth [grade], our data on STAAR were in the 90 percent. So, I feel like the data supports what we're doing." According to interview data, some teachers initially showed concerns about not having enough time for literacy stations or mathematics instructions but now see and understand the academic benefits of STEM in their school. The principal proudly shared that the science and mathematics scores on STAAR are usually within the top five schools in the district; this ranks in the top 3% of Texas when compared with other school districts.

Research Question Two

Research question two, What are K-5 STEM educators' perceptions of STEM education and key components of a successful STEM elementary school?, was answered using an inductive coding process. Open-ended survey and interview data were collected from the principal, STEM specialist, librarian, and teachers regarding their perceptions of STEM education at Gemini Elementary. Observational data was collected during the fourth-grade STEM Block on cargo boats. Major themes and subthemes emerged from the qualitative data analysis process. The major themes were viewed through the lens of the Descriptive Framework for Integrated STEM Education and can be categorized as goals, outcomes, implementation, and integration of STEM education (Honey, Pearson, Schweingruber, 2014). Many of the themes and subthemes intertwined with each other. Thus, the researcher revised the themes and subthemes by the educators' perceptions of the key components of STEM education at Gemini Elementary. For each theme and subtheme, perspectives and comments are presented from the principal, STEM specialist, librarian, and teachers.

Descriptive Framework of STEM Education

According to the framework, "goals are statements of what the developer of the educational intervention hopes to accomplish" and "are the driver for an iterative process of educational change" (Honey, Pearson, & Schweingruber, 2014, p. 33). According to the program proposal, in addition to increasing attendance rates and student achievement, the driving force behind the integration of STEM education into Gemini Elementary was to prepare students for an ever-changing world where they had to solve problems without knowing what technology advancements would take place in the future. When surveyed about what they perceived STEM education was, common responses were "integrated curriculum" or "lens" of STEM subjects, sometimes with the arts, that provides students opportunities to gain "critical thinking," "problem solving," and "creativity" using "project-based," "hands-on," and "real-world application." These concepts are an integral part of the emergent goals, such as using planned integration to build teacher capacity for STEM education.

Survey and interview data provided an insight as to what goals and their related outcomes Gemini Elementary hoped to accomplish with the integration of STEM education into their school. Viewed through the lens of the framework, Gemini Elementary outcomes are closely associated with its goals (Honey, Pearson, & Schweingruber, 2014). There are two teacher goals of integrated STEM education at Gemini Elementary that emerged from the data. The two goals, increase teachers' STEM content knowledge and increase teachers' pedagogical content knowledge, are developed often simultaneously through implementation (e.g., professional development opportunities) and integration (modeling of EDP by the STEM specialist) during the STEM block week.

Most of the survey participants referred to STEM education in terms of an integrated curricula utilizing project-based and inquiry-based learning where students are working on hands-on activities. One participant shared, "STEM education is the conscious integration of STEM subjects thought [throughout] the curriculum. We also have more hands-on STEM focused labs/activities for the kids to experience." Whereas another teacher said, "It [STEM education] is the general education that is enhanced by increased opportunities to explore project-based and inquiry-based learning in the areas of STEM.” Regarding what STEM education is, one participant summed up her perception by stating, “Education that promotes creativity, critical thinking, problem solving and real-world application through the lens of the above [STEM] disciplines.” Thus, participants perceived integrated STEM curricula to utilize 21st century skills that will transfer into the STEM workplace in the future. Teachers’ understanding of an integrated curriculum appears clearly linked to the school goal to increase teacher capacity by developing teachers in professional development to construct their pedagogical content knowledge and awareness for what it means to be a STEM school.

According to survey and interview data, most teachers’ attitudes centered around the belief that the integration of STEM education in their classroom and engineering laboratory is vital to the success of their students who will be competing for STEM jobs. One third-grade teacher stated, “STEM education is the integration of Science, Tech, Engineering, and Math and other subject matters as seamless as possible. It is finding the connections that naturally occur cross-curriculum.” In addition, another third-grade teacher explained how the integration of STEM taught students to constantly use the EDP. “The students are allowed to plan, revise, design a plan, try it out, redesign, try it out, etc., to solve a problem presented to them,” she noted. Furthermore, the STEM specialist believed that providing students with real-world experiences in STEM is the focus at Gemini Elementary. “Engineering is usually missing in elementary school. Our real-world experience focus [focuses] on problem solving and critical thinking,” she shared. A first-grade teacher felt that STEM education will promote interests in and prepare students for STEM careers. Overall, educators at Gemini Elementary felt that integration of STEM curricula was helping them to make connections between disciplines, the EDP, and real-world applications that will allow students' interests in STEM careers to evolve over time.

Based on educators' perceptions, Gemini Elementary displayed well-planned and purposeful implementation and integration strategies, which is critical to their success as a STEM school (Honey, Pearson, Schweingruber, 2014). Qualitative data analysis identified key components within goals, outcomes, implementation, and integration of STEM education at Gemini Elementary. The emergent themes for key components are an instructional leadership team, relevant professional development, teacher collaboration, making connections, vision and school culture, 21st century skills, and the integration of the engineering laboratory.

Key Components

Instructional leadership team. The success of schools and school initiatives is often the result of a strong instructional leadership team. For this research, the leadership team at Gemini Elementary consisted of the principal, STEM specialist, and school librarian. Each team member played an important role in the development of Gemini Elementary STEM curricula and continue to increase teachers' STEM content knowledge and pedagogical practices through a variety of support systems. The principal was very involved with the creation of the STEM school but said that a great deal of the curriculum and support pieces fell to the specialist and librarian due to their roles. This section includes the roles of the STEM specialist and school librarian.

STEM specialist. Support provided by the specialist at Gemini Elementary has helped teachers feel more comfortable integrating STEM and learning the EDP lessons. One first-grade teacher felt the STEM specialist's role was vital to the success of their school. She believed the specialist provided her with support and was helpful when she stated:

> Our wonderful science coach and the other coaches working together, encouraging us, and providing opportunities to learn more STEM activities, giving us the tools we need to implement activities in our classroom and helping us in any way they can.

The specialist developed the lessons using the EDP and continually trained teachers during implementation. In addition to the training at the beginning of the school year, teachers participate in half-day planning sessions once each nine weeks grading period where they work with the specialist on how to implement the engineering design lesson. The principal recalled:

> Our STEM coordinator [specialist] spent a lot of time in the lab, the STEM lab with our teachers, making sure they understand how to go through the lessons. And so that was a key component, I think, is really helping out those teachers that are more uncomfortable with it or not used to it and taking them through it. So that was probably the biggest parts.

The principal perceived that the STEM specialist was a key component to the implementation of integrated STEM curriculum and success of their school's program. As well, it was a constant reminder of the goals that encouraged teachers to achieve a level of confidence and build their STEM content knowledge and skills with integrating the EDP.

Based on interview data, the specialist was also instrumental in the continual professional learning of the staff. Most of the teachers attribute their initial successes with STEM integration to the implementation of the EDP provided by the specialist. Based on teachers' comments, the specialist trained the teachers how to facilitate the engineering laboratory lessons and incorporate the EDP into the school's identity and culture. "She's pushing the kids to go beyond the boundaries, especially during that design part," the second-grade teacher shared. She also noted that the teachers in the engineering laboratory are watching and learning as the specialist models how to question the students to get them to develop their ideas at a higher level.

The specialist's role has transitioned from being the primary facilitator of the EDP for the students to taking a step back and allowing the teachers to facilitate the engineering laboratory. For example, a second-grade teacher said the specialist is in the laboratory two to three times a week. She also stated how teachers are encouraged to begin developing and modifying lessons for the EDP. She recalled:

> Now that we've been through the process so many years, she kind of puts it on us and just kind of is more of a guide for us, and we'll run things past her, like when I started doing the PowerPoints, I'd run it past her.

According to the second-grade teacher, the specialist will now guide teachers and ask them how they can modify their ideas to "make it even more of a challenge." Since this is the fourth year of implementation, teachers are taking a greater role in the engineering laboratory. "There's still modeling going on, but a lot of us have been through the process so many times, it just kind of becomes natural after you go in there so much," the second-grade teacher concluded.

***School librarian*.** The school librarians are campus leaders who are uniquely positioned to take creative risks to support school initiatives while modeling and extending STEM instructional approaches within each discipline. The librarian at Gemini Elementary played an integral part in the implementation and integration of STEM education to achieve the desired outcome of helping students form interests in STEM concepts, which helped create their STEM identity. Based on interview data, the librarian at Gemini Elementary has been instrumental in providing educator supports to the teachers. Librarians need to be ready to help teachers and students and collaborate with other librarians. She has done this through taking the initiative and becoming more creative with ways to integrate STEM into the school. For example, the librarian decided that she would like to have the library play a central role in the development of STEM curricula at Gemini Elementary. When asked how STEM was approached at her school, the librarian stated:

> I would say in makerspace, it's approached where we're teaching STEM topics in an everyday life situation. Organically in their [students'] interest, because there's a lot of choice in makerspace to figure out what they want to study, what they want to learn about in their experience there.

She believed it was important for students to have a place to explore, create, and innovate, and she created a makerspace area in the library that allowed them to do so. She continued to share her perspective and said:

> It's more about experience [than] anything. We're equipping them with the resources, so then in class, when they're doing projects and they can say, "Oh, okay. I can use this resource now that I've learned about green screening or whatever resource" in their projects to show what they've learned.

She believed students would develop greater 21st century skills and perceived this as a key component of STEM education. She wrote a grant to purchase six Raspberry Pi computers and a 3D printer. Other components such as Bloxels, VEX and WeDo robotics kits, Autobots, stained glass, and knitting have been added over the years. She believed as students begin to develop their STEM interests, some find themselves in the library more often playing in the makerspace. She calls them the "makerspace group." Inspired by student engagement and the desire to encourage teachers, she developed creative mays to mobilize the makerspace.

The librarian believed that more students wanted more time in the library to explore the makerspace. “I don’t want people to think that makerspace is something you do in the library for a set amount of time,” she explains. Over the last few years, she has created mobile makerspaces that teachers can use in their classrooms and students can check out to play with at home. The librarian was instrumental in creating take-home makerspaces and collaborated with others on a grant to provide the resources. She recalled:

> We wanted students to have more time with the makerspace resources and that seemed to be an obstacle as we were building our makerspaces [in the library]. And then, also we wanted students to have more time with the books that were relative to the makerspace materials.

The take-home makerspaces allowed students more time to tinker and explore the different components and concepts. In addition, a nonfiction book was paired with the kit to work on expanding their knowledge and literacy skills. This became the standard take-home kit. In addition to students enjoying the makerspace take-home kits, they supported teacher content and literacy skills.

The librarian saw a need to create an educator support to help integrate more STEM ideas into the classroom. She created mobile makerspace carts for teachers to be able to check out. She believed she had a sense of purpose in helping teachers integrate STEM into their classrooms. She said, “I wanted teachers to become comfortable with that material without me standing over them or anyone else seeing what they are doing.” The “popup makerspaces” were created with different groupings in mind. For example, technology-based makerspaces contained littleBits and Autobots, whereas others were based on music, crafts, and logic. She remembered teachers saying, “Now I can use this new material to support my curriculum." The mobile makerspaces allowed the integration of STEM to appear seamless and a natural aspect of Gemini Elementary.

According to the librarian, since the makerspace movement was a relatively new concept for school librarians to utilize across the nation, there was little to no professional development on the subject for librarians. The librarian proudly recalled, "The interesting thing is when makerspace came along, I took to that and ran with it early enough that I was pretty much on the forefront for that." As she began fostering her own understanding of makerspace, the librarian collaborated with librarians within the district and sought to work with librarians across the country. Being at the forefront of utilizing an innovation such as the makerspace has prompted the librarian to share her knowledge at conferences and by writing articles on makerspaces. She believed that creating her own professional learning network (PLN) was a way for her to collaborate with other librarians on how to create a makerspace within school libraries and would help other librarians begin to integrate STEM curricula into their schools. The librarian began to use social media sites such as Twitter to communicate with librarians across the country. "It's crucial for us to build that network so we don't have to reinvent the wheel," stated. Using a PLN allowed librarians to help and support each other in areas in which they struggle. She now uses her PLN as a primary network to be on the forefront of teaching other librarians how to use technology effectively and market the library as a place of innovation and discovery.

Her primary goal of her PLN was to "building [build] a library brand and [share] the importance of library advocacy." "I'm so sad to see the way across the country people are eliminating and thinking that they're saving money by getting rid of the librarian and not seeing their importance," she stated sadly. She feels that librarians can "catapult our education system, because librarians serve a purpose." She believed that purpose is to meet the needs of their patrons, which includes teachers and students, and librarians provide guidance and access to resources for their patrons. Furthermore, she believed that librarians were essential in the curation of resources using open educational resources (OER) and distribution of resources to their patrons. These OERs are “free, authoritative sites for people” that will level the playing field for education because these are databases that people typically must pay for. “There’s now a movement,” she explained, “to make the Internet authoritative for students for research purposes and free.” Currently, curating is being done free using sites like Pinterest and students are able to reinforce and extend their STEM mindset. She predicted that OERs will be the next big innovation to take off. “As OERs start to take off that develop, I could see something like that eventually being free. I don’t know of anything like that, that’s free right now except Pinterest, but I can definitely see that taking off,” she shared. She believed there is a movement with the Internet to make it accessible to all students. She continued, “The Internet, it should be a right and not a privilege for students.” Therefore, librarians are an essential educator support in schools, so they can not only integrate STEM education but also guide students, educators, and parents with the proper resources to use. Furthermore, her belief is that librarians are essential in the curation and distribution of resources to their patrons.

Developing her knowledge and professional learning of makerspace through connecting with other librarians across the nation and researching makerspaces has allowed the librarian to make STEM integration appear to be seamless at Gemini Elementary. She perceived that librarians are a key component in developing the “youth of STEM education” and personalized learning. She believed this is done by being on the forefront of the STEM movement and integrating resources such as the different makerspaces available to students and teachers. She truly believed that “librarians play a central role in building up a STEM program,” and has placed herself and her school at the cutting edge of creating a successful STEM school. Campus leaders take many forms.

Teachers and students are more connected to the STEM initiative because of the work of specialists and librarians who model creative approaches that foster comprehension and a common understanding of STEM.

Professional development. The effectiveness of implementation of integrated STEM depends on developing teacher expertise by developing teachers' content knowledge and pedagogical content knowledge to students with diverse learning needs (Honey, Pearson, & Schweingruber, 2014). During initial implementation, Gemini Elementary educators were provided with opportunities to gain STEM content, pedagogical knowledge and skills, and educator supports were provided by the administration. This section will explain the subthemes that emerged within the key component of professional development. The subthemes are (a) change in practice and (b) presenting at conferences.

As the principal of Gemini Elementary delved deeper into developing a sound, sustainable initiative with STEM curricula, he shared that he knew quality training and educator supports for teachers would be vital to their success. He believed that teachers would have to receive professional development for content and pedagogical skills in their core content areas and in STEM content to develop their abilities to integrate STEM curricula effectively. When asked about the role that professional development played in helping teachers develop their STEM content and pedagogical practices, the principal replied:

> I think the biggest contributor in some ways was simply go attending [attend] conferences because we didn't have a lot of models within the district, for instance, or on our campus about what STEM is or how it functions or how it could function in a school building. So, we really had to go out and do a lot of research by attending conferences.

The STEM specialist shared that their school district's typical model "invested heavily in instructional coaches" and sent them to conferences. They would then share with the teachers at professional development trainings. "I think one of the biggest a-ha's that our principal had was the need for effective staff development," she remembered about how the principal chose to invest in teachers going to national and state conferences.

The main objective of teachers who attended conferences was to gather ideas for furthering the STEM curricula at Gemini Elementary. Teachers who attended shared their learning with the rest of the campus and new ideas began flowing across the campus. Teachers began creating new STEM experiences for students and modified the ones they already had in place. One second-grade teacher shared what she perceived as vital about attending conferences. She recalled:

> It [attending conferences] changes your mindset and even looking at the science curriculum that we already have, one of the activities in our science curriculum, we ended up adapting and changing to a STEM lab just because if you're already thinking that mindset of how can I change, just take a lesson and turn it into a project-based lesson or STEM activity, you can find it everywhere if you're in that mindset.

Thus, she perceived that attending conferences provided teachers with a platform where they felt comfortable modifying science lessons to meet the needs of their STEM students. Having the ability and mindset empowered the teachers at Gemini Elementary, which strengthened their confidence in teaching STEM curricula.

Survey results showed that Gemini Elementary educators attended a vast array of conferences (Table 4.2). A fifth-grade mathematics teacher shared how instrumental attending national conferences were to her and the campus:

> I have attended the NSTA STEM conference once and the NSTA conference three times in the last five years. I feel that these experiences helped me inspire new ideas early on. As a campus, we used some of these experiences to create our own program.

In addition to these conferences, teachers shared that they also attended the American Orff-Schulwerk Association (AOSA) national convention, International Society for Technology in Education (ISTE) conference, Kindergarten Teacher of Texas (KTOT) STEM conference, Music and Technology Conference of Houston (MATCH), Space Center Houston Educators Conference (SEEC), and Texas Music Educators Association (TMEA). The culmination of these professional growth experiences greatly informed educators about the purpose of STEM education as well as the practical application and value of STEM curricula.

Table 4.2

Survey Results for Conferences Attended

Conference	%
American Educational Research Association (AERA)	4.17%
National Council of Teachers of Mathematics (NCTM)	8.33%
National Science Teachers Association (NSTA)	29.17%
National Science Teachers Association (NSTA) STEM Symposium	12.50%
Science Teachers Association of Texas (CAST)	20.83%
South Texas STEM Conference	4.17%
Texas STEM Conference	4.17%
Other Conferences	16.67%
Total	100.00%

The topics covered at the conferences ranged in topics: the introduction of STEM; how to implement STEM activity ideas; and how to ask higher level, open-ended questions; the process of STEM education; integration of the arts into STEM making it STEAM; the integration of technology; and the engineering design process. A fifth-grade teacher perceived that attending conferences were for beginning STEM teachers. She stated,

> Most of the sessions that I attended were specific STEM lessons. They were geared toward teachers that had never taught this sort of lesson before and walked participants through the engineering cycle, materials and classroom management issues. As time went on, I began attending more of the sessions that were given by professionals in the field to broaden my own background knowledge and give me starting points for crafting my own engineering experiences.

Because the addition of the engineering component was new to Gemini Elementary, teachers valued attending conferences and learning about the engineering design process (EDP), which afforded them a way to hone their STEM content and pedagogical knowledge skills over time.

When attending state conferences, the teachers quickly realized these conferences didn't meet their needs. The specialist described her perception of the teachers' initial experience at the state conference. She recalled:

> So, the first thing that was interesting is at state conferences my teachers came back and were like, we're better than most of those people. Especially in science. A lot of people were claiming to do STEM and all they were doing was science. Well, we were already doing good hands-on science curriculum. They're like, that's not STEM.

