ABSTRACT

STANLEY, REBECCA MATTHEWS. What Does It Mean To Be A STEM School: A Comparison of Science Programs. (Under the direction of M. Gail Jones.)

Schools that focus on science, technology, engineering, and mathematics (STEM) have been created to address a perceived need to increase numbers of students in the United States choosing and persisting in STEM career pathways. This study compared science programs in STEM and non-STEM high schools to determine how implementing a STEM design impacts science, a cornerstone of STEM. The multiple case study examined STEM integration, science instruction, and extracurricular opportunities in four high schools, two that were designated as STEM by the state’s department of instruction and two that were comparable but did not have a focus on STEM.

Results from this study indicate that STEM and non-STEM science programs are not significantly different in the schools studied. The two major differences that were found, greater incorporation of engineering design and increased access to extracurricular STEM activities, did not have beneficial impact on students’ attitudes or career choices. Technology and math integration were similar but STEM schools integrated engineering design whereas non-STEM schools did not. Science instruction was similar. The numbers of observed inquiry-based lessons were similar, however, STEM schools had more project-based lessons, a form of inquiry-based instruction in which students create a product. A higher number of science-based extracurricular opportunities was available to students in STEM than non-STEM schools. This study offers important insight into the implementation of STEM education within existing school contexts and constraints.
What Does It Mean To Be A STEM School: A Comparison of Science Programs

by
Rebecca Matthews Stanley

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

Science Education

Raleigh, North Carolina
2017

APPROVED BY:

Dr. M. Gail Jones  
Committee Chair

Dr. Dominique Robertson

Dr. Kathy Trundle

Dr. Eric Wiebe
DEDICATION

To my husband, you made this possible. Graduate school is a team sport, there is no way I would have finished without you! As Sia says, “even superwoman needs superman’s soul.”

To my children, you are the reason my candle burns. I hope I have inspired you to be intellectually curious and to never stop seeking answers to your questions.

To Mom and Dad, that microscope you gave me in 1985 started me down this road. Though it’s had many twists and turns, you walked along with me.

To Sarah, an honorary member of the gyst club, cheers to us conquering the world! Thanks for pushing me when I didn’t want to be pushed.

To Pam, you made the world a kinder place.

To Claire, you help me remember why I love science.

To all the strong women out there burning the candle at both ends, you’ve got this!
BIOGRAPHY

Rebecca Matthews Stanley attended North Carolina State University from August 2011 to December 2017.
ACKNOWLEDGMENTS

“It is good to have an end to journey toward; but it is the journey that matters, in the end.”

Ursula K. Le Guin, *The Left Hand of Darkness*.

The author would like to acknowledge a number of individuals who made this journey possible. First and foremost I would like to acknowledge Dr. Gail Jones, my advisor, for her unwavering support and encouragement. Thank you for pushing when I was ready to give in; it is because of you that this journey is finished.

I would like to acknowledge my committee members Dr. Nikki Robertson, Dr. Kathy Trundle, and Dr. Eric Wiebe for their support and professionalism during this process. I appreciate that you were not timid and asked the hard questions to push my thinking. I must also send thanks to the team of graduate students who rallied around me during different points of the process - Gina Childers, Lindsay Lewis, Rebecca Hite, Elysa Corin, Megan Ennes, Emily Cayton, Katherine Chesnutt – it takes a village!

Lastly, I would like to acknowledge Pauline Younts and Robin Marcus for the finger wagging, cautionary tales, encouragement, and mentorship; you have made me a better, more-thoughtful person.
TABLE OF CONTENTS

LIST OF TABLES ............................................................................................................................................ ix
LIST OF FIGURES .......................................................................................................................................... x

CHAPTER 1: Introduction ................................................................................................................................. 1
Purpose and Significance of the Study ............................................................................................................. 1
Research Questions ........................................................................................................................................ 3
Research Design ......................................................................................................................................... 4
Theoretical Framework ................................................................................................................................. 4

CHAPTER 2: Literature Review ......................................................................................................................... 5
National STEM Landscape ............................................................................................................................. 5
Integrated STEM ......................................................................................................................................... 13
Technology Integration ............................................................................................................................... 14
Engineering Integration ............................................................................................................................... 14
Science Instruction ..................................................................................................................................... 16
Extracurricular Science ............................................................................................................................... 18
Theoretical Framework ............................................................................................................................... 18

CHAPTER 3: Methods ...................................................................................................................................... 22
Overview ....................................................................................................................................................... 22
Research Questions ..................................................................................................................................... 22
Study Design .............................................................................................................................................. 22
Site and Participant Selection Process ......................................................................................................... 24
Data Sources ............................................................................................................................................. 26
LIST OF TABLES

Table 1: State-level Characteristics of STEM Schools ........................................................... 12
Table 2: Demographic Data of Participating Schools ............................................................. 26
Table 3: Science Teachers Demographics at Edison STEM High School ............................. 35
Table 4: Science Teacher Demographics at Vaughan High School ..................................... 46
Table 5: Differences in STEM and Non-STEM Student Responses by Instructional Practice ................................................................................................................................................. 50
Table 6: Differences in STEM and Non-STEM Student STEM Attitude Scores ................... 51
Table 7: Differences in STEM and Non-STEM Student Career Interest ............................... 51
Table 8: Differences in STEM and Non-STEM Science Classroom Observations ............. 52
LIST OF FIGURES

Figure 1. Study Design. ........................................................................................................ 23
Figure 2. Franklin STEM High School schoolwide design process. ................................. 32
Figure 3. Edison STEM High School schoolwide design process...................................... 38
Figure 4. A structure designed to withstand earthquake damage. ..................................... 39
CHAPTER 1: Introduction

Purpose and Significance of the Study

Science, technology, engineering, and mathematics (STEM) are significant components of human culture (Rutherford & Ahlgren, 1990). As we live in an increasingly engineered world (Ellis, 2008), all humans need a level of STEM literacy to enable them to make informed decisions or be informed consumers of science, technology, engineering and mathematics. The global issues facing this generation, such as providing universal access to clean water and sustainably feeding an increasing world population, will require graduates who are well versed in contemporary science (Rutherford & Ahlgren, 1990) as well as the connections between science and the other STEM disciplines.