Through professional growth opportunities, teachers demonstrated their expertise and expectations for STEM and began to realize that lessons claiming to be STEM were missing several STEM components.

Teachers at Gemini Elementary wanted to know the best way to implement STEM in their school and who could help supply them with new ideas for implementation and integration. They felt their district and state conferences could not provide them with adequate knowledge and experiences of STEM education for their school. Though this realization, the need to attend national conferences was born.

As the staff at Gemini Elementary began to develop their STEM content knowledge and skills, they started seeing the benefits of attending national conferences. Many of the teachers who participated in the study shared that they learned new ideas for teaching topics and implementing STEM activities throughout the curriculum and other subject areas. A veteran kindergarten teacher with over 25 years of teaching experience felt strongly that the conferences had helped her to develop as a STEM educator. “I feel that I ask more open-ended, high-level thinking questions. Children are learning how to problem solve. I feel that by integrating curriculum, students are learning how science, technology, engineering, math, and language arts are all connected,” she shared. Utilizing an integrated curriculum provided teachers the opportunity to begin pointing out connections among the STEM disciplines, and this gave their students a better understanding of STEM.

Since STEM education is a relatively recent idea being presented at conferences, some teachers began taking their professional learning to a new level and developing STEM curricula and presenting at conferences. The principal encouraged teachers to bring back creative ideas, develop them to fit the needs of their learners, and share them not only within the district but also at other conferences. As a developer of some of the engineering design projects, one fifth-grade teacher shared part of her journey:

> I feel that these experiences were vital early on in the process. After attending several STEM sessions, however, they became repetitive and I/we began relying more on our own creativity that the ideas presented at conferences. At this time, I began presenting our own Engineering lessons and campus program framework at these national conferences.

The principal soon figured out that sending teachers to different conferences boosted morale and confidence, and the STEM specialists believed this was a key component of the teachers' success at Gemini Elementary. The principal provided the funding for his teachers to attend. School leadership consists of a team of instructional experts (e.g., principal, STEM specialists, and librarian) who mentor, support, and extend learning from professional experiences.

Change in professional practice. As teachers embraced the integrated STEM idea at Gemini Elementary, they began to change their practice due to the increase in STEM and pedagogical content knowledge they acquired by attending and presenting at state and national conferences and teaching experiences in the classroom and engineering laboratory. The K-5 STEM Educators' Perception Survey data indicated that the teachers surveyed at Gemini Elementary felt attending national conferences was essential to increasing their STEM and pedagogical content knowledge. One result of attending conferences was that teachers began to change their professional practice in instruction. In kindergarten classrooms, teachers feel they ask better questions and can get students to the next level. For example, one kindergarten teacher recalled, "I feel that I ask more open-ended, higher-level thinking questions. Children are learning how to problem solve. I feel that by integrating curriculum, students are learning how science, technology, engineering, math, and language arts are all connected." Therefore, they feel their students are learning how to solve problems and see how science, technology, engineering, mathematics, and language arts are linked together.

In second grade, teachers believed that their professional practice had developed as a result of teaching integrated STEM and now they looked for ways to challenge and push students to the next step. When students say, "I'm done," one second-grade teacher responded that her grade-level team asks students, "What can you do to make it even better?" Many teachers believed that students are constantly being taught to think with a growth mindset and in a STEM process. Another second-grade teacher recalled a struggling student who had never been successful in the engineering laboratory. She remembered him saying, "I knew it [the lunar lander] was not gonna work." However, his teacher remembered his cargo boat held the most weight. During the redesign process, the teacher recalled the student saying, "This is the most successful I've ever been." The teacher remembered replying back to the boy, "You should be really proud. I'm proud of you, too." It was a moment that the teacher felt she would not forget and remembered thinking, "Yes, you could!" when referring to the boy she remembered. For her, she felt like it was an extraordinary experience that made teaching in a STEM school worthwhile.

When asked how her professional practice had developed as a result of teaching with STEM integration, one third-grade teacher noted, "I would say more beautiful, but it's maybe just, like, a joy to go there and it's so … I feel like I work more seamlessly." When she began teaching, she felt the subjects were taught in silo. For example, she said "My first-year teaching is was like, okay, time for writing. Okay, time for reading. Okay, time for science. Okay, time for social studies." Now, she loves how her class conversations and transitions just flow because of integrating STEM education into the school. She shared, "But now, it's kind of like okay, we're gonna put our writer's notebooks away and you can grab your science notebook but come back to the carpet and let's continues this conversation. It just kind of … it flows nicely."

Presenting at conferences. As teachers began to change their professional practice according to the STEM and pedagogical content knowledge they acquired, they became the experts regarding integration of STEM into an elementary school and began presenting at local and national STEM conferences. Thus, Gemini teachers helped expand other teachers' STEM content and pedagogical content knowledge. Interview data indicated that soon teachers realized the local and state conferences did not provide them with the necessary STEM content and pedagogical knowledge and skills they needed on their campus. Therefore, they began to create lessons that fit the need of the students at their campus. A fifth-grade mathematics teacher recalled how she began presenting at national conferences and shared: "At this time, I began presenting our own Engineering lessons and campus program framework at these national conferences," the fifth-grade teacher explained. Educators at Gemini Elementary are now leading the STEM movement at the local, state, and national level. For example, the librarian has received national recognition for her work in STEM education and use of makerspaces. Since she was at the forefront of this movement, she has presented at several conferences, among them the American Library Association, the Texas Computer Education Association, and the Texas Library Association. In addition, Gemini's library was spotlighted during the Texas Association of School Administrators STEM Conference. Another fifth-grade teacher believed:

> I think that [attending national conferences] has really built me up as a STEM teacher, just getting other ideas rather than just our own district. Not even really our district, 'cause we're leading the way here. Building a network where you can

> go and talk to other people to build ideas was pretty cool, which I think was really helpful.

Hence, Gemini Elementary educators are in the vanguard of STEM education and are willing to share their ideas and experiences with other educations. A third-grade teacher said it best when she said, “[We are] STEMming our own STEM!” Developing teacher expertise from professional development experiences and support by the leadership team led to purposeful STEM teacher collaboration, connections, and culture, which encouraged student risk-taking and fostered student 21st century skill development.

Teacher collaboration. Teacher collaboration is an important component of the ongoing success of implementing STEM curricula at Gemini Elementary. According to the theoretical framework, implementing two vital components of integrated STEM education, teacher collaboration and the development of professional learning communities (PLCs), is necessary for effective implementation (Honey, Pearson, & Schweingruber, 2014). The principal has set aside professional development opportunities at the beginning of the year and throughout the school year. In addition to a teachers’ planning period, he provided a half-day of planning each nine-week grading period to allow teachers to collaborate on the EDP during the engineering week.

When surveyed, teachers perceived teacher collaboration as the primary key component of a successful STEM school. Gemini Elementary educators stated during interviews that they were encouraged to collaborate with horizontal grade level and vertical content teams by the school administration. The music teacher believed that “collaboration between grade levels, disciplines, and specialties plays a huge role in our success. I support teachers with their units of study and they support my requests for rehearsal time.” At Gemini Elementary, teachers collaborate in team planning meetings and PLCs to create effective instructional materials for the classroom and determine how students will learn from them. Effective collaboration among teachers, librarians, and school leadership is necessary when implementing intentional integrated STEM curricula into a school (Honey et al., 2014). This section will explain how teachers collaborate during instructional design, team planning, and PLCs.

Instructional design. Teachers' collaboration and methodical planning during the instructional design of the engineering lessons is a key component of a successful engineering laboratory. These lessons were originally developed by the STEM specialist and teachers with numerous years of experience. The lessons for K-5 grade levels (Figure 4.3) were developed to cover a 3-5-day engineering unit using the engineering design process. According to the original program proposal, the purpose of these lessons is to incorporate the EPD into a STEM-block every nine-weeks for K-5 students. The proposal also stated that language arts, mathematics, and social studies will be integrated into the different units of study at each grade level when applicable.

Table 4.3

STEM Block Examples for K-5

Grade Level	STEM Block Examples
Kindergarten	Make your own Observer
	Sailboat Races
	Engineering Pollinators
First Grade	Invention Boxes
	Ramps and Sleds
	Designing Windmills
	Egg Drop
Second Grade	Huff and Puff House
	Robotics Kits and Moon Lander
	Designing Plant Packages
Third Grade	Loco Bean Harvester
	Roller Coasters
	A Slick Solution: Cleaning an Oil Spill
Fourth Grade	Cargo Boats
	Oobleck Lander
	Marble Mover
	Mars Rove
Fifth Grade	Design a Water Filter
	Designing Alarm Circuits
	Solar Cars

As part of the implementation of the engineering laboratory, teachers attended schoolwide professional development that taught them how to integrate STEM. The principal also allocated specific planning time prior to the beginning of the 2014-2015 school year where teachers focused on learning and reviewing the EDP lessons. The specialist attended these planning sessions to discuss and model the lessons. Each subsequent year, the teachers attend STEM specific professional development opportunities and trainings to help them integrate STEM education.

During the initial phases of STEM education implementation, the specialist trained teachers on the engineering lessons and instructed students in the engineering laboratory during the summer and start of school prior to implementation. Additional training occurring during the team's planning periods and PLCs. During the implementation year, one second-grade teacher, now a third-grade teacher, recalled how the specialist took the burden of designing EDP lessons off the teachers. She recalled what many teachers believed:

> [The STEM specialist] was the one kind of in charge. There was discussion about it [designing plant packages EDP] with the second grade [teachers] but for the most part since we were at [year] zero, we had input but it was more about we need to follow our curriculum because that's how we're gonna get our grades, that's how we're gonna get our learning, our [standards] met.

It appeared to the researcher that the teachers appreciated the help from the specialist to help them understand the engineering process and integrate STEM into their classrooms. Furthermore, the teachers initially depended on the specialist to learn how to implement the integration of the STEM Block EDP lessons. As the specialist taught the lessons to the students, she also modeled the facilitation of the lessons for the teachers.

As teachers gained STEM content knowledge, they began to contribute more to the instructional design of the lessons. According to most of the teachers and the specialist interviewed, the principal set aside a half-day planning during each nine-weeks for teachers to plan and review the engineering lesson. According to the interviewees, this planning was specific to the engineering lesson and was in addition to team planning and PLCs. A second-grade teacher shared that these meetings consisted of teachers in the same grade level meeting to identify the TEKS or standards for that nine-week timeframe. During this time, teachers collaborated to find a key concept that could be applied to solve a real-world problem and draw arrows connecting the cross-curricular concepts, not just STEM (Figure 4.5). According to the specialist and second-grade teacher, teachers select a topic within the area with the most connections, which usually happens within science. Then they begin the daily planning the STEM Block unit (Figure 4.6).

Figure 4.5

Example of Collaboration During Second-Grade Teacher Planning

Science	Language Arts	Math	Social Studies	Technology	Engineering
Characteristic of Scientists a. Tools they use b. Safety Scientists Communicate – GEMS Group Solutions Inquiry Investigation – Observation and Inferences - Mexican Jumping Beans Scientists conduct experiments using structured steps Best Raincoat material	Launching Reading Workshop Readers Build Good Habits -Read aloud Writing – Quick Write week and Writer's Notebook Personal Narrative	Addition and Subtraction to 99 Addition and subtraction with money Perimeter of a square Learn the number line Rounding Estimation Place value	Where in the World? Using a Compass Rose United States Texas – State Mexico – Country Geography Learn states and directions	Students watch Safety and Tools PowerPoint	

Figure 4.6

Example of Daily Planning for the STEM Block

Monday	Tuesday	Wednesday	Thursday	Friday
Language Arts: Read Aloud Lucas and His Loco Bean Predict what it is Science: Give loco beans to students Explore: Bean properties....observe and make inferences. Test with heat and light. Finish book Math: Intro into perimeter	Science: Hot/Cold – How does temperature effect loco beans? Math: Estimate number of bean jumps in one minute. Create a fences to contain a loco bean. How can you measure the perimeter?	Engineering: ASK: Can you design a tool to help farmers gather loco beans effectively? Engage: Show a tub with plants and seeds on the ground. Need a tool to pick up the seeds off the ground. Imagine: Show materials. Have five minutes to sketch several possibilities. Share with across neighbor. Share with neighbor behind you. Plan: Share ideas with your partner and plan in	Engineering: CREATE: Build your tool TEST/ReTEST: (incorporate math when they count how many beans they collect. Subtraction when they compare how many beans they collect each time) Tell students final test in front of class on Friday. Writing: Write a persuasive paragraph selling your tool to a farmer.	Engineering: Science Showcase: Show your design and tell how it works.

Previous themes are supported when teachers obtain new knowledge and ideas from conferences—they share the information with colleagues and begin collaborating on ways they can adapt it for their curriculum. For example, a second-grade teacher recalled how one of her colleagues attended a conference and won a lab about Fulton’s ferry. She remembered her colleague saying, “Well, this would fit with what we’re doing right now,” and recalled that her team decided, “Well, let’s develop this into a STEM lesson.” Therefore, they modified the lesson to meet the needs of their STEM students and made connections to the TEKS and standards during their cross-curricular team planning. As teachers acquired STEM content and pedagogical knowledge and skills, they were able to collaborate effectively and begin to improve the instructional designs of current EDP lessons and begin to create new ones.

Team planning. Team planning is critical to STEM schools. According to 13 of the 17 (76%) survey participants, the development and writing of lesson plans was a collaborative effort during team planning. When interviewed, teachers, academic coaches, and the STEM specialist reflected upon how cross-curricular team planning impacted STEM lessons in their classrooms and engineering laboratory. Most of them agree that team planning is key to effective integration of STEM to determine how connections are made in each content area and the laboratory. For example, one kindergarten teacher who teaches reading, writing, and mathematics perceives:

> Planning with my team impacts STEM lessons because we try to make sure to include all areas of study in the experience. I have the opportunity to supplement what they [students] know about a topic through reading nonfiction text before and after their STEM lesson. I also support the students' learning through writing about their work and thinking all throughout the process of each lesson.

Through team planning, Gemini teachers provided each other with opportunities to determine different ways to include the STEM content areas into reading and writing.

Team planning allows experienced STEM teachers to mentor other teachers prior to them teaching lessons. One first-year STEM teacher in first grade believed, "It helps me understand and solidifies the STEM process for me." A fifth-grade teacher believed that working with other teachers on how to increase the number of problem-solving opportunities in mathematics and science provides ways for teachers to help students connect the concepts. "We brainstorm real-world topics/situations that could tie into the curriculum and link to STEM," she noted. Through team planning, teachers provided support to other colleagues and shared ways they could make STEM content connections in other subjects. Relevant learning experiences are vital to making the integration of STEM viable and concrete.

When collaborating as a team, teachers at Gemini Elementary believe they work together to try to ensure all subjects are included. When planning their engineering laboratory lesson, for example, second-grade teachers map out their curriculum for their upcoming units and draw arrows on how the material connects (Figure 4.5). One second-grade teacher shared in the survey:

> Planning with a team gives us a chance to look at all subject areas and integrate our STEM lessons into our curriculum. Each teacher thinks about how integration would look in each subject area. How could we use technology? Is there a literature connection? Can we graph our results at math time? Is there a social aspect that we can address? We look at all areas and integrate as much as possible.

The STEM specialist observed this kind of collaboration daily and explained that planning together ensures every child on the grade level has the same type of experience and increases teacher creativity. These shared experiences increase the knowledge base for all teachers and influence all classrooms. The advanced academics instructional coach summed it up by saying, "Collaboration creates effective integration." As evidenced, the outcome of effective teacher collaboration during team planning develops teachers' professional practice and provides them with opportunities to determine what is best for the learners.

Professional learning communities. When implementing effective integrated STEM education, developing PLCs is equally as important as teacher collaboration in team planning (Honey et al., 2014). Sixteen of the 17 (94%) participants who completed the survey stated they meet with other teachers as a professional learning community. The survey data indicated that all the core teachers and academic coaches participate in PLCs. Educators shared that their primary focus is going over student data to determine which intervention and differentiation practices need to be implemented to ensure the success of all students. A fifth-grade science teacher shared her perception of the team's PLC focus and said, "We may spend time analyzing student data, reading professional articles, planning intervention, working with coaches to improve teacher practices, learn a new strategy to implement, etc." As students learn and grow, the PLC members believe they adapt to their needs and center their focus around what is best for them at that time.

In addition, PLC members discuss how to differentiate student learning, analyze assessment data, improve literacy, and incorporate guest speakers to relate learning to the real world. Regarding the kindergarten PLC, one kindergarten teacher shared regarding differentiation:

> We always focus on doing what is best for our students. We discuss differentiation so that we can meet the academic needs of all of our kids. We try to meet and make decisions about our grade level and campus needs.

Teachers believe that using student data as their primary focus in conjunction with other strategies and topics discussed in the PLC provides them opportunities to adjust the learning environment as needed. A first-grade teacher felt the school's primary focus was "academics." She said they "discuss the district curriculum and go over data from any testing we have done so we can gear our lessons to better fit our students' needs." Additionally, a teacher who teaches multiple grade levels felt the PLCs she is involved in focus on improving literacy by utilizing "delivery interventions to struggling readers and evaluation of reading disabilities." A second-grade teacher, however, stated that their team's focus was "to get speakers to talk to the kids related to our learning." With team planning and good discussions in PLCs, teachers begin to make connections and craft disciplinary-based STEM instruction to aid student connection and critical thinking skills.

Making Connections. The importance of making connections within different STEM disciplines is essential in solving problems within real-world contexts, and these later transfers to the workplace (Honey et al., 2014). In addition, it develops students' and teachers' awareness of the connections, which expands student learning. The participants' perceptions of the types of connections and how they help make connections within the STEM disciplines will be explained in this section. At Gemini Elementary, many of these connections are pointed out by the teachers and include STEM and non-STEM content areas.

***Types of connections*.** Through the lens of the framework, connections can be made by combining concepts from different disciplines, relating the concept of one discipline with the practice of a different one, or assimilating two methods (Honey, Pearson, Schweingruber, 2014). Sometimes teachers point out simple, everyday connections within the classroom. For example, one third-grade teacher shared how students found connections by looking at the clock and realizing that there were fractions there. Other connections teachers make are cross-curricular and combine methods that teachers at Gemini Elementary believe can increase student interest and engagement; these will be discussed in the following sections.

Cross-curricular connections. At Gemini Elementary, many of the connections teachers make are with all disciplines, not just STEM disciplines. For example, a second-grade writing teacher believed she helps students to make connections during the engineering lab with historical figures whom they can write about. She continued, "So we learned about Thurgood Marshall, and just Fulton Ferry, why is he important, why are historical figures even important to learn about?" As students delved deeper into this lesson, they were questioned on what inspired Ferry to do what he did and asked how that could help them in their lives. "So, just connecting it to something that we've already learned when we're getting ready to start an engineering lab so they kind of know what to look for," she explained.