STEM education is also good for the American economy. Thomasian (2011) asserts “linkages between innovation and economic growth are fairly well established” (p. 19). Workers with STEM degrees tend to earn more and experience lower unemployment rates than comparable workers (National Science Board, 2012). However, while other nations have seen rapid growth in the percentage of STEM degrees conferred, the United States has remained stagnant at 17%; the United States ranks 20th among all nations in the proportion of 24-year-olds who earn degrees in natural science or engineering (Kuenzi, 2008).

The dismal performance of American students on national and international science assessments has garnered national attention and calls for improvements in science programs. The United States ranked 17th of 34 countries in science on the 2009 Programme for International Student Assessment (Fleischman, Hopstock, Pelczar, & Shelley, 2010). Over a
third of eighth graders scored below basic on the 2011 National Assessment of Educational Progress Science assessment (U.S. Department of Education, 2011). In 2012, 69% of high school graduates failed to meet the readiness benchmark levels in science on the American College Testing exam (ACT, Inc., 2012). In addition to the lackluster performance on assessments, the United States is losing its edge in innovation. The U.S. share of high-tech exports is on the decline, while China has become the single largest exporting country for high-tech products. Correspondingly, the U.S. high-tech trade deficit continues to grow and foreign competitors filed over half of the nation’s technology patent applications in 2010 (National Science Board, 2012).

STEM education is increasingly a topic of national discourse, spurring many reports from respected U.S. academic, scientific, and business organizations (Kuenzi, 2008). One commonality from the discourse is the importance of preparing K-12 students to pursue STEM pathways in higher education in order to increase America’s potential for innovation (Thomasian, 2011).

Getting students interested in STEM education in high school is critically important to getting them to choose and persist in STEM pathways in college. In a recent study of factors promoting the retention and persistence of students of color in STEM at the university level, Palmer, Maramba, & Dancy (2011) identified involvement in STEM related activities and strong high school preparation as commonalities. High schools focusing on STEM are poised to get students interested in STEM and to persist in STEM career pathways. There is
no one definition of STEM programs for high schools and it is defined and implemented differently across different states.

Science programs are a key component of STEM education in secondary schools. However, there are no clear distinctions between general science programs that are present in all typical high schools and STEM programs that are present in specialized schools. The purpose of this multiple case study was to compare science programs in four high schools, two of which have been recognized by the state of North Carolina as STEM schools. The information learned from these case studies can provide insight into how STEM programs are implemented and how STEM schools vary across different locations. Schools are increasingly redefining themselves as STEM schools and understanding how this is interpreted and implemented can help other educators make decisions about this process.

**Research Questions**

The broad goal of this study was to understand how science programs differ in STEM and non-STEM secondary schools. The following research questions focusing on specific aspects within science programs were investigated:

RQ1: Are there differences in integration of technology, engineering, and mathematics in science instruction?

RQ2: Are there differences in instructional methods used by science teachers?

RQ3: Are there differences in school-based extracurricular science opportunities (clubs, field trips, competitions, internships, etc.) available to students?
Research Design

In order to capture the rich details and contextualized factors that influence science instruction at STEM and non-STEM schools, a qualitative multiple case study approach was used. Teacher interviews, classroom observations, teacher surveys, and student surveys were used to explore science programs at each school. Within case analysis and cross-case analysis were used to describe and examine the integration of technology, engineering, and mathematics into science classes; instructional methods used by science teachers; and extracurricular science opportunities within two STEM schools and two comparable non-STEM schools.

Theoretical Framework

This study is grounded in sociocultural and constructivist frameworks in which school leaders, teachers, and students must make sense of the ideals of science literacy and STEM literacy and that the enactment of these philosophies could look quite different in schools depending on their unique contexts and sense-making practices. It is the differences between the ideal and the enacted realities that were uniquely interesting and the focus of this study.
CHAPTER 2: Literature Review

The review of the literature begins with setting the national landscape of STEM education in the United States. This context thus provided, the focus then shifts to defining STEM schools in the state of North Carolina, where the study took place. Next, research on the key components of STEM schools for this study - technology, engineering, and mathematics integration in science lessons; science instructional practices; and STEM identity - are explored deeper. Finally, the overlapping theoretical frameworks of STEM literacy and science literacy are presented to provide structure for data analysis.

National STEM Landscape

STEM education has garnered the national spotlight for a decade. The federal government has invested $3 billion annually in STEM education since fiscal year 2006 (Mervis, 2013). There have been several congressional acts supporting STEM education.

- National Aeronautics and Space Administration Authorization Act developed, expanded, and evaluated educational outreach programs in science that serve elementary and secondary schools
- Deficit Reduction Act established the Academic Competitiveness Grants and National Science and Mathematics Access to Retain Talent Grant programs
• America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act – expanded current STEM education program and created new STEM programs (Kuenzi, 2008)

• The National Science Foundation has added a broader impact requirement to grants requiring recipients to integrate research, teaching, and learning in order to improve STEM education (Mathieu, Pfund, & Gillian-Daniel, 2009).