In third grade, students created posters in which they had to identify, explain, demonstrate, and investigate what happened to the land after an earthquake or a landslide. A third-grade teacher shared that, as she reviewed students' work, she noticed some did not have the correct punctuation and grammar. She referred them to the poster she had hanging in her room which read, "It's a sentence no matter the subject you are in!" She further explained how she connects science concepts with writing: "I do a lot of integration when writing in science." She instructed students to place a culminating paragraph of what they learned, in science and writing, and have them place it in their notebooks.

Other connections are typically made connecting mathematics with other subjects. For example, a second-grade writing teacher talked about when students were generating story problems for addition and subtraction equations. She would provide students with equations and say:

> Okay, how can we relate this to what we were doing in the engineering lab? If you're on a boat and we want to go so many miles, my boat was able to travel for 54 miles and then I went backward 17 miles. How many, at what mile am I at now?

She connects mathematics with writing and then has students make an additional connection. "That just builds and builds and builds," she shared, "and that's true learning."

Connecting one or more disciplines. Students continue to make connections using concepts from one or more disciplines with the practice of a different one. One fifth-grade teacher invites STEM professionals from different careers to "participate in classroom activities or provide insight into specific engineering labs" as they relate to the content students are learning. For example, each spring NASA engineers work with fifth-grade students to build solar cars. At the end of the week, students race the cars. "Since I teach math and science, it is fairly easy to find overlap in the two subjects. Many of the science labs the students conduct have a heavy math element," the fifth-grade teacher explained. Another fifth-grade teacher believes that her students begin to naturally make connections between mathematics and science at the end of this unit.

The music teacher integrates STEM concepts throughout her lessons. She explained, "Since music encompasses all of the STEM subjects, I am constantly using STEM language right alongside my music language (especially mathematics and science)." She continued to explain, "I have focused short discussions connecting science, technology, engineering, and math to music." When answering the survey, the music teacher elaborated on an upcoming project and wrote, "Next semester, my fifth-graders will be building a tuned monochord based on a STEAM [science, technology, engineering, art, and mathematics] session taught by Marcelo Caplan (from Columbia [College Chicago]) I attended this semester." As students develop STEM literacy over the K-5 STEM elementary experience, students are guided to independently make connections between the STEM subjects and the arts.

Connecting different methods. Many of the connections are made by way of assimilating two main methods, scientific inquiry and engineering design process (EDP), during the STEM block (engineering laboratory). It is important to note that scientific inquiry focuses on gathering empirical data which supports a hypothesis and explains why something is occurring, whereas the EDP has students create a project or solve a problem using constraints and specifications (Nadelson et al., 2011). At Gemini

Elementary, these two methods are used in conjunction with each other, but the focus is the EDP. The EDP will be discussed in later sections.

Vision and school culture. School visions are important constructs that serve as check points for appropriate action and a reminder of the aspiration for the school culture and for members of the school environment. At Gemini Elementary, the vision is to prepare and inspire lifelong learners to meet the challenges of a global society through critical thinking in STEM for generations to come. Implementation of the vision revealed that students' interests and STEM identity is constantly being developed by the shared vision of the administration and teachers. This supports Honey, Pearson, Schweingruber (2014), who identify the "development of students' interest and identity in STEM" as an important outcome of implementing an integrated STEM program (p. 63). In this section, participants' perceptions will explain how the school culture is essential to increasing students' interest and STEM literacy and creating a STEM identity.

School culture. Survey and interview data indicated that Gemini's STEM school culture/vision emerged as one of the primary key components of a successful STEM school. At Gemini Elementary, students' interest and STEM identity is constantly being developed by the shared vision of the administration and teachers. Based on the school's vision statement, students are prepared and inspired to be lifelong learners who will meet the challenges of a global society through critical thinking utilizing STEM concepts for generations to come. In this section, participants' perceptions will explain how the school culture creates the outcomes of increasing students' interests and STEM identity.

Acceptance of an innovative way of thinking and acting produces confidence that encourages a culture of risk-taking. Students taking control of their own learning and taking risks during that learning is the ultimate act of a constructivist learning environment that is necessary for STEM education. The school culture at Gemini

Elementary allows students to increase their confidence level within themselves and motivates them to begin taking risks. Additionally, students are taught that making mistakes is a necessary part of learning.

The school culture and motto, "We are here to make mistakes, learn and redesign," resonates throughout the school and was identified by educators as one of the key components at Gemini Elementary. One kindergarten teacher stated how some of her students struggle in the beginning. She said, "I see my perfectionist kids even at five have to overcome that hurdle of, 'That's okay that that didn't work the first time.'" As a kindergarten teacher, she felt it was important to begin teaching students that it is all right to change their thinking and try something different. A mindset such as this reinforces the values (vision) and norms (culture) of the school, which is supported and enriched in subsequent grade levels.

It is not just the students who must learn that failure is necessary but the parents as well. One third-grade teacher noted:

> They [parents] have to be on board just letting their child be able to fail. And I think that's one of the biggest parts of it, is being okay with failure, and try again, and just really building that perseverance.

Gemini Elementary teachers felt it is important that parents understand the importance of instilling grit and a growth mindset in children. First- and fourth-grade teacher discussed an earlier conversation they had with each other that morning. The first-grade teacher recalled:

> The one thing you [the fourth-grade teacher] said in the morning was, mistakes is [are] how we learn. It's okay to fail. That to me is huge because so many want to be perfect all the time. The fact that you have an idea and you try it out, and then

> you go back and redesign and try again, that to me is the biggest part of their success. It's okay to fail, and it's okay to try again.

Thus, according to the teachers, the school culture supports the mindset of making mistakes, learning, and redesigning and has students practicing this mindset throughout the day and in the engineering laboratory.

STEM interest and engagement. As students begin to learn and explore more about how integrated STEM impacts the world around them, teachers believe that student interest in STEM increases. A second-grade teacher shared how they developed the idea during PLC meetings of using STEM bins in the classroom. They rotate the STEM bins each week to another second-grade classroom. The bins have different STEM activities that connect STEM to literacy, reading, and writing through the utilization of fiction and nonfiction stories. "So if they [the students] had that constant practice on a weekly basis, of engineering and designing and working cooperatively with whoever's in their group, when they get to the engineering lab, it's just a seamless process," she elaborated on the purpose of the STEM bins. Teachers believe that these examples build students' interest and engagement during the engineering laboratory. "They [the students] become different kinds of learners when they've been exposed to that in lots of different places," shared one second-grade teacher. "Either at the makerspace in the library, the engineering lab, or our STEM bins." During a follow-up interview, she noted that she perceived that student interest and engagement increased when students know the teachers are excited and provide them with a purpose. She shared:

> I guess just showing that I'm excited about going in the lab, making sure that they know their purpose and they know what their expectation is, but bringing in books and literacy in the classroom for them to, even if it's the week before, just to get them familiar with the topic.

She continued to explain how videos are used to increase student interest in topic. “So, like with lunar landers, we actually showed the video at the beginning of the day of them [astronauts] landing on the moon so they [the students] could see” what their project would entail, she shared. She believed showing the videos increased student engagement for the lunar lander EDP.

As students continue to build their 21st century skills, their interest and engagement in different aspects of STEM education increase and they begin making connections between the disciplines. Students engage in a passion project where they pick a topic they love and work on it. Many times, it will intertwine with the research they are working on in writing. The topic is open-ended, and the students get to choose whether they would like to create a PowerPoint, Prezi, or other form for their final product. “One of my gentlemen is learning coding,” a third-grade teacher explained. “He’s going to want to create something he’s coded,” she continued. She explained that in several instances students’ ending products are different than their initial report. “They love that, because it’s them motivating themselves,” she shared excitedly. Teachers believe that as student interest progresses over time, they are more apt to make connections within disciplines and STEM multidiscipline without teachers directly pointing them out. These quotes provide examples of how student engagement and connections are intertwined, with increased engagement often leading to cross-discipline connections.

Many teachers build their students’ interests by making sure students know what the purpose and expectations are for learning the materials. To integrate STEM across content areas, teachers bring books and literacy into the classroom prior to the engineering laboratory so students become familiar with the topic. In second grade, teachers show them a video of the moon landing and tell the students, “This is what we’re gonna be designing." The second-grade students then used robotic kits and created a lunar lander. As students' interests are piqued in engineering projects, robotics, and makerspace, they live and breathe the STEM culture, according to the participants.

STEM literacy. STEM literacy is a complex goal, especially at an elementary level. Within the classroom, the teachers are working on increasing the seamless integration of STEM throughout all subjects and not teaching the core subjects in silo. Students' confidence is also built by becoming STEM literate. STEM literacy is a new concept that is not well defined. The framework states that it could include:

> (1) Awareness of the roles of science, technology, engineering, and mathematics in a modern society, (2) familiarity with at least some of the fundamental concepts from each areas, and (3) a basic level of application fluency (e.g., the ability to critically evaluate the science or engineering content in a news report, conduct basic troubleshooting of common technologies, and perform basic mathematical operations relevant to daily life). (Honey et al., 2014, p. 34)

To acquire STEM literacy, students need consistent practice with the EDP and an awareness of different aspects of STEM such as being fluent in 21st century skills while working collaboratively in a STEM environment, thus increasing students' interest and engagement in STEM applications within the modern society. In this section, participants' perceptions of how STEM literacy relates to the goals and outcomes of students taking risks is explained.

For example, as discussed previously, many teachers use STEM literacy stations and STEM bins for students to explore different concepts of STEM throughout the day and different units. Additionally, students' self-identity (i.e., attitudes, beliefs, self-esteem, self-confidence, and motivation) is cultivated to value how STEM education plays an important role in their life. For example, the STEM specialist shared how she believes students' creativity flourishes at Gemini Elementary and that results in them doing better academically. She said:

> I see this creativity and spirit in kids. They want to be here. They like what they're doing. And so academically that carries over into a quest to approach problem's [with] risk. They are willing to take a risk. They are willing to try academically, and that comes from the STEM program.

Building students' STEM literacy helps build their confidence and allows them to be risk takers, which sets them up to face challenging situations in the future. A fifth-grade teacher describes her perspective about STEM literacy:

> It's building risk-takers, not teacher-pleasers. They know they're going to make mistakes, and they know that they're not going to be right all the time. Being able to share when they make mistakes, or, not just in the engineering lab but in math, when they're making mistakes. Being able to raise their hand, and be like, "Oh, I want to change my answer because I figured out that this is why I messed up," they're open to sharing their mistakes. They're open learners. They learn from each other.

Providing a safe environment where students can develop their self-esteem supports students' STEM literacy development. Anecdotally, risk taking can be difficult and learning environments can be safe spaces for making and learning from mistakes.

When students are doing well academically, they begin to build their self-confidence. As previously stated, the STEM specialist noted how students are willing to take an academic risk. Students' willingness to take risks, both academically and socially, is an important part of developing their STEM identity, and is further developed as students acquire 21st century skills.

STEM identity. Students' STEM identities help empower their voices. The librarian believed many students go through school and are never asked questions like, "What are your thoughts? How can you contribute to all of this?" and feels that one thing they do differently at Gemini is try to empower and strengthen students' voices. "When they're able to go out and get a job," she shared, "they're able to do something that a lot of people can't do, which is offer ideas." As students develop their STEM identities, they begin making connections among STEM disciplines on their own and are willing to begin taking risks. The school motto seemingly creates a culture in which mistakes are embraced and is where real learning takes place and students just redesign their EDP, assignments, or way of thinking.

That a sense of failure is part of learning, and that being successful means being resilient and persistent, helps to create students' STEM identity at Gemini Elementary. The librarian works with students to help develop their STEM identity. She shared:

> The library is where students find their STEM identity. We're very much into empowering student voices. That's found in choice, and that's also found in them being encouraged to research and to gain experiences in things that they're truly interested in.

This student outcome that emerged explained how the librarian at Gemini Elementary fostered students' interest and development of their STEM identity. Building students' self-confidence and embracing mistakes as part of the learning process begins to set students up to be successful in the 21st century where risk taking is necessary to their learning.

21st century skills. The goal of making this innovative shift at Gemini Elementary was to prepare students for successful futures. Developing 21st century competencies or skills is an essential goal for students to acquire to be ready to enter the

STEM workforce (Honey et al., 2014). Educators believe that, through their observations in the classroom and engineering laboratory, students who attend Gemini Elementary build these skills each year. Developing 21st century skills is a primary student outcome at Gemini Elementary and falls into different categories: learning and innovation skills; and information, media and technology skills (P21, n.d.). Students' learning and innovation skills are evolving through the development of their creativity and innovation, critical thinking and problem solving, communication, and collaboration.

Critical thinking, problem solving, and creativity. Educators perceive that students continuously develop their critical thinking, problem solving, and creativity while attending Gemini Elementary. One third-grade teacher believes that critical thinking is a skill for every century and it is important for students to develop this skill, so they can problem-solve without their parents or teachers doing it for them. Teachers believe students can think critically and problem-solve daily. For example, a third-grade teacher perceived students working through problems no matter their frustration level. She recalled a time when they were using solar paper in class:

> They thought that the sun had made the blue suck all the way up underneath to their item, rather than the sun's light energy fading. And then we started to talk about it more and more. And they're like, "wait a minute. No." So they go through it. But it's their thought process, it's not mine.

During this problem-solving process, the teacher guided students and had them question their initial response of why the paper was faded. As the discussion progressed, the teacher perceived her students beginning to think critically as she guided their thought process. Through her questioning and guidance, students began to realize that their initial thought was incorrect. The teacher perceived they had an "ah-ha" moment when they realized the sun faded the paper. This example demonstrates how important teachers' pedagogical content knowledge and skills are to the development of students' critical-thinking skills.

The prevalent example provided by the principal, specialist, and some teachers during interviews was when students would apply what they learned to optional projects such as the engineered Valentine's Day box. All students are encouraged to create a Valentine's box and are provided with creative freedom which allows them to create any type of box. Some of their innovations include mechanical boxes which collect Valentine's cards, while others dispense candy (Figures 4.7). For example, "She [the student] constructed a mechanism to disperse the Smarties candy out of the mouth," the specialist recalled. This is evidence that students are developing the necessary 21st century skills (i.e., creativity, critical thinking, problem-solving, and real-world application) at Gemini Elementary. Application of STEM practice beyond required assignments clearly illustrates that students are interested in STEM topics and are taking the initiative to apply the 21st century skills acquired over the years.

Figure 4.7

Example of Outside and Inside of a Student's Valentine's Day Box

Teachers shared their perceptions that parents, teachers, students, and surrounding campuses are often amazed at how students at Gemini can critically think and solve problems. The STEM specialist commented on how "they [the students] think differently." She said:

> So, I see critical thinking. Huge. All kindergarten through fifth grade. The critical thinking component, the parents comment on it, the kids comment on it. Teachers who are new to our campus and come from another campus are like, these kids, whatever it is, they think differently.

A third-grade teacher believed her students are prepared for future STEM careers and said, "Everything is changing. It's changing so fast. Just ask them [students] what they want to be, they're like, YouTuber, I want to be a YouTuber. And five years ago, that was not an occupation." She believed that not knowing what jobs her students would have because they were not yet created makes it challenging to teach. She continued, "So, if we can build that foundation of independent thinkers and problem-solvers, and critical thinkers, then when those jobs do arise, or if they're the ones creating those jobs, they're gonna be ready for it." She believed these 21st century skills are necessary for students to be successful in future careers and building the foundation for students to critically think and problem solve are necessary for students to be successful in an ever-developing technological world.

Communication and collaboration. Communication and collaboration are integral to the Gemini Elementary school culture. Teachers believe that much of the communication and collaboration develop simultaneously. For example, during the STEM Block, students must communicate effectively as they collaborate during the EDP in the engineering laboratory. A first-grade teacher believed students communicate and really think about what they would like to say to their partner and then have it come across in their plan. She continued:

> That can be tough for a six-year-old, but that very idea that they get to communicate and it's not always with the same partner, and then present their ideas in front of the class, those are the things they're going to use with every grade level.

She believed that students gain communication skills in all grade levels and embraced the idea that students had to communicate and work together to decide on their final product.

A fourth-grade teacher recalled how she was terrified of public speaking and could relate to the students. She shared a story about a student who would not speak to his teachers in kindergarten but, now in third grade, he would sit there and speak in front of people seemingly like it is not a big deal. She stated:

> Seeing them from completely having [an] anxiety attack when it's your turn to getting up there and talking about it like no big deal, just in one year is huge to see. The kiddos that have this experience from K through five here, when they get older, public speaking is not going to be a big thing at all.

Many other teachers felt similar and believed that building students' confidence and providing multiple opportunities to communicate with others while working with teachers or students one-on-one or with a group will have a greater impact on students later in life. Thus, students are attaining necessary public speaking skills that are required in many careers and jobs later in the future workplace.

Educators believe in most classrooms and the engineering laboratory, students work collaboratively as they communicate their ideas and merge them together. In some instances, teachers recall how some students disagree with each other, but they are taught to solve their own problems. The specialist shared an example:

> They talk out their own problems. We do not referee their fights. We go over, we have them work it out themselves. Again, all adult behavior but you're training

> them young that that's just the way life is. And our motto is, make mistakes, learn, redesign. So, we're not going to cry about it. We're not going to fuss about it. If you're disappointed or sad it didn't work out, and that motto is engineering lab, that's a culture here.

This process of solving problems and communicating with each other is constantly being repeated; thus, students become effective communicators and collaborators in the process. Additionally, the school piloted a virtual science fair where all the information is presented online using PowerPoint instead of a traditional trifold science fair board. "It really blows some teachers' minds, and parents because it's like you have to have the board. Well, the board's just the communication tool," the specialist shared. The virtual science fair was so successful that now the whole district does it.

Collaboration with students, teachers, and other educators is an essential skill for students to acquire. Furthermore, it enhances student confidence to risk communication on an academic level to an unknown audience. Many teachers' perceptions aligned with the librarian's when she said, "I think collaboration is huge here. There's no one working in silo. I think that's really important for our kids to see as professionals, but then also it's something that's expected of them as well." Gemini teachers not only expect their students to collaborate, but also believe they model collaboration among other teachers. Thus, the perception that collaboration is important for all members of Gemini Elementary points to buy-in for the students and faculty.

Guest speakers and real-world application. All the 21st century skills are culminated into one of the most important skills, real-world applications. In addition, training students to present academically to a broader audience further develops their capacity to apply STEM education to the real-world. Guest speakers shared their experiences about NASA missions or how engineering applies in their lives. Teachers believed students are equipped to attack real-world problems which are regularly presented in class. A fourth-grade teacher perceived the culmination of having a guest speaker during the engineering laboratory impacted students. She recalled:

> We did a robotic hand. One year we had a parent that was a quadriplegic, which actually stared this lab that we created around him, because he actually tests robotic arms to help him. We got that flown in. The kids got to see that first-hand. Last year, we had a parent that worked at NASA during the time that they were making the Canada Arm.