Several policy documents have also called attention to the importance of STEM education. The U.S. Department of Education (2007) described literacy in science and mathematics as the “creative intellectual energy of our workforce” and laid out several action items to improve science and mathematics education, including preparing more highly qualified teachers, increasing access to Advanced Placement (AP) and International Baccalaureate courses, investing in high quality curricular materials, and increasing the number of students entering college prepared for STEM pathways (Committee on Prospering in the Global Economy of the 21st Century (U.S.) & Committee on Science, Engineering, and Public Policy (U.S.), p. 112). The National Governor’s Association published a tool kit to aid state governors in building a STEM agenda in their individual states (Thomasian, 2011). In 2010, the President’s Council of Advisors on Science and Technology (PCAST) presented a report to the president of the United States that called for preparing students with a strong foundation in STEM subjects and inspiring students so they are motivated to pursue STEM pathways. The council proposed creating STEM schools as a way to improve STEM literacy in the United States (Holdren & Lander, 2010).
Schools focused on STEM are not a new phenomenon. According to Thomas and Williams (2010) specialized technical schools opened as early as 1904 and were generally “schools of choice that actively engage students’ natural interests in pursuit of coursework” (p. 18). At least 16 states have residential STEM schools serving a highly talented student population. According to Olszewski-Kubilius (2010), these schools “offer a unique and comprehensive environment – one that includes an advanced curriculum and opportunities for significant immersion in the work of the field through mentorships, internships, and research apprenticeships” (p. 61). While these highly selective STEM schools add to the STEM talent pipeline, they are not sufficient to significantly increase the numbers of students pursuing STEM pathways and can continue racial and ethnic gaps found in the STEM workforce (Jones, 2009). In order to engage a wider range of students in STEM, a new inclusive model of STEM schools has emerged. Inclusive STEM schools accept students on the basis of interest rather than previous achievement in STEM (Peters-Burton, Lynch, Behrend, & Means, 2014). According to Peters-Burton et al. (2014), inclusive STEM high schools have the potential to “develop new sources of STEM talent among underrepresented students” (p. 65).

Some scholars argue that many jobs require STEM skills and knowledge. According to Singer (2011), “quality STEM learning and literacy are goals for all students, and increasingly non-STEM jobs require some element of STEM capability” (p. 4). Getting students interested in STEM in high school is critically important to getting them to choose and persist in STEM in college. In a study of factors promoting the retention and persistence
of students of color in STEM at the university level, Palmer et al. (2011) found that “all of the participants discussed the strong preparation they had in high school” (p. 498).

There are varying definitions of what it means to be a STEM school. All schools teach science and mathematics, the bookend subjects of STEM. Many schools are working to more purposefully integrate technology throughout their curricula without having a particular focus on STEM. Hence it is important to distinguish how STEM schools are unique from all other schools. Means, et al (2016) defined inclusive STEM schools as accepting students based on interest, rather than prior achievement, and that “provides all of its students with more intensive math and science preparation than regular high schools” (p. 710). R. Brown, et al. (2011) concluded that there was “not a clear vision for STEM education even amongst those who believe it is important.” Lacking a federal definition of a STEM school, defining attributes from individual states were examined to guide this study.

According to the Ohio STEM Learning Network, STEM schools were different from other schools because they provided “challenging, student-centered, inquiry-based educational experiences that are cross-disciplinary in nature and relevant to the real world” (“Frequently Asked Questions | Ohio STEM Learning Network,” n.d.). In addition, STEM schools were designed to be small, around 100 students per grade level, to personalize learning so each student could reach mastery of STEM content. The Ohio STEM Learning Network valued integrated coursework and high school students earning college credit. They argued that instruction should be inquiry-based, which can include project-based, problem-
based, and peer-to-peer learning. They also valued enrichment to enhance STEM mastery (“OSLN Design Principles,” n.d.).

In Texas, STEM schools were required to meet seven benchmarks:

1. Mission-driven leadership
2. T-STEM culture (respect, personalization, partnerships, valuing student voice)
3. Student outreach, recruitment, and retention
4. Teacher selection, development, and retention
5. Curriculum, instruction, and assessment
6. Strategic alliances
7. Academy advancement and sustainability (Texas High School Project, 2010)

Diving into the fifth benchmark, one finds characteristics of STEM within classrooms, specifically integrated STEM curriculum, relevant and rigorous content, and imbedding critical thinking and problem solving.

In Maryland, “STEM education was an approach to teaching and learning that integrated the content and skills of science, technology, engineering, and mathematics” (“Maryland STEM,” n.d.). Maryland adopted the following seven STEM Standards of Practice that guided STEM curriculum and instruction:

1. Learn and apply rigorous Science, Technology, Engineering, and Mathematics content
2. Integrate Science, Technology, Engineering, and Mathematics content
3. Interpret and communicate information from Science, Technology, Engineering, and Mathematics
4. Engage in inquiry
5. Engage in logical reasoning
6. Collaborate as a STEM team
7. Apply technology strategically ("Maryland State STEM Standards of Practice," 2012)

The California STEM Learning Network defined STEM as an interdisciplinary and applied approach that is coupled with hands-on, problem-based learning ("What is STEM?," n.d.). It goes on to describe the implementation of national standards in science and mathematics, community partnerships, new assessment systems, and hands-on learning in STEM.

In North Carolina, leaders in public and private sectors convened to create a STEM Strategic Plan containing a set of attributes, with accompanying rubrics, to recognize schools with a focus on STEM. Schools applied to be recognized as a STEM school by completing a self-assessment process that included submitting evidence of placement on the STEM attributes rubrics (North Carolina Department of Public Instruction, 2015). The eleven STEM attributes were:

1. Project-based learning with integrated content across STEM subjects
2. Connections to effective in- and out-of-school STEM programs
3. Integration of technology and virtual learning
4. Authentic assessment and exhibition of STEM skills

5. Professional development on integrated STEM curriculum, community/industry partnerships, and postsecondary education connections

6. Outreach, support, and focus on underserved students, especially females, minorities, and the economically disadvantaged

7. A communicated STEM plan is adopted across education, communities, and businesses

8. STEM work-based learning experiences, to increase interest and abilities in fields requiring STEM skills, for each student and teacher

9. Business and community partnerships for mentorships, internships, and other STEM opportunities that extend the classroom walls

10. Alignment of the student’s career pathway with postsecondary STEM programs.

11. Credit completion at community colleges, colleges, and/or universities (Robelen, 2013)

Though each of these attributes may be found in STEM education research, the combination of them and their links to STEM achievement have not been studied. State-level characteristics of STEM schools are summarized in Table 1.
Table 1

State-level Characteristics of STEM Schools

<table>
<thead>
<tr>
<th>State</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| California | • Interdisciplinary  
             • Applied content  
             • Problem-based learning                                                                                                                     |
| Maryland   | • Strong disciplinary content in science, technology, engineering, and mathematics  
             • Integrated STEM content  
             • Inquiry-based learning  
             • Collaboration                                                        |
| North Carolina | • Integrated STEM content  
                  • Project-based learning  
                  • Authentic assessment  
                  • Focus on historically underserved student populations  
                  • STEM opportunities outside of the classroom  
                  • Alignment with post-secondary learning institutions |
| Ohio       | • Inquiry-based instruction  
             • Student-centered environment  
             • Cross-disciplinary  
             • Relevant to real world  
             • Mastery learning and early college credit attainment  
             • Small schools                                                                                                          |
| Texas      | • College-going culture  
             • Targets historically underrepresented student populations  
             • Integrated STEM curriculum  
             • Strategic partnerships  
             • Relevant and rigorous content  
             • Project-based  
             • Embed critical thinking and problem solving |

There were many attributes of STEM schools worthy of further examination. This study focused on integrated STEM, science instructional methods, and STEM related extracurricular opportunities in order to gain a holistic view of the science programs within
STEM and non-STEM schools. Research pertaining to those areas is explored in the following sections.

**Integrated STEM**

STEM professionals are able to nimbly navigate knowledge in each of the four domains; work in STEM is not siloed in the real world. Some STEM educators and researchers advocate that the acronym STEM is meant to convey the interconnectedness of the four discreet disciplines. However, secondary schools typically teach science and mathematics completely separate from one another and may offer technology and engineering only as separate elective courses. One could argue that this separation of the four content areas of STEM creates fragmented knowledge and produces students who are not able to seamlessly integrate concepts within the STEM disciplines. Sanders (2008) stated, “amidst the realization that the T and E will play a critical role with regard to our welfare in the twenty-first century, the call for support has shifted from ‘science and mathematics’ to ‘STEM’” (p. 25). There are many who disagree with this notion of integrated STEM, arguing that the disciplines are too complex and teacher education programs are not equipped to prepare teachers for meaningful integration (Lederman & Lederman, 2013). Another perspective is that each of the disciplines really are unique and there is no such integrated discipline as STEM (Jones, n.d.).

Curricula in STEM schools have typically been designed to integrate the four STEM disciplines (J. Brown, 2012). This does not mean that all four STEM content areas are integrated all the time, but rather that integrating the disciplines is strategic, blending content
when and where it made sense for the learning targets (Sanders, 2008). *Science for All Americans*, published by the American Association for the Advancement of Science in 1989 and intended to guide science reform efforts through 2061, also stressed the importance of recognizing the interconnectedness of science, mathematics, and technology (Rutherford & Ahlgren, 1990).

**Technology Integration**

One potential way to accomplish STEM integration is by the pervasive use of technology for learning and using interdisciplinary problems requiring knowledge from two or more STEM domains (Daugherty, 2013; Rockland et al., 2010; Sanders, 2008; Singer, 2011). STEM professionals use technology in the field to collect and analyze data and communicate with a wide range of audiences. By engaging students in the way adults use technology in the world of work, technology is not an add-on but rather it is an integral part of the learning process that augments the learning experience instead of being the focus of the learning experience (Sanders, 2008).

**Engineering Integration**

The “E” in STEM is often enacted through incorporation of engineering design into existing classes. The engineering design process provides a scaffold for problem solving that fits into many curricular contexts. The engineering design process can take many forms, but it typically includes brainstorming, designing, analyzing, building, and testing in a cyclical process (“The Engineering Design Process - www.TeachEngineering.org,” n.d., and MSFC, 2013). This process mirrors other cycles that students are exposed to in school including the
traditional scientific method (Rockland et al., 2010) and the writing process. According to Dym et al. (2005), when schools adopt the engineering design process as their “problem solving framework” across the curriculum, students develop habits of mind that support innovation and creativity including “the ability to tolerate ambiguity, maintain sight of the big picture, think as part of a team, and communicate in several languages of design” (p. 104). Several studies have highlighted the benefits of student participation in engineering design in K-12 science classes (Berland, Steingut, & Ko, 2014; Capobianco, Yu, & French, 2015; Wendell & Rogers, 2013).