The teacher believed the experience of the guest speaker, a parent, about being on the team was important for students to learn about. She remembered the guest speaker bringing in real pictures to show students how they made a replica in the pool. She stated:

> That was really cool, because it brings to real life why do we need technology? Why do we need to go to think on our toes? If it doesn't work, we need to have a backup plan. That was really cool, bringing in guest speakers, because it makes it real to them.

She believed students were able to see the importance of their work on the robotics project in school and how it related to the real-world. More detail regarding the application of real-world problems will be addressed later in the STEM block section.

In addition to guest speakers, students' EDP while working in the engineering laboratory helped make connections to real-world problems. One fifth-grade teacher believed:

> Even in terms of an engineer, there are so many different kinds of engineers, so they're [the students] getting to experience a little bit of what that could be, and where they thought, "Oh, an engineer. That sounds boring," and then they learn about a specific type of engineer that actually sounds very interesting to them.

Providing students with different real-world problems during the engineering week allows them to develop their interests in different real-world applications of STEM.

One first-grade teacher believed students also need to communicate and work collaboratively for ideas to merge. “It’s critical with the technology, with the space program and all the things that we’re going into. Those [problem-solving and communication skills] are huge,” she shared. She perceived that everything Gemini Elementary does is always with the STEM process in mind and how students can relate it to the real-world.

Students are equipped to address real-world problems, larger projects (virtual science fair), social and academic risk-taking, in daily class activities, and continuous problem-solving experiences (e.g., robotics). Learning from mistakes provides students with knowledge that informs the next step in the process. Recognizing that this is an interactive cycle natural to everyday learning is a critical real-world, lifelong learning concept.

Technology literacy. Students today are digital natives, but may not understand how to apply technology knowledge and skills in ways relevant to engaging in the modern world. To be well-rounded in the 21st century workforce, students need to increase their technology fluency, so they can function, since STEM technologies are a natural part of their world (Zollman, 2012). Information, media, and technology skills are also essential 21st century skills students gain at Gemini Elementary. The interview and observational data supports that Gemini Elementary students appear prepared for the future STEM workforce.

Teachers believe students learn how to research information effectively through appropriate Internet sources and media mediums such as Seesaw to display their work for teachers and parents to view. Seesaw is a learning management system (LMS) many teachers use at Gemini Elementary for students to increase student engagement through the use to technology. When asked what Seesaw was a second-grade teacher responded:

> It’s a [an] online digital portfolio. It’s a place for kids to add in either things from their notebooks, they can record themselves, they can take pictures. You can also set up activities where they can go in and do the activity and then they can save it. And it pushes off to the parents that have signed up. So, they have instant access to it.

Learning management systems such as Seesaw provide students with a platform in which they can communicate with their teachers, peers, and parents the media products such as videos and presentations they have created in class. In addition to the use of Seesaw and other LMS, teachers believe students acquire skills and become fluent in PowerPoint, Prezi, and other presentation tools throughout the year. One third-grade teacher felt that having students utilize digital notebooks and other media tools has been effective in her classroom. She shared:

> “OneNote has helped a lot because kids can work on it at home. There’s always PowerPoint. One of my students today learned there’s something called Prezi and I showed it him and he freaked out. And then Sway, Padlet. The kids bring more than I even know. They’re like, “Look at this, I can use this!” I’m like, “What is that?”

Thus, the culture created at Gemini Elementary empowers students to take a risk and try new resources and media tools to determine what works best and what does not. Students also feel comfortable to communicate and share their successes or failures with their teachers and peers as part of the learning process. Students participate in a virtual science fair project where they are encouraged to develop their final product utilizing different media tools. One fourth-grade teacher felt that “flexibility with their presentations” allowed students “that creativity to figure out how they want to present” and “what mode of technology they want to present.” These technological skills in conjunction with collaboration, communication, and presentations skills students build over grades K-5 prepare them to enter the 21st century workforce.

Most teachers at Gemini agree that being technology literate is an important outcome of their STEM integration. Teachers in kindergarten through third-grade perceive that the blended learning model for classroom instruction and access to about eight iPads per class helps students begin to acquire technology skills. A third-grade teacher recalled how much technology she felt the students are utilizing at Gemini Elementary. She shared:

> Tablets are one-to-one for fifth and fourth [grade students]. The kids want to just get on and get whatever they’re doing going. You can go in any classroom that has, like the science classroom, and you can see evidence of learning via technology. I don’t think I’ve walked into a classroom where something wasn’t on as far as like a computer or the tablets or the iPads or, what else do they use? I see them in the hallways videotaping each other, like presenting whatever they learned.

Fourth- and fifth-grade teachers have iPads in a one-to-one setting, which allows them to utilize both blended and personalized learning models in their classrooms daily. The STEM specialist attributes them to aiding teachers on differentiated instruction for students. “So we’re doing a lot of blended learning. A lot of personalized learning. But that’s not a [district] thing, so part of it’s STEM.” They believe having one-to-one technology is essential for students to develop the necessary technology skills required in the 21st century. One first-grade teacher believed that students in the lower grade levels would benefit similarly from having one-to-one technology. She wished she could have "more devices for kids." She continued, "K-2, we don't have as much per kid. We have five iPads in our class and three computers that most of the time don't work." Equipping students with the proper technology and applications at all levels of K-5 is vital to the development of students' technology literacy.

In addition, students at Gemini are exposed to different types of robotics programs which educators believe contributes to their technology literacy. The STEM specialist taught LEGO WeDo Robotics to first, second, and third-grade students. Whereas, the fourth- and fifth-grade students have an opportunity to be in the robotics program and approximately 15 students join the team. These students compete in VEX Robotics every year. The team qualified for VEX Robotics World Championship in 2018 but was unable to attend. In robotics, teachers believe students rely heavily on technology for the coding and use the 3D printers. Students are taught to use applications such as Code.org and Scratch. "Doing the robotics … and going to [the] makerspace and seeing a lot of the different materials that are available," a second-grade teacher explained, "helps kids branch out in a new way of thinking that generally wouldn't have that opportunity." With the rapid development of technology, integrating coding software and robotics provide students with deeper connections to STEM applications that are necessarily in engineering or robotics fields of study.

Teachers perceive makerspace as a key component to students' success and interest in STEM. It includes six Raspberry Pi computers, 3D printer, VEX and LEGO WeDo robotics kits, Boxels, stained glass, and paper crafts. "So, we have a makerspace in our library that's amazing," the specialist began to share, "[and] we got national recognition for that." The librarian also created makerspace kits teachers and students can check out which include books and supplies to fit a theme. Many of these kits include Arduino, Makey Makey, and littleBits. Students will sometimes skip recess and go play with the makerspace components in the library. Providing students with the opportunity to tinker with the makerspace components allows the acquisition of additional technology knowledge and skills in ways that pique students' interests in STEM concepts, thereby increasing their technology literacy.

Engineering laboratory. The integration of STEM at multiple levels is critical to the success of a STEM school. According to the Descriptive Framework for Integrated STEM Education (Honey et al., 2014), designing integrated curricula is especially important. The "STEM Block" at Gemini Elementary school is the main integrative curriculum, which is an engineering laboratory for all grade levels. The students in the laboratory utilized science, technology, engineering, and mathematics to solve real-world problems that also reflects parts of the curriculum for one or more content areas. According to the faculty and school leaders, the engineering laboratory is the root of the success of their STEM school. This section describes the structure of the engineering laboratory on buoyancy, offers a fourth-grade experience as an example of STEM integration, and discusses teachers' and school leaders' perception of the STEM Block, or engineering laboratory.

Engineering laboratory structure. According to the Descriptive Framework for Integrated STEM Education (Honey et al., 2014), the integration of STEM curricula requires duration, size, and instructional design. Duration refers to the time in which the integration took place. At Gemini Elementary, the engineering laboratory spanned grades K-5. Annually, students attended four one-week-long engineering laboratory sessions. Each occurred at some point during the nine-week grading period during the regularly scheduled science class. Typically, about 50 minutes are devoted daily to science. However, during the STEM Block, the time may fluctuate to accommodate the needs of the laboratory. The instruction was carefully designed by the STEM specialist to build on what is learned each week during an academic year. Each year provided a layer of authentic knowledge and skills necessary for subsequent yearly projects. By the time students complete fifth grade, students appear to acquire an engineering mindset. The principal concluded, “If they’ve gone through our building from K to fifth grade, they’ll have gone through the 24 sessions, and you can see them emerge as with that engineering thing, understanding the engineering process.” He continued to share how with students’ understanding of the EDP, the students have started upgrading the engineering projects through the years. The STEM specialist trained teachers on the STEM lessons, including modeling how to facilitate student learning and behavior and thinking as an engineer. Additionally, she worked collaboratively with teachers when facilitating and co-facilitating students in the laboratory. Engineering laboratory lessons were taught and facilitated by the grade-level science teacher and STEM specialist, and the engineering laboratory aide, who has worked part-time in this role for three years, helping students as needed.

Students worked through different parts of the EDP (Figure 4.8) throughout the STEM Block week. Posters explaining the process for each engineering phase were posted on the walls, referred to by educators, and used as anchors for student thinking and action (Figure 4.8). The phases represented were Ask, Imagine, Plan, Create, Improve, and Communicate. Throughout the weeklong laboratory, students were prompted to refer to these posters to help them through the EDP. The engineering laboratory facilitators prompted students to identify a problem and its possible solutions during the “Ask” phase. During the “Imagine” phase, students identified the possibilities, explored options, and agreed on the best solutions for their problem. Students created a “Plan” and determined the necessary materials to build their cargo boat. Next, students created a model and evaluated it to decide if they followed their plan and met their goal.

At the end of the “Create” phase, students tested their model. During the “Improve” phase, students analyzed and appraised their model to assess whether or not it worked, explored what they could have done differently, and considered what would make it better. In the final phase, “Communicate,” students discussed if changes were needed, listened to feedback from others, and determined whether the problem was solved. The laboratory experience appears to culminate in the necessary knowledge and skills students need to be a successful engineer and provides a safe atmosphere where the EDP encourages students to make mistakes, learn, and redesign.

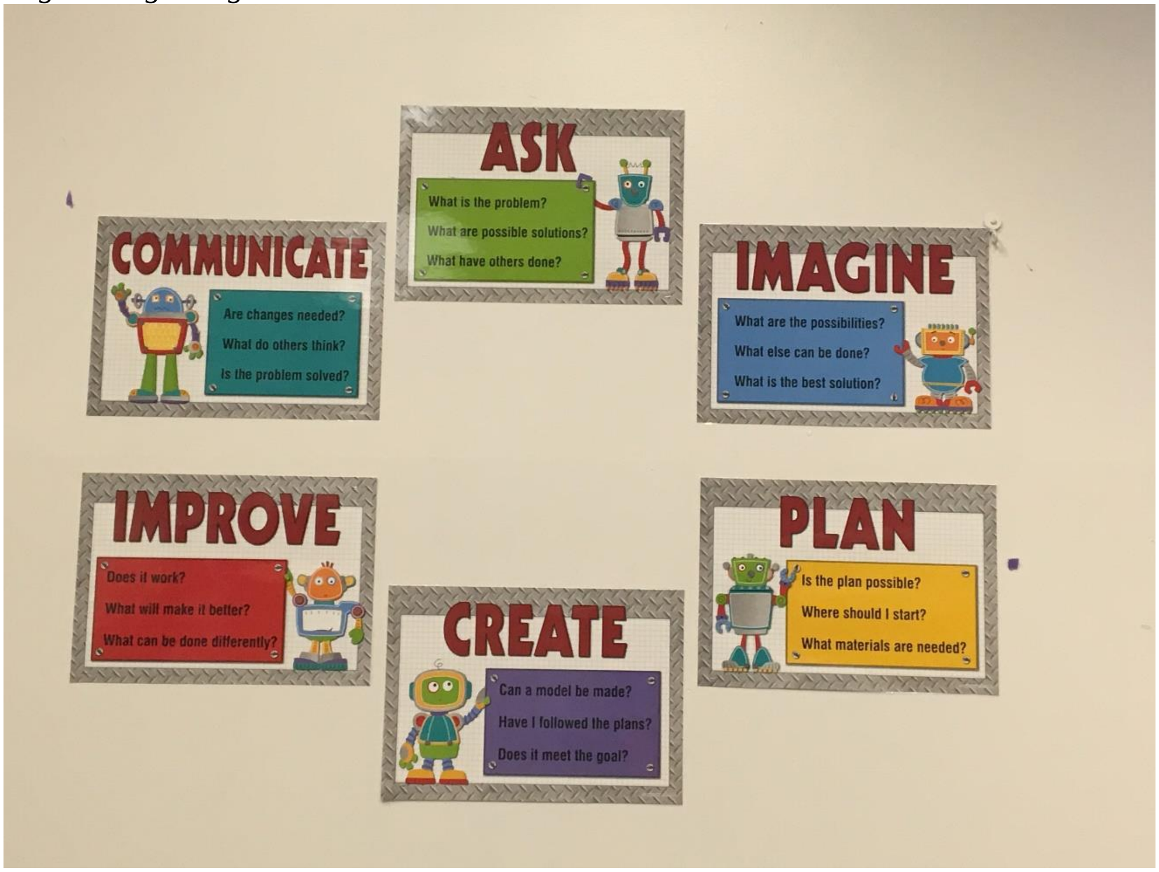
“The engineering lab has been key to the success” of Gemini Elementary, the specialist proudly shared, citing the STEM Block as being a key component of their success. Several teachers shared their beliefs that students demonstrated a shift in the way they think and act as a result of participating in the engineering lab. One third-grade teacher noted, “[The] engineering lab, like I said, it creates that mindset” for students to become an engineer. Students often work in groups of two to three. Students are expected to follow the EDP and communicate their results at the end of each STEM block. The following section describes how fourth-grade students worked through an EDP on buoyancy, offering an example of how the engineering lab is implemented at Gemini Elementary.

Gemini Elementary EDP: Cargo Boats

The Science STAAR Grade 5 data indicated students struggled with the concept of buoyancy. Therefore, fourth-grade teachers chose the cargo boats EDP, which integrated social studies and science concepts. Science was the dominant content area used to develop this concept, but the inclusion of social studies concepts helped to deepen students’ learning of the history of ship building and how buoyancy was an important scientific concept that aides in successful ship building. The researcher observed the introduction of the cargo boats EDP for a fourth-grade class and all phases of the engineering of the cargo boat, except the “Final Testing” and “Communicate” phases. The final testing and communication phase experience was described to the researcher by the STEM specialist after the completion of the fourth-grade engineering laboratory. The project was facilitated by the teacher, the STEM specialist, and engineering aide. The fourth-grade science teacher was absent during the Tuesday observation, so a fifth-grade teacher taught the engineering laboratory to the students. The fifth-grade teacher had prior knowledge about the cargo boat EDP but was asked that morning to be a substitute in the engineering laboratory. Therefore, the STEM specialist interjected and often took the lead in facilitating this project during the Tuesday observation. Additionally, there was an engineering laboratory aide who walked around to help students if they had questions. This section will explain how the teacher facilitates the EDP as students worked through the EDP (Figure 4.8) during the STEM Block.

Figure 4.8

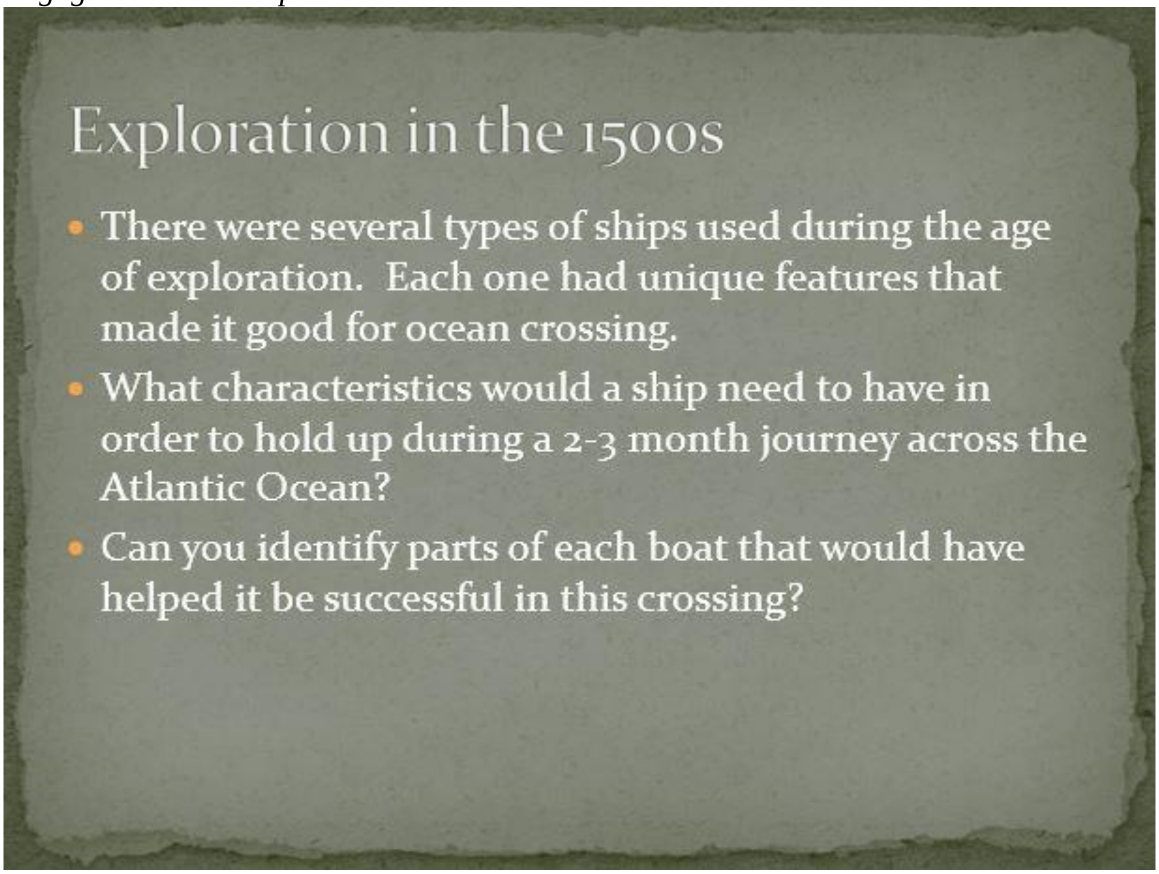
Engineering Design Process



Before beginning the EDP, the researcher observed the teacher begin the lesson with a PowerPoint titled "Ships for Exploration." During the presentation, students discussed how explorers would cross the Atlantic Ocean during the 1500s (Figure 4.9).