How does this purposeful integration fit into the current schema of science education that exists in high schools? Science education in America is poised to change dramatically as states increasingly are adopting the Next Generation Science Standards (NGSS). Released in 2013, the NGSS represent a national effort to create common standards in science, engineering, and technology for all American children. The effort utilized the combined expertise of the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and the nonprofit educational reform organization Achieve, along with input from 26 lead states (“Development Overview,” n.d.). According to Banilower, Gess-Newsome, and Tippins (2014), “the NGSS sets forth an ambitious set of goals for what students should know and be able to do as a result of their science education” (p. 1). Passmore (2015) asserts that the NGSS requires a shift in science learning from “knowledge acquisition” to “figuring out how the world works” (p. 25). States and school districts can accomplish the standards using a wide array of science curricula, but
any curriculum mapped to the NGSS must actively engage students in the three dimensions established in the National Research Council’s Framework for K-12 Science Education: science and engineering practices, crosscutting concepts, and disciplinary core ideas in the physical, life, earth, and space sciences (Committee on Conceptual Framework for the New K-12 Science Education Standards; National Research Council, 2011), thus the curriculum should focus on a predefined set of science concepts taught in a way that enculturates students into the processes of science and engineering. So even schools that are not focusing on STEM are expected to integrate science, engineering, and technology standards to some degree. How schools accomplish this complex integration is left to the discretion of the school. Roehrig, Moore, Wang, and Park (2012) found a mix of co-teaching, team-teaching, team planning, and individual planning strategies as teachers implemented integrated STEM.

Research on the effects of STEM integration is limited. Guzey, et al. (2017) studied STEM integration in middle school and found significant gains in student learning of physical science content. However, they did not find similar gains in life science, engineering, or mathematics content knowledge.

**Science Instruction**

According to the state-level definitions of STEM schools provided in this section, instruction in STEM schools was characterized by explicit connections to the real world by engaging students in inquiry. STEM schools may have used a variety of inquiry-based methodologies to incorporate real-world problems into classroom instruction; however, project-based learning (PBL) was directly mentioned in the North Carolina STEM attributes
as the inquiry-based method employed in STEM schools (Friday Institute for Educational Innovation, 2013). Project-based learning is a teaching method that engages students in investigating an authentic, complex problem or question. In the process of investigation, students learn content and develop a product, which can be a presentation, website, or other tangible artifacts (“What is PBL? | Project Based Learning | BIE,” n.d.). David (2008) explained that in this student-centered approach the “teacher plays the role of facilitator, working with students to frame worthwhile questions, structuring meaningful tasks, coaching both knowledge development and social skills, and carefully assessing what students have learned from the experience” (p. 80).

Research on the implementation of PBL has been limited. Ergul (2014) found PBL improved success in learning about electricity in middle school students. Al-Balushi (2014) found positive results when PBL was used to teach environmental science topics to eleventh grade female students in Oman. Geier (2008) examined the effects of PBL science when teaching middle school students in Michigan and found improved performance on standardized tests. Though the results seem positive, David (2008) urged caution in implementing full-scale PBL particularly when other supporting conditions for success are not in place. Teachers tended to express trepidation in transitioning to PBL, particularly in the current high-stakes testing climate (Dole, Bloom, & Kowalske, 2015 and Efstratia, 2014).

How does PBL fit into the existing vision for science instruction? PBL is a form of inquiry-based learning, so in that respect it is cohesive with the vision of teaching science through inquiry by engaging students in science and engineering practices. It is unknown,
however, how a focus on PBL impacts the use of other inquiry-based practices (model-based inquiry, problem-based inquiry, scientific investigation, etc.) or if a narrow focus on PBL impacts overall science learning.

**Extracurricular Science**

School science is not limited to student experiences within the classroom. Many schools offer science experiences for students outside of the standard class time and space, including science clubs, competition teams, internships, summer programs, and field trips. These types of opportunities nurture students’ interests in science and science careers and can increase student interest in STEM (Crawley, 1998; Hofstein, Maoz, & Rishpon, 1990; Hong, Chen, & Hwang, 2013; Stanger, 2010). Taking this a bit further, the NC STEM attributes rubric includes language requiring students to have work-based learning experiences with STEM industries (Friday Institute for Educational Innovation, 2013).

**Theoretical Framework**

One could argue that the purpose of science programs in schools is to develop scientifically literate citizens. STEM schools take this a step further by promoting STEM literacy. Are these philosophies aligned or are they competing with each other for traction? Where is there overlap between developing science literacy and STEM literacy? Does one necessarily precede the other?

*Science for All Americans* outlined a definition of science literacy intended to transform the American experience in science, as detailed below.
A science literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (Rutherford & Ahlgren, 1990, p. xvii)

The book provided details about each of the criteria, delineating key concepts in science, mathematics, and technology along with habits of mind that every citizen should possess in order to be scientifically literate. Scientific habits of mind included:

- curiosity
- openness to new ideas
- informed skepticism
- computation and estimation
- manipulation and observation
- communication
- critical response skills (Rutherford & Ahlgren, 1990, p. 184-194)

Priest (2013) argued that defining science literacy in terms of content and habits of mind was not enough; science is a social process and individuals need to be enculturated into science. Feinstein (2011) offered that individuals connect scientific ideas with their lived experiences thus becoming “competent outsiders, remaining anchored in their own social contexts” and “reaching in for bits and pieces of science that enrich their understanding of their own lives”
(p. 180). In this model of scientific literacy, one did not need to become an “insider” of science but could understand and use science without letting go of their lived experiences. This was only possible through engagement with science through “personally relevant science-related questions” (p. 181).

Defining STEM literacy was a complex task and involved more than simply defining literacies in each of the content areas represented in the acronym. Zollman (2012) argued that the definition included three components:

1. literacies of science, technology, engineering, and mathematics
2. personal, societal, and economic needs
3. cognitive, affective, and psychomotor learning domains (p. 15)

Bybee (2010) advocated for STEM literacy to include:

- Acquiring scientific, technological, engineering, and mathematical knowledge and using that knowledge to identify issues, acquire new knowledge, and apply the knowledge to STEM-related issues
- Understanding the characteristic features of STEM disciplines as forms of human endeavors that include the processes of inquiry, design, and analysis.
- Recognizing how STEM disciplines shape our material, intellectual, and cultural world
- Engaging in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as concerned, affective, and constructive citizens. (p. 31)
Science literacy is a component within STEM literacy. By focusing on STEM literacy, do STEM schools necessarily realize the vision of science literacy? Or by focusing on STEM literacy, could schools miss realizing science literacy? Does a focus on STEM lead to the use of inquiry-based pedagogy espoused in science education research? How science or STEM literacies are implemented in schools can vary greatly based on context.
CHAPTER 3: Methods

Overview

This multiple case study compared science programs in STEM and non-STEM high schools to gain an understanding of the differences in integrated science lessons, instructional methods, and extracurricular opportunities in four high schools, two of which were recognized by the state as STEM schools.

Research Questions

The broad goal of this study was to understand how science programs differ in STEM and non-STEM secondary schools. The following research questions focusing on specific aspects within science programs were investigated:

RQ1: Are there differences in integration of technology, engineering, and mathematics in science instruction?

RQ2: Are there differences in instructional methods used by science teachers?

RQ3: Are there differences in school-based extracurricular science opportunities (clubs, field trips, competitions, internships, etc.) available to students?

Study Design

According to Yin (2009) “cases studies are the preferred method when (a) how or why questions are being posed, (b) the investigator has little control over events, and (c) the focus is on a contemporary phenomenon within a real-life context” (Chapter 1, When to Use Each Method, para. 19). The study met those requirements: the research question asked how science programs differ in STEM and non-STEM schools, the investigator had no control
over the events at the schools, and the focus was on the contemporary phenomenon of STEM education set in the context of high schools. The main unit of analysis was the science program in the school, which consisted of science curricula, instruction within science classes, and extracurricular science offerings including summer programs, internships, clubs, events, or competitions. See Figure 1 for an overview of the study design. A case study approach was used, so the study focused on gaining insight to STEM and non-STEM schools and not on making claims about those schools more generally.

Figure 1. Study Design.
Data collected for each school was analyzed to develop a case. Figure 1 shows the sources of data collected. Cross-case analysis was used to compare and contrast STEM schools and non-STEM schools.

**Site and Participant Selection Process**

The STEM schools were selected first. North Carolina had a process to recognize schools as STEM that was in its third year of implementation. Elementary, middle, and high schools applied for recognition, and the process consisted of a self-assessment of the school’s STEM program based on a set of STEM attributes rubrics. Schools submitted evidence of placement on the rubrics and then received a site visit by a team assembled by the state’s Department of Public Instruction. The team determined if the school met the criteria and was worthy of state recognition. Schools were recognized at one of two levels: model and prepared, with model being the highest level. The list of recognized schools is published in the fall of each year, and schools retain their recognition for five years before they must reapply. Only two high schools have been recognized at the “model” level, and they declined to participate in this study, citing too many other obligations. High schools receiving the “prepared” level of recognition were invited to participate, and the first two to agree were included in the study. One of the included STEM schools was an early college, in which students completed high school and up to two-years of college courses concurrently. Students applied to and were selected to attend based on predetermined criteria and number allotments. The second STEM school included was a catchment area school, in which the
local school board created attendance zones and all students within that zone attended the school.

Once the STEM schools were selected and agreed to participate, the non-STEM schools were selected based on similarity to the STEM schools. State, district, and school level data released by the North Carolina Department of Public Instruction was imported into Tableau software, a tool that allows for data visualization (Grebing, 2015). Non-STEM schools were selected that matched the STEM schools as closely as possible in terms of student population and demographics, number of teachers, levels of free/reduced lunch, and school context (rural, suburban, urban). A non-STEM early college was selected that closely matched the STEM early college, and a non-STEM catchment area school was selected that closely matched the STEM catchment area school.

At each school, all science teachers were invited to participate in a group interview and complete a survey. Classroom observations were conducted of earth science, biology, and chemistry classes at each school as these were science courses offered at each of the four schools. All students enrolled in science courses at each school were asked to participate in a survey. To maintain the anonymity of the schools and teachers included in the study, pseudonyms were used. School and district demographic data is included in Table 2.
Table 2

Demographic Data of Participating Schools

<table>
<thead>
<tr>
<th></th>
<th>Franklin STEM High School</th>
<th>Johnson High School (non-STEM)</th>
<th>Edison STEM High School</th>
<th>Vaughan High School (non-STEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population of county</td>
<td>107,431</td>
<td>58,098</td>
<td>58,505</td>
<td>45,422</td>
</tr>
<tr>
<td>School size</td>
<td>341</td>
<td>278</td>
<td>728</td>
<td>834</td>
</tr>
<tr>
<td>Minority composition</td>
<td>26.1%</td>
<td>37.8%</td>
<td>81.6%</td>
<td>76.1%</td>
</tr>
<tr>
<td>Free and reduced lunch</td>
<td>41.7%</td>
<td>49.2%</td>
<td>73.1%</td>
<td>56.6%</td>
</tr>
</tbody>
</table>

Data Sources

Data included teacher interviews and surveys, student surveys, and classroom observations. These multiple sources were used to provide and confirm information and triangulated to answer the research questions.

Teacher interviews were conducted in small groups. A semi-structured interview protocol was used and is included in Appendix A. Interview questions were designed to elicit a general overview of the science curriculum; how technology, engineering, and math are integrated into science; and what extracurricular opportunities are available to students. All interviews were audio-recorded and transcribed verbatim for analysis.