Figure 4.9

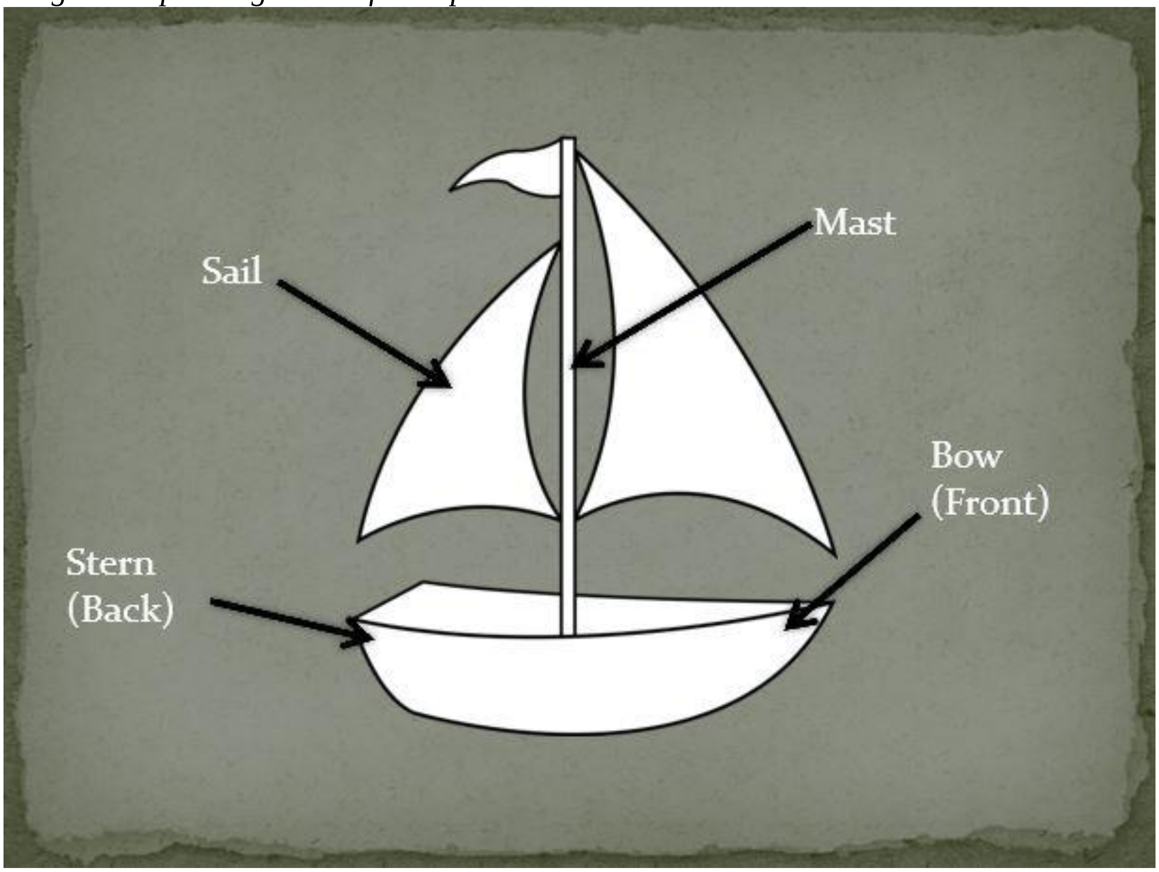
Engage Lesson on Exploration in the 1500s



The researcher noted the teacher used a Think-Pair-Share instructional strategy with students to begin to brainstorm what types of unique features ships would have to travel across the Atlantic Ocean for two to three months. "What features or characteristics of a ship are needed to withstand travel across the Atlantic Ocean?" the teacher asked. Then, as students looked at a generic diagram of a ship (Figure 4.10), the teacher discussed the important features their ships would need in the EDP.

Figure 4.10

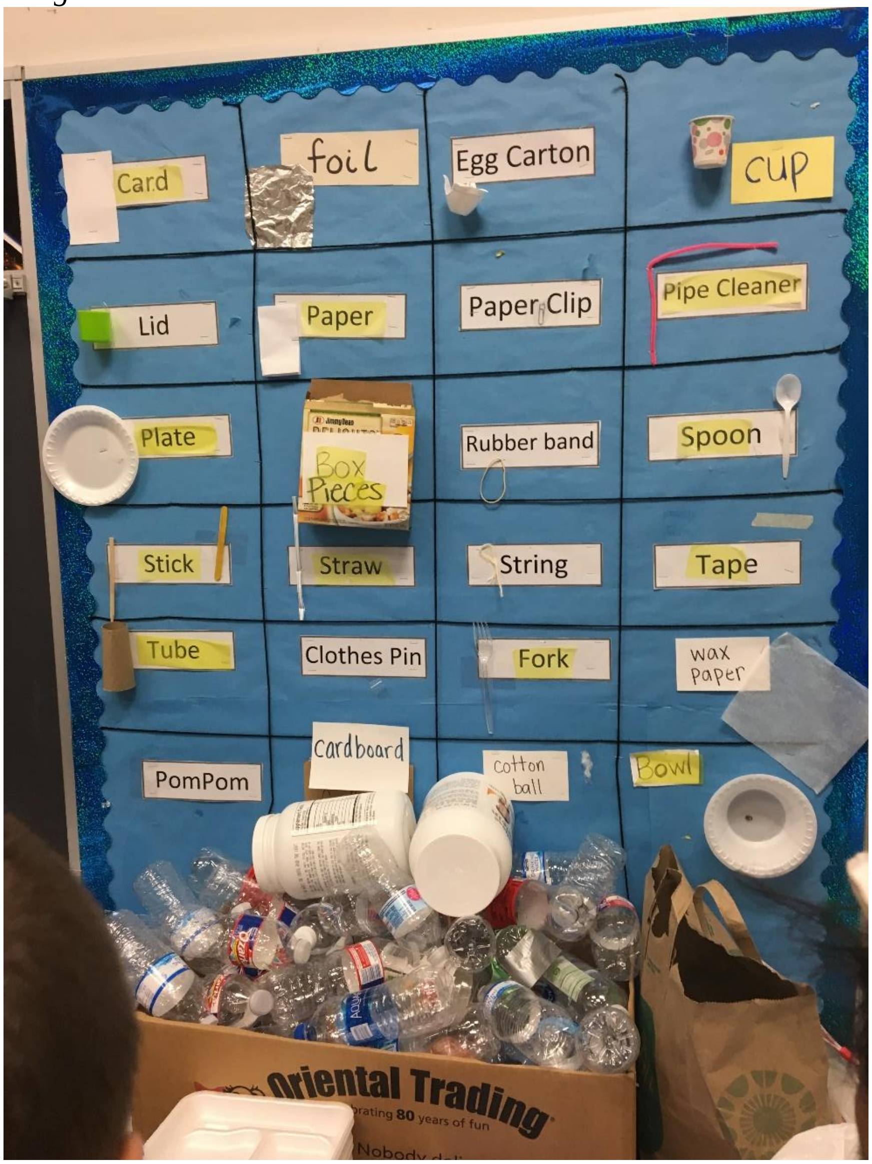
Diagram Explaining Parts of a Ship



Toward the end of the Ships for Exploration lesson, the researcher noticed the lesson shift from teacher-driven to the student-driven EDP. The fifth-grade teacher and STEM specialist, who substituted for the fourth-grade science teacher, explained the project together. Both appeared familiar with the students and the project. They were, therefore, able to fully describe the expectations and to facilitate students' ability to think and act as engineers. The teacher asked, "Can you design a ship that can carry a crew and cargo and withstand wind, rain, and waves in the Atlantic Ocean?" During this moment, the researcher noticed students appeared to think about the problem and it appeared they were shifting their mindsets to become cargo boat engineers. Students were then prompted to write the "Ask" question in their science journal. Next, detailed information was provided that aided the "Imagine" and "Plan" phases. The teacher showed students the materials list (Figure 4.11) for their cargo boat build and explained they were allotted a $10.00 budget by the king. The teacher provided time for students to ask questions about the type and amount of materials. According to the STEM specialist, question time reflects the brainstorming that engineers do at the start of a project as they consider realistic options. Engineers often include an interdisciplinary approach while brainstorming possible solutions, which allows for creativity and ingenuity (Gormley & Boland, 2017; Marcos-Jorquera et al., 2016). The STEM specialist explained the budget was for the prototype and the final design. She continued to explain that the boat should not sink, and they would "take a fan and blow on it" to simulate wind to test their design. Rainstorms would be simulated by using a water can and typhoons/hurricanes would be simulated by shaking the side of the pool extremely hard. "[There will be] a massive rainstorm that will see if your boat can make it across the sea. This is what our explorers did," the specialist enthusiastically explained as she made the connection between social studies and science.

Figure 4.11

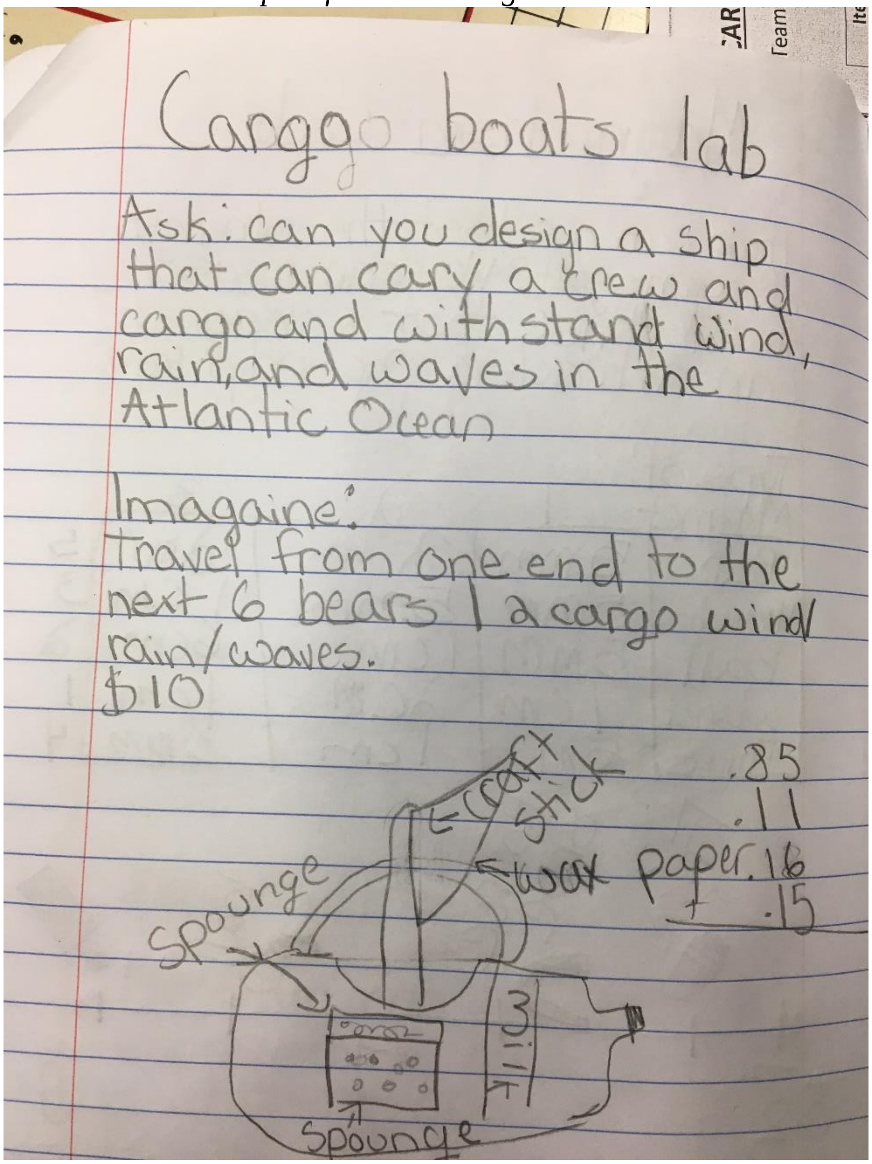
Cargo Boats Material List



Before an engineer designs a project, the specialist explained, the questions during the brainstorming session are used to imagine the design and to weigh alternatives. During the next phase in the EDP, students were asked to "Imagine" what their boat needed to look like (Figure 4.12). The researcher observed students sketching their ideas in their science journals as they were encouraged by the specialist not to worry about their budget constraints. The sketch had to be large and labeled with materials. Students were encouraged to look at the materials list. Students were reminded by the specialist that the ship must carry a crew and cargo. The crew consisted of six miniature teddy bears and cargo 40 grams of clay. Students had five minutes to individually complete the "Imagine" portion (Figure 4.12). "Individual ideas only. No talking; by-yourself time," the specialist reminded students. Students continued to transition from the teacher-centered instruction to a more student-centered "Plan" phase where the design was collaboratively constructed.

Figure 4.12

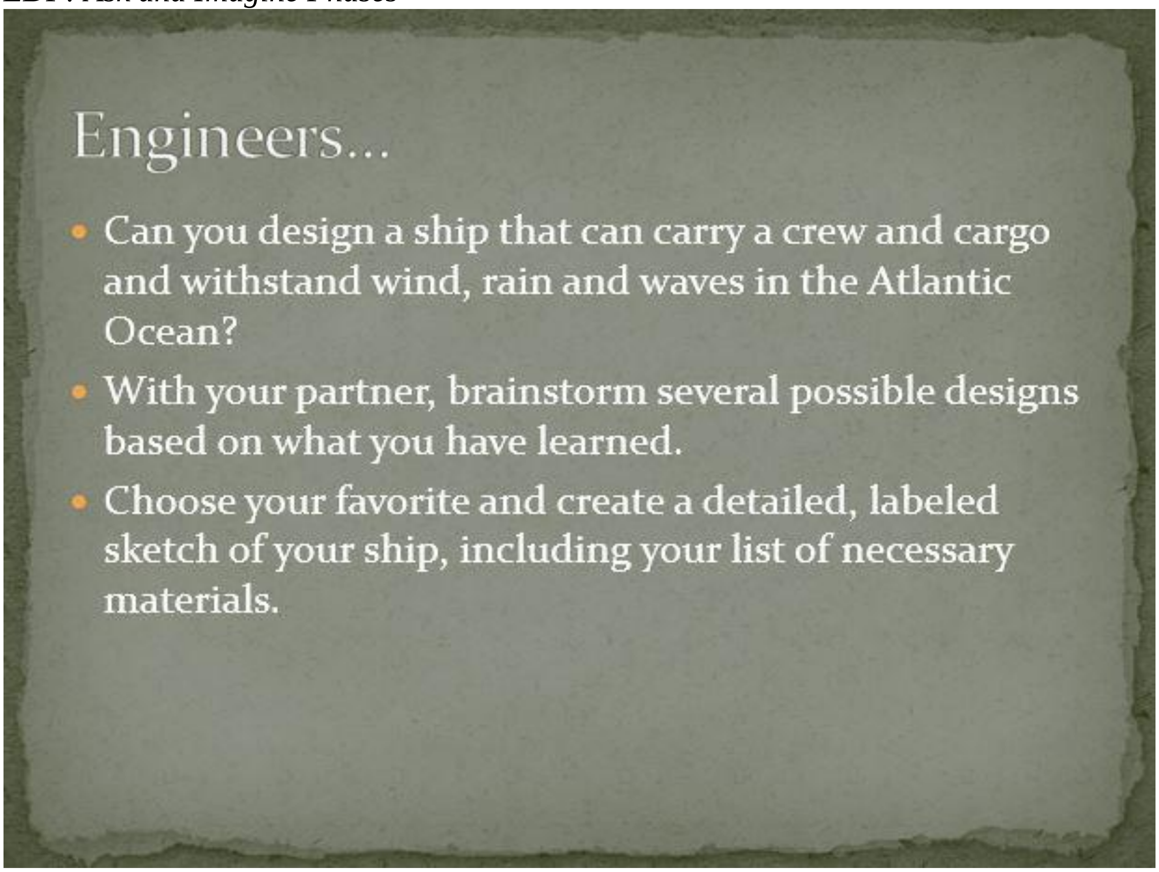
EDP: Student Example of Ask and Imagine Phase



At the end of five minutes, the researcher observed students sharing their ideas with their "A and B partners." Many students appeared to enthusiastically use their hands to explain their ideas and sketches to their partners and pointed to materials if needed. The researcher observed students share their ideas with the class in a whole group discussion, which modeled a “think tank” atmosphere which can be found on engineering teams as they “learn and adapt to innovate solutions to new problems” (Larson et al., 2017, p. 2).

Figure 4.13

EDP: Ask and Imagine Phases



After sharing, students combined both designs and ideas and created a “Plan” with a new sketch on a clean sheet of paper in their science journals. The researcher observed groups receiving an approval stamp by either the teacher, specialist, or engineering aide after they were finished with the new design and completed the budget sheet individually. If needed, students were directed to the mathematics anchor charts in the back of the laboratory (Figure 4.14). They were reminded by the facilitators, “The king has told us you have $10.00 for this boat [so] stay within your budget.” Many engineers must work under specific constraints such as budget constraints which can limit the design by eliminating different possibilities (Dym et al., 2009). Therefore, completing their Cargo Boat EDP within the proper constraints provides students with a real-world application of properly budgeting and managing materials for their project.