The teacher survey used a combination of two existing survey tools and is included in Appendix B. The first question presented teachers with a list of potential classroom activities and asked how often students participated in each of the tasks; examples included listening to a lecture, analyzing data, writing reflections, and making presentations to the class. For each task teachers indicated the frequency of use on a Likert scale from never to all or most science lessons. The task list was modified from the 2000 National Survey of Science
Education Questionnaire (Weiss, Pasley, Smith, Banilower, & Heck, 2003). The remainder of the survey was developed by Unfried, et al. (2015) and measured teacher efficacy and attitudes towards STEM. The student survey used the student versions of the referenced survey tools and is included as Appendix C.

A Classroom Observation Protocol was used to assess the lessons observed and is included in Appendix D (Arshavsky et al., 2012). Every different teacher of biology, earth science, and chemistry was observed at each school. The observation protocol included four dimensions: mathematics and science content accuracy and presentation, meaningful and conceptual mathematics and science content, inquiry learning, and use of technology. Each dimension included multiple indicators rated on a 0-4 scale and a summary indicator rated on a scale of 1-4. The researcher received training on the use of the instrument from the creator at SERVE Center. During the two training sessions, the researcher and personnel from the SERVE Center assessed classroom video segments and then discussed their ratings. All discrepancies were discussed and consensus reached for each indicator. The researcher then administered a similar training session to a small research team at the university. Inter-rater reliability was obtained.

**Data Analysis**

Interview data were coded into the a priori categories of technology integration, engineering integration, math integration, science instruction, and extracurricular STEM experiences to follow the theoretical propositions that led to the case study (Yin, 2009). Data collected at each site were analyzed to make a detailed description of each of the four cases
and themes within the cases (Creswell & Creswell, c2013). Next, thematic analysis across the cases was performed to examine integration, instruction, and extracurricular opportunities in STEM and non-STEM high schools. Student surveys were analyzed using the Mann-Whitney U test, a nonparametric test of the null hypothesis that the distributions of student responses from STEM schools are equal to the distributions from non-STEM schools. The Mann-Whitney test was appropriate for the survey data because the groups were independent of each other and the data were ordinal. A STEM attitude score was computed for each respondent by calculating the mean score of individual student responses for the cluster of questions within each attitude domain (science, math, and engineering/technology).

Methods for Verification

Data were collected from different sources in order to answer the research questions. Triangulation was used to verify the validity of data collected. Two coders were employed to analyze teacher interviews and inter-coder agreement was 90%. Four raters were employed for classroom observations and Cohen’s kappa (1960) was calculated to be 0.92 on the Classroom Observation Protocol, which indicates strong agreement between raters. Peer review was used throughout the process to provide an external check of the data coding and interpretation. As each case was developed, it was sent to the science teachers at the school for member checking to ensure that the researcher’s views matched the participants’ views and to determine if any information was missing. In addition, rich, thick description was used to allow readers to make their own decisions regarding reliability (Creswell & Creswell, c2013.).
CHAPTER 4: Results

Four case studies were conducted to compare science programs in STEM and non-STEM high schools. In the sections that follow, descriptions of four case study schools (two STEM and two non-STEM) are presented. Pseudonyms throughout the results protect the identity of the participants. Thematic analysis within and across the cases is presented that describes STEM integration, science instruction, and extracurricular opportunities in STEM and non-STEM high schools.

Case One: Franklin STEM High School

Franklin STEM High School, a STEM early college, is located in a large rural, suburban county in North Carolina, situated between two medium sized cities. The median age of residents in the county is 50, and the primary occupations are sales and service, as there are strong tourism and retirement draws to the area. The poverty rate of the county is 16.7%, which is lower than the 41.7% of students in the school who receive free or reduced lunch (Table 2). The school opened in 2006 and became a STEM school in 2014.

Franklin STEM High School is located on the campus of the local community college in a two-story building. The campus is large and well landscaped with a library, café, and fitness center accessible to students. The school had two high school science teachers and both participated in the study. Mary and Barbara are Caucasian females with master’s degrees and had 16 and 22 years of experience, respectively. Their classrooms were located on the first floor of the school. Barbara’s classroom was converted from a cosmetology lab to a science lab, and had ample storage but uncomfortable stools for students to sit on. Mary’s
classroom did not have a traditional lab design but rather had large free-standing tables with chairs. The two rooms were adjoined by a shared storage room and prep space. Both teachers were interviewed and an earth science, two biology, and two chemistry classes were observed.

Students at Franklin STEM High School took earth science as freshmen, biology and chemistry as sophomores, and then college level science courses as juniors and seniors. Students have the option of pursuing an Associate’s of Arts (AA) or Science (AS) degree. Students will take one college level science course for the AA degree or three college level science courses for the AS degree. Twenty students completed the student survey.

The following sections present themes within the case related to the study areas of STEM integration, science instruction, and extracurricular opportunities.

**STEM Integration**

**Technology.** Mary and Barbara reported that freshmen and sophomore students at Franklin STEM High School were issued iPads to use for instruction. In addition, teachers reported having access to laptop carts, Vernier probeware, and a 3D printer. Barbara and Mary reported that they used technology every day during science lessons and students used technology multiple times per week to research, gather and analyze data, and communicate. Teachers used technology in each of the five lessons observed, but no student use of technology was seen during the observation sessions.

**Engineering.** Teachers reported several ways engineering was integrated into the science program and the school in general. For example, Mary invited engineers to speak to
her biology and chemistry classes and excitedly described how she has incorporated the 3D printer; “I showed all of my classes how to use tinker cad and thingiverse. That’s the coolest; they make something and then print it and see how it needs to be changed.” She also stated, “I like to have them make things, like wind turbines, and test the voltage that is created.”