Figure 4.14

Adding and Subtracting Decimals Review Anchor Chart

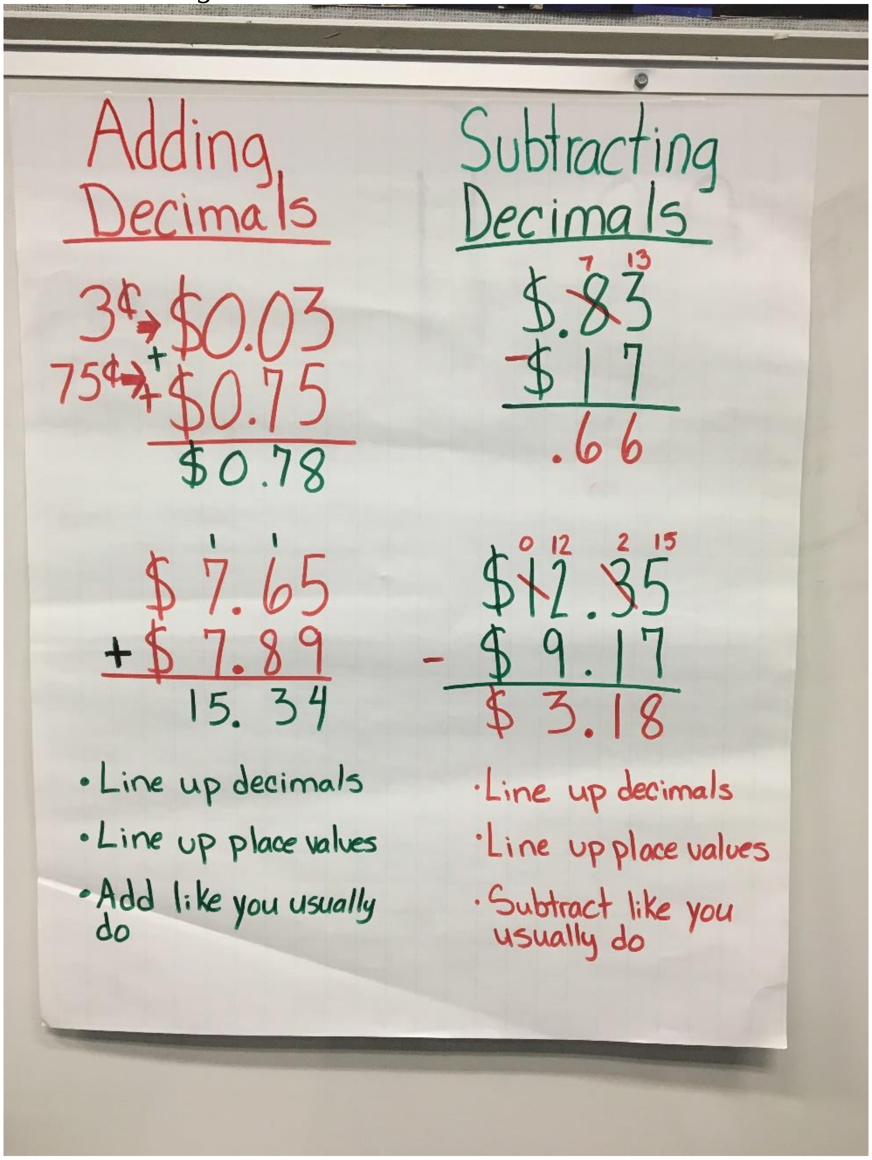
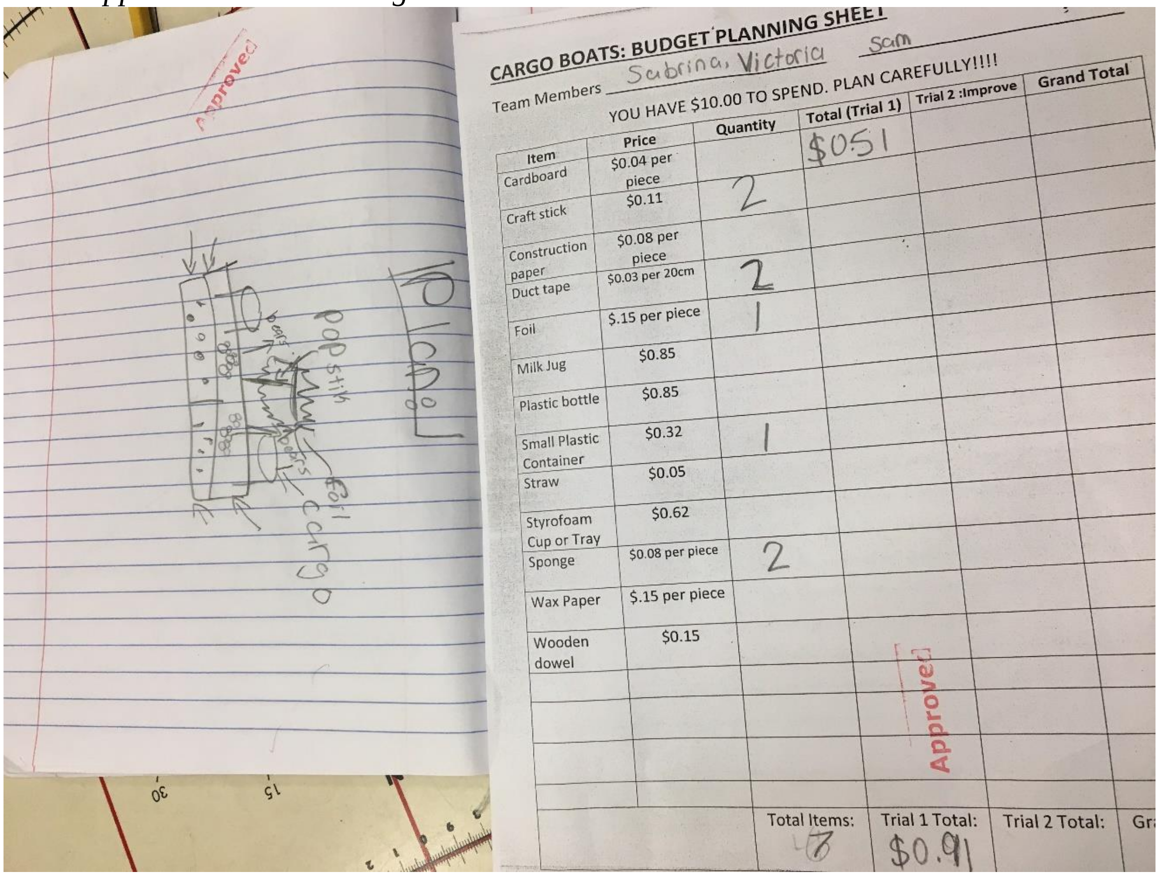


Figure 4.15

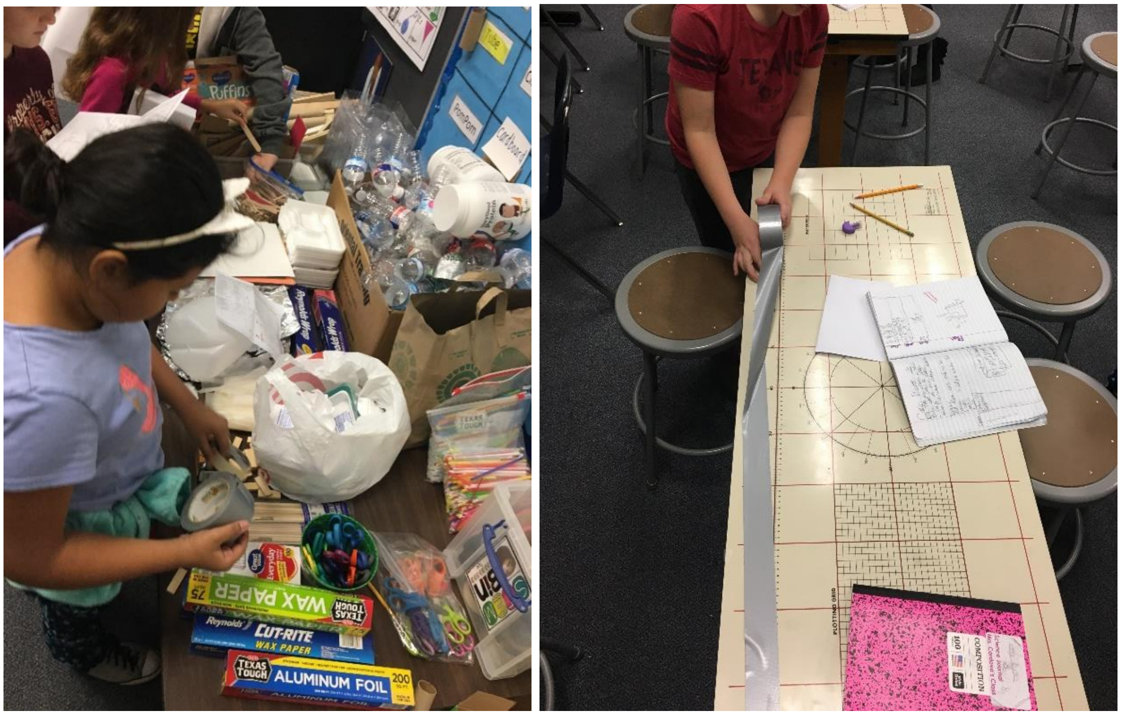
EDP: Approved Plan and Budget Sheet



The researcher observed that the “Create” phase began when students received approval for their “Plan” with the new design and budget (Figure 4.15). The researcher saw students beginning to review and collect materials as they began the “Create” phase (Figure 4.16). The use of duct tape was permitted to build the cargo boat; however, students budgeted and measured the appropriate amount on their own.

Figure 4.16

EDP: Students Review and Measure Materials in Create



Using their design plan, the researcher observed students work collaboratively to build their cargo boat (Figure 4.17). They communicated regularly about the plan and reality of the build as a check-and-balance and to ensure accuracy. According to the teacher and specialist, students' final products should match their approved designs (Figure 4.18). Students' collaborative teamwork and adherence to specific criteria is integral to the work engineers do (Marcos-Jorquera, Pertegal-Felices, Jimeno-Morenilla, & Gilar-Corbi, 2016). This phase marked a clear move to a student-driven environment with students thinking and acting more like engineers.

Figure 4.17

EDP: Students Create Their Cargo Boats

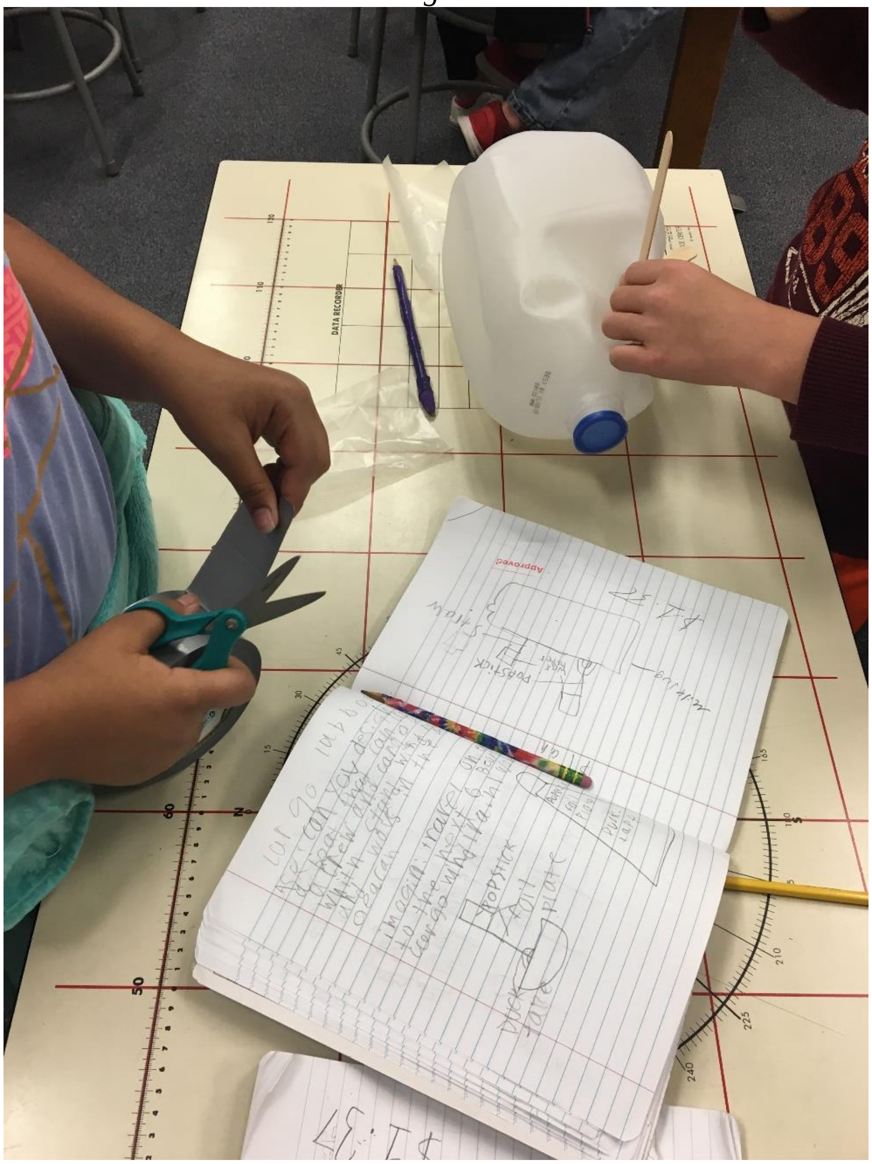
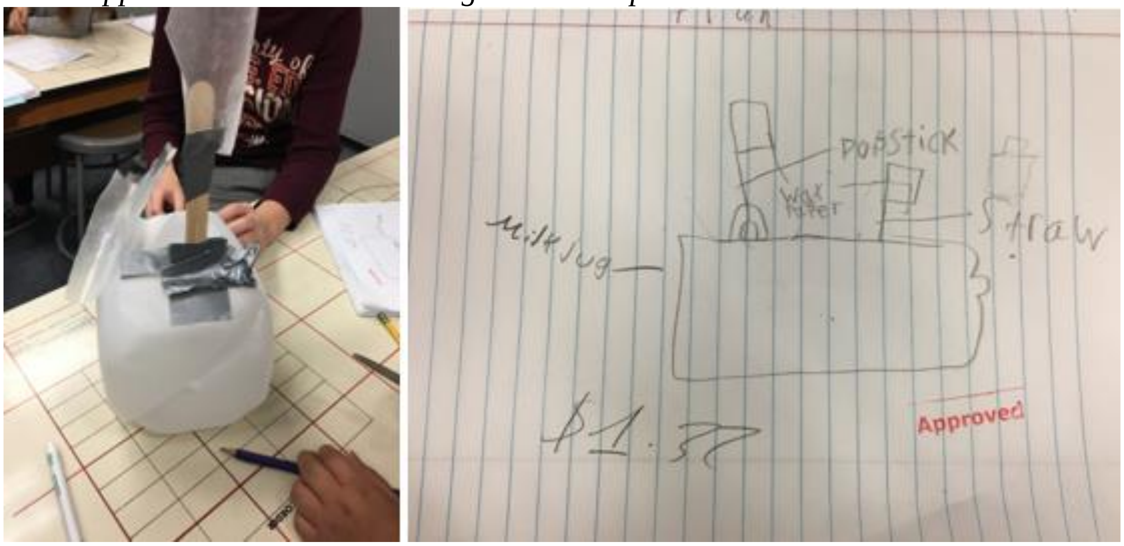


Figure 4.18

EDP: Approved Plan and Built Cargo Boat Comparison



Students tested their cargo boats in a small plastic pool (Figure 4.19). As stated, the teacher provided “extreme weather conditions,” utilizing a fan for wind, water can for rainstorms, and shaking the side of the pool for typhoon and hurricane waves. During testing, the teacher and STEM specialist prompted students to think about how they could improve their designs by analyzing what worked and what did not work. After testing, students were provided time to “Improve” and redesign their cargo boats and retest them. During the trials, students collected data and then placed them into an Excel spreadsheet.

Finally, students shared the results of their designs. The researcher did not observe students during the “Communicate” phase; the STEM specialist provided information as to what students completed during this phase and the grading rubric for students’ presentations. She said the students wrote a persuasive letter to the king asking him to fund their expedition, which included the ship’s design and how well it held up to severe weather conditions, thus making it able to cross the Atlantic Ocean. The final presentation included a skit in which they presented their cargo ship to the king (Figure

4.20). Students used the Oral Presentation Rubric: Presentation to the King (Figure 4.21) to guide them.

Figure 4.19

EDP: Testing Extreme Weather Conditions

Figure 4.20

EDP: Students' Final Cargo Boats

Figure 4.21

Example of Oral Presentation Rubric: Presentation to the King

CATEGORY	4	3	2	1
Preparedness	Student is completely prepared and has obviously rehearsed.	Student seems pretty prepared but might have needed a couple more rehearsals.	The student is somewhat prepared, but it is clear that rehearsal was lacking.	Student does not seem at all prepared to present.
Speaks Clearly	Speaks clearly and distinctly all (100-95%) the time, and mispronounces no words.	Speaks clearly and distinctly all (100-95%) the time, but mispronounces one word.	Speaks clearly and distinctly most (94-85%) of the time. Mispronounces no more than one word.	Often mumbles or can not be understood OR mispronounces more than one word.
Volume	Volume is loud enough to be heard by all audience members throughout the presentation.	Volume is loud enough to be heard by all audience members at least 90% of the time.	Volume is loud enough to be heard by all audience members at least 80% of the time.	Volume often too soft to be heard by all audience members.
Posture and Eye Contact	Stands up straight, looks relaxed and confident. Establishes eye contact with everyone in the room during the presentation.	Stands up straight and establishes eye contact with everyone in the room during the presentation.	Sometimes stands up straight and establishes eye contact.	Slouches and/or does not look at people during the presentation.
Listens to Other Presentations	Listens intently. Does not make distracting noises or movements.	Listens intently but has one distracting noise or movement.	Sometimes does not appear to be listening but is not distracting.	Sometimes does not appear to be listening and has distracting noises or movements.

Through observational data, the researcher witnessed fourth-grade students acquiring authentic real-world learning experiences as they designed cargo boats during the engineering laboratory. She witnessed the teacher and STEM specialist work in tandem to facilitate the project and encourage the type of behavior and thinking required in each phase of building and evaluation of the cargo boat. Throughout the project, she observed students move from a teacher-centered introduction to a student-centered, authentic working environment that demonstrated a shift toward engineering behavior and thinking practices. The fourth-grade cargo boat STEM Block learning experience exemplified the integration phase of Descriptive Framework for Integrated STEM Education (Honey et al., 2014), which is highly valued by the Gemini Elementary teachers and school leaders according to the interview data.

Perceptions of the engineering laboratory. Based on survey and interview data, the specialist role is instrumental in the success of the STEM Block in that it guides and models the EDP lessons for the teachers. The researcher observed several key moments where the specialist's in-depth STEM knowledge and pedagogical content knowledge provided opportunities for the teacher to learn as well as the students. For example, when the teacher explained the introduction of the cargo boats EDP and reviewed types of ships that crossed the Atlantic, the specialist interjected and described some of the treacherous weather conditions that these ships encountered when sailing to America. In addition, prior to the "Create" phase, she informed students that during the test phase she and the teacher would use a fan to simulate wind, use a plant-watering bucket to simulate rain, and violently shake the sides of the baby pool to simulate rough water conditions. When the STEM specialist shared her expertise with students and teachers, she painted a picture of how the teacher and specialist will try to duplicate the hazardous weather conditions that sailors and ships encounter when crossing the Atlantic. Based on the examples cited above, the STEM specialist modeled the way to provide students and teachers an in-depth learning experience; this sparked a sense of curiosity and interest in students and provided the teacher with modeling and guidance that will increase their STEM knowledge and pedagogical knowledge and skills when facilitating an EFP.

Based on the data, the engineering laboratory is a key component in how Gemini Elementary integrates STEM education. It provided a place for students to utilize and improve their 21st century skills. In addition, it provided a place for teachers to develop their STEM knowledge and pedagogical content knowledge by watching and co-teaching with the STEM specialist. Furthermore, K-5 teachers expressed that the engineering laboratory is in high demand by all grade levels, and they wished their classes were scheduled more than once per nine-week period.

In conclusion, the engineering laboratory appeared to be an engaging learning experience for students who enthusiastically took the role of a ship designer. The engineering laboratory appears to be a key component in how Gemini Elementary integrates STEM education, based on teacher and school leader comments as well as researcher observations. It provided a place for students to utilize and improve their 21st century skills. It also created an environment for teachers to develop and hone their STEM knowledge and pedagogical content knowledge, by watching and co-teaching with the STEM specialist. Finally, it was a dedicated setting for the purposeful integration of STEM for every grade level at regularly scheduled intervals.

CHAPTER V:

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

STEM education has become a widely discussed concept among educators, policymakers, and stakeholders. The review of literature, however, showed little research regarding implementation of an integrated STEM initiative in an elementary school. In addition, the difficulty in defining STEM and STEM integration could limit the implementation of STEM education in more schools and limit the students entering the STEM workforce in the future (NRC, 2014; Schneider et al., 2016). These authors echoed the need for educators, policymakers, and stakeholders to agree upon common terminology to increase STEM education in the U.S. and fulfill the need of 1 million STEM workers. Therefore, Honey et al. (2014) created A Descriptive Framework for Integrated STEM Education with the purposes of providing clarity among specific features within STEM education and providing a framework that grants a common language for researchers, educators, policymakers, and stakeholders to use that will help decrease the confusion for this under-researched trend in the U.S. schools. This chapter summarizes the results obtained from the data analysis of this mixed-methods case study at an elementary school in Texas and presents a detailed discussion of the findings, generated implications of these findings, and future research recommendations.

Summary

The purpose of this mixed-methods study case (QUAL-quant) was to determine if implementing integrated STEM curricula into an elementary school would increase student achievement as measured by STAAR scores. In addition, the researcher sought to identify K-5 STEM educators' perceptions of STEM education and key components of a successful STEM elementary school. Therefore, the study addressed the following research questions:

Research Question 1: Does integrating STEM curricula into an elementary school increase students’ Grades 3-5 Reading and Mathematics and Grade 5 Science STAAR scores?

Research Question 2: What are K-5 STEM educators' perceptions of STEM education and key components of a successful STEM elementary school?

The summary derived from this mixed-methods case study pertains to the participants’ perceptions of STEM education and key components of a STEM elementary school in Texas. Results relevant to the research questions have been presented in narrative and table form. With this in mind, the following conclusions are presented.

Research Question One

The first research question addressed by this study was: Does integrating STEM curricula into an elementary school increase students’ Grades 3-5 Reading and Mathematics and Grade 5 Science STAAR scores? In addressing this research question, the researcher analyzed publicly available archival STAAR data from TEA. However, learning and achievement is a student outcome measured using STAAR within schools in Texas. The descriptive analysis of the data was not enough to determine if implementing integrated STEM curricula increased STAAR scores for Grades 3-5 Reading and Mathematics and Grade 5 Science. Additionally, students’ scores could fluctuate from year to year because a different group of students were assessed. Similarly, fluctuations in scores could be due to the principal’s decision on moving teachers into a different content area or grade level throughout the years. Interview data, however, from the principal and STEM specialist reflected that the implementation of integrated STEM education has not caused any “harm” in students’ learning and achievement. Some teachers initially showed concerns about not having enough time for literacy stations or mathematics instructions, but now see and understand the academic benefits of STEM in their school. The principal proudly shared that the science and mathematics scores on STAAR are usually within the top five schools in the district, which ranks in the top 3% of Texas when compared with other school districts. There were no significant differences in trends between the STAAR scores from Gemini prior to implementation and the STAAR scores from Gemini after the implementation; therefore, the results of research question one were inconclusive.

Research Question Two

The second research question addressed by this study was: What are K-5 STEM educators' perceptions of STEM education and key components of a successful STEM elementary school? In addressing this research question, the researcher collected and analyzed data from K-5 Educators' STEM Perception survey, interviews with the principal, STEM specialist, librarian, and teachers to determine common themes pertaining to educators' perceptions about STEM education and key components of a successful STEM elementary school. Based on the survey and interview data, six common themes emerged from K-5 STEM educators' perceptions of STEM education: Instructional Leadership Team, Importance of Attending National Conferences, Teacher Collaboration, School Culture, 21st Century Skills, and Integration of the Engineering Laboratory. Based on the results presented, the researcher found these themes were attributable to the successful implementation of integrated STEM curricula in an elementary school.

Theme 1: Instructional Leadership Team. The instructional leadership team emerged as one essential contributor to the themes from the educators' perceptions. Multiple responses from educators' perceptions mostly agreed that the instructional leadership team played an important role in providing a clear vision, creating buy-in, and supporting teachers' professional development. The instructional leadership team, which for this research consists of the principal, STEM specialist, and school librarian, were instrumental in implementing effective and successful integrated STEM curricula.

The principal was initially concerned with his school's reduced attendance rates due to the school district rezoning, which included fewer GT students attending the school, and this prompted him to find innovative ways to solve the problem of fewer numbers of students zoned to his school. Although it seems counterintuitive, several options—including creating a science magnet school and a STEM program—came to mind. They created an exploratory committee to determine the best options for meeting the needs of the school and students. The exploratory committee collected information and observed several STEM and magnet science schools and programs in Texas. They collected information and began to discuss their findings with other faculty and staff members. The principal also met personally with each department and grade level and discussed their thoughts and ideas about the options. The idea of transforming the elementary school into a STEM school would come to fruition during this time, as the staff agreed that a STEM school would meet the needs of their students, the school, and the community. The principal thought implementing STEM curricula would be the best way to increase student enrollment and provide students with the necessary 21st century skills for generations to come.

To ensure the success of the transformation to a STEM school, the principal hired a previous GT coordinator to be the STEM specialist. Her leadership role consisted of developing authentic engineering design process (EDP) projects to engage students in a rigorous, real-world problem that would develop their 21st century skills. In addition, the specialist developed both the teachers' STEM content and STEM pedagogical knowledge and skills through a series of in-service professional development sessions prior to the beginning of the school year and throughout the school year. Furthermore, the specialist's role consisted of assisting teachers with strategies to integrate STEM concepts into their content areas. During team planning sessions and professional learning communities (PLCs), the specialist provided teachers, once again, with the STEM content and pedagogical knowledge and skills, but also with the support needed incorporate the engineering laboratory into their curricula. As well, she explained and modeled the EDP for the teachers.

During the initial phase of implementation of the integrated curricula, the specialist assumed the role of the EDP's lead facilitator in the engineering laboratory. Teachers acquired a deeper understanding of the STEM content and pedagogical knowledge and skills needed to be a successful facilitator of EDP by watching the STEM specialist. Teachers learned how to facilitate EDP as the specialist taught the lessons to the students. The STEM specialist exampled how to provide students an in-depth learning experience that would spark the students' sense of curiosity and interest. This also provided the teachers with modeling and guidance, and increased their STEM knowledge and pedagogical knowledge and skills when they would facilitating an EDP. As teachers' STEM content and STEM pedagogical knowledge and skills increased, teachers assumed the roles of co-facilitator and facilitator. Based on the interviews, most of them stated they were comfortable with their knowledge and skills and now fully facilitate the EDP lesson during the engineering week. Therefore, the specialist's role has transformed into a secondary co-facilitator during the EDP she attended. The specialist was thus an integral part of the successful implementation of STEM curricula.

In addition to the specialist, the school librarian took a leadership role and was a trailblazer in the integration of STEM throughout the school. She was determined that the library be a safe place where students could explore new concepts and technology at their own pace. Having little knowledge and experience in the STEM fields, the librarian researched and networked with other librarians around the country. She learned about the makerspace movement and wrote grants to develop a makerspace in the school library. The success of the library makerspace prompted the idea of mobilizing the makerspace. This allowed students to take makerspace boxes, consisting of specific content or concepts, home, which enhanced the students' interests and STEM identity. This also allowed the teachers to take the makerspace into their classroom as another tool to support their lessons and connected STEM to their lessons. National recognition was bestowed upon the school's librarian and on Gemini Elementary due to the success of the integration of the library makerspace and the mobilization of the makerspace. With the librarian's forward thinking and willingness to take a risk on a new concept, such as the makerspace, the students at this school were more interested in the STEM fields and better prepared to meet the needs of the 21st century workforce. Therefore, librarians are an essential educator support needed in schools, so they can not only integrate STEM education but also guide students, educators, and parents with the proper resources to use.

The Instructional Leadership Team was the unit that provided the vision, resources, communication, and impetus to begin and move forward with the STEM school concept. Three things especially surprised the researcher: the principal's innovative thinking to address solving a declining school population problem in the face of losing half his school's GT students; the importance of the role of the school librarian; and the combined leadership of the principal, specialist, and librarian, as each was instrumental in the successful transition from a traditional school to a STEM school.

Theme 2: Importance of Attending National Conferences. The importance of attending national conferences was one of the leading themes from the educators' perceptions. Shared viewpoints emerged from the educators' perceptions regarding developing teacher expertise by attending national conferences. Multiple responses from educators' perceptions indicated agreement with the principal's vision of what a successful implementation of integrated STEM would require and that prompted him to invest in his staff by sending them to local, state, and national conferences. Based on the survey and interview responses, his support was significant and afforded teachers the opportunity to develop their STEM content and pedagogical knowledge and skills.

Teachers attended local and state science, mathematics, and STEM conferences. Many conference sessions claimed to be STEM based but consisted mainly of one or two STEM content areas. The educators quickly realized that these conferences were not meeting the needs of developing their STEM content and pedagogical knowledge and skills; the principal, therefore, began sending teachers to national conferences. Data indicated that the principal, specialist, and teachers agreed on the importance of teachers attending national conferences, compared with state and local professional development opportunities. Many teachers attributed the acquisition of STEM content and STEM pedagogical knowledge and skills to attending national conferences such as NSTA and NSTA STEM Forum & Expo. As a result, these conferences prompted changes in their teaching practices.

While attending conferences, staff members capitalized on the opportunity to network with other STEM educators and began to collaborate with a national network of STEM professionals on content and pedagogical practices. As teachers' STEM content and STEM pedagogical knowledge and skills developed, they became the experts in the field and presented at state and national conferences. Because of the principal's investment in sending teachers to national conferences, teachers were equipped with the necessary knowledge and skills to teach students in the 21st century and prepare them for the STEM jobs of tomorrow.

Theme 3: Teacher Collaboration. Teacher collaboration emerged as one of the leading themes from teachers' perceptions. Survey and interview data regarding teacher collaboration agreed that the importance of teacher collaboration helped develop their STEM content and STEM pedagogical knowledge and skills, created cross-curricular lessons that utilized STEM concepts, and met the needs of and prepared diverse learners to approach and solve problems that might arise in their future.

Teachers collaborated during the creation or modification of the EDP lessons, team planning, and PLCs. Many of the EDP lessons were created prior to the schoolwide implementation of STEM curricula. Over time, teachers shared new ideas on how to make connections between cross-curricular content areas and/or support STEM concepts with each other and the STEM specialists. Teachers also developed new ideas for possible future EDP. Team planning was an essential time where teachers shared their ideas and collaborated with each other on ways to improve their lessons or integrate STEM concepts into their classroom. During this time, experienced teachers and the STEM specialist explained and modeled classroom content and EDP lessons for new teachers. This collaboration helped teachers to be consistent across grade level and content teams.

Theme 4: School Culture. School culture also emerged as one of the leading themes from teachers' perceptions. Shared viewpoints became apparent from the educators' perceptions regarding the school culture. Survey and interview responses regarding school culture agreed regarding the important role school culture played in developing the mindset of both the students and the teachers. The principal's vision of creating a STEM elementary school where students were encouraged to make mistakes, learn, and redesign, created a school culture that embraced failure. This mindset was utilized and seen continuously in the engineering STEM Block and throughout daily activities in classrooms. During the EDP, students were encouraged to reflect on why their design was not effective and then prompted to improve, redesign, and retest their design. Thus, this approach provided a safe environment that accepted failure as a natural part of learning. Educators shared that this understanding and mindset could be seen in the regular classrooms, and students would ask if they could redo or change their work in an assignment as a result of learning a new concept or strategy. Thus, elementary students were in a constant state of improvement due to the positive and constructive school culture created at the school. The researcher interpreted these shared beliefs as to how the vision and school culture helped determine students' learning and success in a STEM school.

Theme 5: 21st Century Skills. Acquiring 21st century skills was another leading theme from the educators' perceptions. The integration of all core subjects and art into real-world application is the foundation of STEM education. Most of the elementary educators perceived STEM education as the integrated curricula of STEM subjects, sometimes with the arts, that provided students with opportunities to develop critical thinking, problem solving, and creativity using project-based, hands-on, and real-world applications. Most teachers believed that the integration of STEM education in their classroom and engineering laboratory was vital to the success of their students as far as their competition for STEM jobs in the future.

Theme 6: Integration of the Engineering Laboratory. The integration of the engineering laboratory is the last theme addressed from the educators' perceptions. The survey and interview data provided educators' insights regarding perceptions of integrated STEM education at the school. The primary tool for the integration of STEM education was the use of the STEM Block, which included a weeklong EDP where students attended and studied in the engineering laboratory. The researcher found that all the educators who participated in this study agreed the engineering laboratory was the most effective way to integrate STEM into their elementary school. The engineering laboratory created an environment which allowed for the teaching of the engineering processes and was an encouraging space for students to possibly shift their mindsets and become engineers. Furthermore, students collaborated and communicated with adults and peers when creating their EDP.

The researcher found that teachers perceived that they integrated STEM education in their classrooms through multiple ways. This included researching topics and STEM careers, making connections between disciplines and STEM, science literacy stations, STEM bins, hands-on science laboratories, and continual use of problem-solving skills throughout different subjects. By utilizing these strategies, survey and interview data suggest that many teachers believed they provided students with an opportunity to develop prior knowledge and piqued their interest about upcoming EDP. Teachers felt students improved their communication skills as they wrote about their research process. Students were encouraged to find ways to solve problems and collaborate with others in the classroom and engineering laboratory. Thus, these shared values, as interpreted by the researcher, were teachers trying to create an environment in which STEM education was fully integrated into their classrooms and utilized in the engineering laboratory.

Implications

As the results from this study were examined and explored, there were many factors worth considering that will provide school leaders ideas for developing a vision to create the necessary STEM culture that creates buy-in. Additionally, it will provide teachers implications of the importance of embracing a growth mindset which fosters their likelihood to apply the EDP to their professional practice. The results indicated that implementing integrated STEM curricula into an elementary school benefited the students and educators. Holt, Colburn, and Leverty (2012) found that U.S. students need to obtain the necessary STEM skills to compete in a global STEM economy, whereas English (2016) found that an integrated, interdisciplinary STEM approach was vital for students to fully conceptualize how the content areas were connected and to advance STEM integration. Furthermore, Tanenbaum (2016) stated that early interest in STEM concepts was the groundwork for creating a competitive STEM workforce who will rise to the challenges of rapidly developing scientific and technological innovations. Imperative to providing a greater understanding for researchers, policymakers, and stakeholders were knowing the elementary STEM teachers' perceptions and key components of a successful STEM school. Two primary implications related to STEM education and further research were implications for school leaders and implications for teachers.

Implications for School Leaders

As a result of this study's examination of educators' perception of STEM education and key components of a STEM elementary school, implications for school leaders emerged. The National Research Council (2011) noted the primary objectives of STEM education were to increase STEM training and careers, develop a skilled STEM workforce, and increase science literacy among U.S. citizens. Research indicates that the projected deficit in STEM workers has been prompted by a dynamic global economy and workforce (Kennedy & Odell, 2014). Therefore, school leaders need to prepare a creative and innovative environment conducive to learning 21st century skills that will prepare students to compete in a global STEM economy and workforce.

This study indicated that school leaders such as principals, STEM specialists, and librarians have vested interests to prepare their teachers to effectively implement integrated STEM curricula into their school. Principals need to utilize adequate funds to provide the necessary trainings and national conferences teachers will need to expand their STEM content and pedagogical knowledge and skills. Additionally, principals need to continue providing teachers with the time throughout the school year to network and collaborate with other STEM educators during planning days and conferences.

This study also indicated that it is essential for principals to invest in personnel and resources. It is imperative that the principal hires the proper STEM specialist. The STEM specialist needs to also attend national conferences with the teachers to develop a sense of camaraderie where collaboration of ideas is fostered. Furthermore, the STEM specialist must develop teachers’ STEM content and pedagogical knowledge and skills and shift their thinking from co-facilitating an EDP to facilitating the EDP during the engineering week. This will build teachers’ confidence and skill set. In addition, the principal needs to allow for staff members such as the librarian to foster their vision of the role the library and librarian needs to have within a STEM school. Furthermore, the librarian needs to be provided with the freedom to create a vision for how the library and librarian can help develop students’ and teachers’ STEM identity. This can be done through using different resources, such as makerspaces. Thus, the implications for school leaders needs to provide the staff members with the freedom to promote their creativity in addition to monies and time needed to properly implement a new initiative such as integrated STEM curricula.

Results from this study revealed an effective implementation of professional development for educators implementing new STEM curricula. It may be wise to consider the level of investment school leaders need to make when implementing a new initiative such as integrated STEM curricula. They must provide a way to equip teachers with the necessary STEM content and pedagogical knowledge and skills that would prepare 21st century learners for the future STEM workforce. Therefore, school leaders must send faculty members to science, mathematics, and STEM conferences and set aside funds specially to send faculty to national conferences. National conferences are where teachers see STEM in action and begin to form their own vision and confidence in implementing it in their classrooms. Thus, school leaders must provide adequate resources, including sending teachers to national conferences and ensuring the proper time for teachers to continue to collaborate and develop their knowledge and skills.

Additionally, the principal's vision created a STEM school culture where students and teachers believed it was acceptable to make mistakes, learn, and redesign. Survey and interview data indicated that the educators participating had strong perceptions regarding how important a clear vision and mindset are needed to propel a new initiative such as implementing integrated STEM curricula to ensure the school was successful. Data also revealed that teachers felt it was vital to create a STEM culture in which teachers and students are in a constant state of professional and academic evolution, and where failure is not only accepted but embraced. This mindset creates the idea that learning which takes place in classroom and the engineering laboratory after mistakes are made, and is then enhanced by redesigning and reworking ideas, provides students and teachers a safe environment. In fact, Hernandez et al. (2014) agreed that providing students with authentic learning experiences such as problem solving, innovation, and design in an integrated environment which helps them make connections between STEM disciplines were high priorities for all nations. Implications related to mindset influence how students and teachers are willing to take risks and try new designs and ideas. Thus, it is imperative for school leaders, especially principals, to create an environment which embraces a STEM-driven, growth mindset and promotes the innovation of ideas among faculty and students.

The importance of an effective implementation of integrated STEM curricula in an elementary was also revealed by the study. For example, providing ample time for teachers to collaborate during team planning, PLCs, professional development, and conferences are essential to the success of the STEM implementation. PLCs are necessary not only for the success of the implementation but for teachers to grow in their professional practice and determine how to integrate STEM in a way that is best for a diverse population. Another example of effective implementation is the expectation that educators will attend national conferences and share additional STEM content and pedagogical knowledge and skills that were shared with the school and district. Teachers need to be encouraged to share their expertise about STEM education and present at local, state, and national conferences. Creating meaningful professional development such as attending and presenting at national STEM conferences, establishes opportunities for educators to expand their knowledge of implementation and integration of STEM education, thus benefiting the educators greatly.

The implementation of STEM curricula creates an atmosphere for practicing that innovative environment for the school leadership. School leaders need to present their STEM vision and growth mindset in such a way that there is total buy-in from the teachers, students, parents, and community. This is done partly by engaging school leaders and teachers in rigorous and purposeful professional development such as attending national conferences that will provide instrumental STEM content and pedagogical knowledge and skills they can implement at their school, thereby providing teachers an opportunity to transform themselves from ordinary elementary teachers into STEM experts who presents at conferences. Thus, school leaders must create a culture in which teachers are encouraged to have a STEM-driven, growth mindset and seek expanding their STEM content and pedagogical knowledge and skills.

Implications for Teachers

This study indicated that the educators participating had strong beliefs that high-quality professional development provided them with the opportunity to acquire STEM content and pedagogical knowledge and skills needed to be successful at a STEM elementary school. According to Penuel et al. (2007), curriculum-linked PD is more effective because it promotes a change in teacher pedagogy by training the teachers how to use new strategies, materials, and assessments. In addition, Witworth and Chiu (2015) noted that sometimes teacher motivation, school culture, and working environment can impede the impact of educator PD. This study, however, indicated that the school culture fostered a positive environment which provided teachers with the encouragement to attend high-quality PD at national conferences and an environment that allowed them the freedom for new teaching styles and methods.

This study also indicated that teachers need to embrace the vision of the leadership team, have total buy-in to the new initiative, and trust in the STEM process. It is imperative that teachers have a STEM-driven, growth mindset which will create a constant state of evolution in their STEM content and pedagogical knowledge and skills. It is essential for teachers' to be willing to fail publicly at trying something new in the classroom and then apply the EDP to their teaching practice. Hence, teachers will show students and colleagues that they not only facilitate the EDP but also apply it to their professional practice. Therefore, the school's culture dominates the thinking and actions of all members, including educators and students, and fosters an environment in which failure is embraced and part of the natural learning cycle.

Recommendations for Future Research

Another mixed-methods study should be conducted on pre-service teachers who graduated from various university teaching programs to continue the study of common language of STEM education. A pre- and post-test could be used on pre-service teachers to determine if there is a common STEM language that develops while attending teaching programs. In addition, a focus group could be conducted to determine pre-service teachers' perceptions of STEM language.

A qualitative analysis of teachers' and students' perception of how school mottos impact school culture should be conducted to gain an idea of how a positive environment can impact students' and teachers' mindsets. A case study could be conducted utilizing both educators' and students' perspectives. Documentation through focus groups, interviews, and surveys could provide the data needed to evaluate the impact a school motto has on school culture.

A longitudinal study could also be conducted to assess the K-5 STEM students' academic progress against students who attended a traditional elementary school. The study should begin with kindergarteners and these same students should be tracked, by name/ID number, through 12th grade. Students should be compared with students of the same age who did not attend a STEM elementary school. At the beginning of first grade, end of fifth grade, end of eighth grade, and end of 12th grade, students' STEM literacy should be assessed using the same instrument. This approach is time-consuming and would require funding, and the assessment should provide outstanding results that measure the benefit of the program.

A study should also be conducted on the role the librarian plays in schools wanting to implement an integrated program. This study should be qualitative in nature to provide the greatest depth and scope of the librarians' role. Focus group data could provide much richer data on why libraries should be the mecca for STEM integration in schools.

Conclusion

This study has analyzed student achievement using descriptive statistics and qualitative data to determine the educators' perceptions of STEM education and key components of a successful STEM elementary school in Texas. Research determined that STAAR data was inconclusive due to the limited number of years the data were available, but the perceptions of the school leadership believed implementing integrated STEM curricula has positively impacted students' achievement. Six key components were essential to instituting the new STEM initiative.

The elementary school's motto can sum up the importance of STEM education. It states, "We are here to make mistakes, learn and redesign." This creates a culture in which failure is a necessary and acceptable part of the learning. Thus is created a paradigm shift of how failure is viewed. This paradigm shift moves education from the old education paradigm of failure as a taboo to failure as a necessary component of learning. It therefore changes the definition of failure within the school and learning process.

The motto plus STEM education establishes failure as the process of learning. It creates an incredible explosion of freedom and it removes the stigma of failure. This is an innovative age. We must prepare our students with the freedom to create, the freedom to be different, and the freedom to innovative. STEM education is the future and the future is now.

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APPENDIX A: INFORMATION LETTER

University of Houston Clear Lake

October 2017

Dear Educator:
Greetings! I am a doctoral student in the Department of Education at the University of Houston-Clear Lake and am conducting a study on science, technology, engineering, and mathematics (STEM) education. The purpose of this study is to determine K-5 teachers' perceptions of STEM education and identify K-5 teachers' perceptions of key components of a STEM school. The data obtained from this study will be used in the researcher's dissertation at the University of Houston-Clear Lake. You are invited to participate in the STEM education dissertation study!

The STEM job field is exploding, but our students may not be able to take advantage of it. According to the President's Council of Advisors on Science and Technology (PCAST), the projected growth for science and technology jobs is unprecedented, and one million STEM professionals will be needed within the next decade (Olson & Riodan, 2012). However, the United States is in a national crisis and in danger of losing its global leadership in technology which will affect the future of our students. Lack of science and technology components and human capital affects the nation's economy, security, and role as a world leader.

STEM education is a fairly new approach to teaching; collecting data on the impact of a STEM school on test scores may support the efforts of implementing more STEM schools. By identifying perceptions of STEM education and key components of a STEM school, educators may create, design, and implement a STEM school with a higher success rate.

This study will provide qualitative data that will allow educators, researchers, and policy makers to have a better understanding of educators' perceptions of STEM education. These data can be used to help shape future STEM education professional development for the district and will contribute to the education community by identifying teachers' perception of STEM education and teachers' perceptions of key components of a STEM school. Participation in this study will include semi-structure administrator interviews and teacher focus groups where questions will be provided before an agreed upon meeting.

Your cooperation and willingness to participate in this study is greatly appreciated and will provide invaluable data for the researcher. If you have any further questions, please feel free to contact me.

Thank you,

Carol

Carol Waters, MST
Doctoral Student College of Education
University of Houston-Clear Lake
CurtisC@UHCL.edu

APPENDIX B: SURVEY COVER LETTER

University
of Houston
Clear Lake

October 14, 2017

Dear Educator:

Greetings! You are being solicited to complete the *K-5 Teachers' STEM Perception* survey. The purpose of this survey is to examine teachers' perceptions about STEM education and key components of STEM schools. The data obtained from this study will allow be used in the researcher's dissertation at the University of Houston-Clear Lake.

Please try to answer all the questions. Filling out the attached survey is entirely voluntary but answering each response will make the survey most useful. This survey will take approximately 10-15 minutes to complete and all of your responses will be kept completely confidential. No obvious undue risks will be endured, and you may stop your participation at any time. In addition, you will also not benefit directly from your participation in the study.

Your cooperation is greatly appreciated and your willingness to participate in this study is implied if you proceed with completing the survey. Your completion of the *K-5 Teachers' STEM Perception* survey is not only greatly appreciated, but invaluable. ***All participants who complete the survey will be entered into a drawing to win a $25 gift card.*** If you have any further questions, please feel free to contact me.

Thank you,

Carol

Carol Waters, MST
Doctoral Student College of Education
University of Houston-Clear Lake
CurtisC@UHCL.edu

APPENDIX C: K-5 EDUCATORS' STEM PERCEPTION SURVEY

K-5 Educators' STEM Perceptions Survey

Dear STEM Educator,

The purpose of this study is to contribute to the education community by identifying teachers' perception of STEM education and teachers' perceptions of key components of a STEM school. Your cooperation is greatly appreciated and will provide invaluable data for the researcher.

Please try to answer all the questions. Filling out the attached surveys is entirely voluntary but answering each response will make the survey most useful.

This survey will take approximately 15-20 minutes to complete and all of your responses will be kept completely confidential. Your completion of this survey is not only greatly appreciated, but invaluable.

Your willingness to participate in this study is implied by pressing the button below.
If you have any further questions, please feel free to contact me.

Your permission to use this data is implied by pressing the button below.

Thank you,
Carol

Carol Waters, MST
Doctoral Student College of Education
University of Houston-Clear Lake
CurtiscC@UHCL.edu

Research Study: Exploring K-5 STEM Educators' Perceptions of a Successful STEM Elementary School

Page Break

Q1 What are the last four digits of your phone number? This number will be used as an identifier for the researcher in the study.

Q2 What does the acronym STEM stand for?

Q3 What is STEM education?

Page Break

Q4 What is your role in STEM education?

Page Break

Q5 Do you write/develop lesson plans with others?

- ◯ Yes (1)
- ◯ No (2)

Q6

If you write/develop lesson plans with other teachers, how does planning with your team impact STEM lessons in your classroom or laboratory? Please be as descriptive as possible.

Page Break

Q7 Do you meet with other teachers as a professional learning community (PLC)?

- ◯ Yes (1)
- ◯ No (2)

Q8 If you meet as a PLC, what is your primary focus during this time?

Page Break

Q9

How do you implement STEM education in your classroom? Please be as descriptive as possible.

Page Break

Q10 What are key components you feel makes your STEM school successful? Please elaborate.

Q11 What key components of a STEM school do you wish were in place at your school? Please elaborate.

Q12 What are types of STEM education professional development training you have received? Please list and elaborate.

Q13 What was the specific focus for the professional development you attended on STEM education? Please be as descriptive as possible.

Page Break

Q14 What conferences have you attended on STEM education? Check all that apply.

- ☐ Science Teachers Association of Texas (CAST) (1)
- ☐ National Science Teachers Association (NSTA) (2)
- ☐ National Science Teachers Association (NSTA) STEM Symposium (3)
- ☐ American Educational Research Association (AERA) (4)
- ☐ American Society for Engineering Education (ASEE) (5)
- ☐ National Council of Teachers of Mathematics (NCTM) (6)
- ☐ Texas STEM Conference (7)
- ☐ International Technology and Engineering Educators Association (ITEEA) Texas (8)
- ☐ South Texas STEM Conference (9)
- ☐ Other International Society for Technology in Education (ISTE) (10)
- ☐ Other (11)

Q15 What was the specific focus for the conferences you attended? Please be as descriptive as possible.

Q16 How do you feel the STEM focused conferences and professional development helped to develop you as an educator?

Q17 What is the highest level of education you have completed?

- ○ Bachelor degree (1)
- ○ Master degree (2)
- ○ Doctorate degree (3)

Q18 List all STEM related courses you took while pursuing your Bachelor degree?

Q19 List all STEM related courses you took while pursuing your Masters degree?

Q20 List all STEM related courses you took while pursuing your Doctorate degree?

Page Break

Q21

What is your gender?

- ○ Male (1)
- ○ Female (2)

Q22 What is your age?

- 18-24 years old (1)
- 25-34 years old (2)
- 35-44 years old (3)
- 45-54 years old (4)
- over 55 years old (5)

Q23 Ethnicity origin (or Race): Please specify your ethnicity.

- African American (1)
- Hispanic (2)
- White (3)
- American Indian (4)
- Asian (5)
- Pacific Islander (6)
- Two or more races (7)

Page Break

Q24 How many years have you been in education?

- 0-5 years (1)
- 6-10 years (2)
- 11-15 years (3)
- 16-20 years (4)
- 21-25 years (5)
- 25 or more years (6)

Q25 What is your role?

- ☐ Administrator (1)
- ☐ Content Specialist (2)
- ☐ Librarian (3)
- ☐ Teacher (4)
- ☐ Support Facilitator (5)

Q26 If you are a teacher, what content area do you teach? Check all that apply.

- ☐ English Language Arts/Reading (1)
- ☐ Engineering (2)
- ☐ Fine Arts (3)
- ☐ Mathematics (4)
- ☐ Physical Education (5)
- ☐ Science (6)
- ☐ Social Studies (7)
- ☐ Technology (8)
- ☐ Writing (9)
- ☐ Other (10)

Q27 If you are a teacher, what grade level(s) do you teach?

- ☐ Kindergarten (1)
- ☐ 1st Grade (2)
- ☐ 2nd Grade (3)
- ☐ 3rd Grade (4)
- ☐ 4th Grade (5)
- ☐ 5th Grade (6)

Q28 Have you worked in a STEM school before?

- ○ Yes (1)
- ○ No (2)

Q29 If so, how many years did you work in a STEM school prior to working at this site?

- ○ 0-3 years (1)
- ○ 4-6 years (2)
- ○ 7-9 years (3)
- ○ 10+ years (4)

Q30 How many years have you worked at this STEM school?

- 0-3 years (1)
- 4-6 years (2)
- 7-9 years (3)
- 10+ years (4)

Page Break

APPENDIX D: TEACHER INTERVIEWS

Interview Protocol

Participants will be provided the interview protocol and questions prior to participating in the interview group. Consent forms will be given to the STEM content specialist prior to the interviews for participants to complete. The interviews will be audio recorded and the participants will state their name and last four digits of their phone number during the introduction. Prior to answering a question, participants will state their name. Participating in this study is completely voluntary and will provide invaluable data to the researcher.

1. What is your name and last four digits of your phone number?

2. What is your current role at this school?

3. At this school, how is STEM education approached?

4. What do you think are key components of a successful STEM school?

5. Which of the following components do you feel are vital to a successful STEM school?
    a. Tangible STEM components, Makerspace (regular and portable), Engineering lab, use of technology (what type of technology do students have access to), Robotics?
    b. Guest speakers, Field trips, Donations?
    c. Professional development?
    d. Other?

6. What 21st century skills do students acquire here?

7. How do you feel integrating STEM into your school helps prepare students for their future?

8. What would you change if you could to increase the effectiveness of STEM integration in this school?

APPENDIX E: REQUEST FOR TEACHER FOLLOW-UP FOCUS GROUP

K-5 STEM Teacher Focus Group

_____ Yes, I would like to participate in an additional teacher focus group about STEM education. The focus group will take place for approximately 45 minutes at a local restaurant after the workday and light appetizers will be served. The researcher will contact you with the final date and time. *Thank you!*

Name ____

Last four digits of your phone number ___________________________

Email ____

Grade Level(s) ____

Subject(s) ____

Number of years taught _____________________________________

Number of years taught at this school __________________________

Age _____________ Ethnicity ___________________________________

APPENDIX F: STEM SPECIALIST INTERVIEW PROTOCOL

STEM Interview Protocol

The principal will be provided the interview protocol and questions prior to participating in the telephone interview. Prior to conducting the interview, the researcher will ask for the participant to consent verbally to be a part of the study. The telephone interview will be audio recorded and the participant will state his name and last four digits of their phone number during the introduction. Participating in this study is completely voluntary and will provide invaluable data to the researcher.

1. Why was this site chosen as a STEM school?

2. What was your role in this transformation?

3. How does the principal ensure you have the best teachers in place?
    - a. Hiring
    - b. Professional Development
    - c. PLCs
    - d. Other

4. What is your current role at this elementary school?

5. How does the principal support your role at this school?

6. What do you think are key components of a successful STEM school?
    - a. Stakeholders (District, teachers, parents, community, industry)
        - i. Guest speakers
        - ii. Field Trips
        - iii. Parent Volunteers
    - b. Tangible STEM components
        - i. Makerspace (regular and portable)
        - ii. Engineering lab
        - iii. Use of technology - what type of technology do students have access to?
        - iv. Robotics?

7. How do you know students are successful?
    a. Academic benefits
        i. STAAR
    b. Social benefits
    c. Community connections

8. What stakeholders do you feel have been the most instrumental in making students successful since it became a STEM school?

9. What impact has this school had on the community?
    a. Increase in population

APPENDIX G: PRINCIPAL INTERVIEW PROTOCOL

Principal Interview Protocol

The principal will be provided the interview protocol and questions prior to participating in the telephone interview. Prior to conducting the interview, the researcher will ask for the participant to consent verbally to be a part of the study. The telephone interview will be audio recorded and the participant will state his name and last four digits of their phone number during the introduction. Participating in this study is completely voluntary and will provide invaluable data to the researcher.

1. What is your name and last four digits of your phone number?
2. Will you please share how your school became a STEM school within your district?
3. How did/do you obtain teacher buy-in?
4. What role has professional development played in helping teachers develop the necessary STEM content and pedagogy practices to ensure students are successful in STEM education?
5. How has student enrollment changed since becoming a STEM campus?
6. How is STEM literacy obtained at your school?
7. How do students develop their STEM identity?
8. What key components do you feel are vital to the success of a STEM school?
9. How do you think early implementation of STEM education will impact your students as compared to other elementary students in a traditional school environment?
10. Looking towards the future, what changes are you making to improve how STEM is integrated at your school to increase STEM literacy of all students?

APPENDIX H: TEACHER FOLLOW-UP INTERVIEW PROTOCOL

Teacher Interviews #2 Protocol

Participants will be provided the interview protocol and questions prior to participating in the interviews. Consent forms will be completed at the teacher interview group #1 and collected by the researcher. The interviews will be audio recorded and the participants will state their name and last four digits of their phone number during the introduction. Prior to answering a question, participants will state their name. Participating in this study is completely voluntary and will provide invaluable data to the researcher.

Goals

1. What is your name and last four digits of your phone number?

2. As a teacher, how do you build STEM literacy?

3. How do you boost interest and engagement in STEM education with your students?

Nature of integration

4. How do your students engage in the engineering design process as a way to study core content through a variety of challenges?

Implementation

5. How does the STEM specialist help integrate STEM into classrooms and the engineering lab? Are activities modeled in the classroom?

6. How are teachers provided with "proven units" for STEM education during professional development sessions?

7. Do all teachers participate in developing research questions for design challenges? What are the norms for that process?

8. What professional development/planning helps teachers identify and make explicit to their students' connections among disciplines?

9. How would providing teachers more time to plan impact students' ability to make connections within STEM content areas and STEM integrated projects?

Outcomes

10. How is STEM integration made explicit at your school/grade level? (student supports, technology, software, etc.)

11. How is the students' knowledge in individual disciplines supported and STEM connections made within individual disciplines?

12. How do you feel your professional practice has developed as a result of teaching at a school with STEM integration?

13. How do you think early implementation of STEM education will impact your students as compared to other elementary students in a traditional school environment?

14. How do students develop their STEM identity at your school?