Barbara added that the school adopted an engineering design process to be incorporated into all classes in some way, see Figure 2, and that “students completed an engineering design challenge as part of their seminar class.” Both teachers emphasized the problem solving involved in engineering design and reported that students were regularly engaged in problem solving tasks. Engineering integration was not observed during classroom observations, but the engineering design process was displayed prominently in each classroom and in the hallway where you enter the school.
Mathematics. Barbara and Mary described the importance of math in science classes, as exemplified in the following statements:

Data is important and we try to incorporate that as much as possible (Barbara).

I feel like a math teacher some days (Mary).

Today in chemistry the bell ringer was math and in earth science we did a salinity lab (Barbara).

We use math in chemistry every day (Mary).

I don’t think it’s on purpose; it’s just the nature of the course (Barbara).

Students were observed making calculations in a chemistry class as they reviewed for a test.
When asked about collaboration between math and science teachers, Barbara described an instance of collaboration in which pre-calculus students participated in a pH lab experiment to develop the concept of logarithms. Mary added, “The other math teacher has a degree in engineering. They do a lot more math in context” which often includes science related ideas.

**Science Instruction**

Barbara and Mary described a typical week in a science class as consisting of lab experiments, data interpretation, short lectures, class discussions, practice questions, collaborative group work, and reading. When asked about inquiry-based learning, both teachers agreed that it was used at least weekly. Barbara described “inquiry can take lots of different forms; a web quest, experiment, trying to answer a broad question given a set of tools, or a design challenge with a set task.” Project-based learning was included but “more common in earth science than in biology or chemistry” (Mary). Inquiry-based learning was present in three of the five science lessons observed and included students making ice cream to investigate energy, students presenting results of a classification project, and dissections to explore animal systems.

**Extracurricular Science Opportunities**

Mary and Barbara reported that students had the opportunity to participate in the following activities:

- Science Olympiad—a competition in which teams of students participated in science events
• Engineering club—a biweekly club that included a Remotely Operated Vehicle (ROV) competition team
• Hour of Code—a global event in which students spent an hour learning to code
• STEM Ambassadors—a leadership role that included service on a district-wide STEM advisory council
• STEM Tours—a county-wide effort to expose students to STEM careers and local businesses
• STEM Speaks—opportunities for students to listen to talks by and have conversations with STEM professionals; modeled after TED talks
• Girls that Code—a club for girls to learn computer science
• College Tours—a focused look at science and engineering opportunities after high school

Time was built into the school schedule every other Friday afternoon for students to participate in clubs. Some clubs also met after school, which required students to provide their own transportation home. Funding for extracurricular activities came from a variety of sources including school funds, community sponsors, fundraising, and student fees. Posters for engineering club and science Olympiad were observed in the school hallways.
Case Two: Edison STEM High School

Edison STEM High School is located in a rural county in North Carolina. The median age of residents is 39. The primary occupations in the county are agricultural production and farming, and the poverty rate is 26.7%. The percent of students in the school receiving free or reduced lunch is 73.1% (Table 2). The school opened in 1958 and received STEM designation in 2014.

Edison STEM High School is in a single-story, cinderblock building with locker-lined hallways and leaky ceilings; reminiscent of many other small-town high schools in rural America, where Friday night football still draws a crowd. The school had five science teachers, all of whom participated in the study. Demographic information is included in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Race</th>
<th>Years of experience</th>
<th>Highest Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patricia</td>
<td>Female</td>
<td>Caucasian</td>
<td>7</td>
<td>Bachelor’s</td>
</tr>
<tr>
<td>Sally</td>
<td>Female</td>
<td>Caucasian</td>
<td>7</td>
<td>Bachelor’s</td>
</tr>
<tr>
<td>Bette</td>
<td>Female</td>
<td>Caucasian</td>
<td>1</td>
<td>Bachelor’s</td>
</tr>
<tr>
<td>Grace</td>
<td>Female</td>
<td>Caucasian</td>
<td>0</td>
<td>Bachelor’s</td>
</tr>
<tr>
<td>Thomas</td>
<td>Male</td>
<td>Caucasian</td>
<td>2</td>
<td>Bachelor’s</td>
</tr>
</tbody>
</table>

Science classrooms were standard but aging; lab stations were around the room with drawers, water, and gas and there was open space in the middle for desks or tables. The gas was not connected but most of the lab stations had running water. Lab equipment was dated and not replaced regularly. Some of the ceiling tiles had been removed due to leaks, but not
yet replaced. One room had a pipe sticking up through the floor that had been cut off but not yet covered. Observations were performed of earth science, biology, and chemistry classes.

Students at Edison STEM High School took earth science as freshmen, biology as sophomores, and physical science as juniors. More advanced students could double up and take earth science and biology as freshmen. Once the requisite science courses were completed, students had the option to take chemistry, physics, AP biology, or forensic science. In addition, the school had a partnership with a local community college where students could take college level science courses if they chose. Eighty one students participated in the student survey.

The following sections present themes within the case related to the study areas of STEM integration, science instruction, and extracurricular opportunities.

**STEM Integration**

**Technology.** The five teachers in the science department shared two Chromebook carts, with 30 Chromebooks each, and one laptop cart, which had fewer working computers. They also had the option to use a computer lab in the library. Teachers reported utilizing technology in science classes at least weekly. The following quotes exemplify how teachers used technology:

For some of my labs I don’t have enough equipment so we’ll go on and do a virtual lab. We did a virtual photosynthesis lab (Sally).
Today I did lab stations where they had to rotate and each station was different. They had to watch a video and answer questions, navigate to illustrations and answer questions, or read an article. Those were on computer or Chromebook (Patricia).
My kids take all of their formative assessments online (Sally).
I rely heavily on the document camera (Thomas).
Students do slow motion video on their phones to study centripetal force (Thomas).
I put all of my PowerPoints on Canvas (Grace).
Teachers were observed using technology to support lectures (PowerPoint) and to play video clips. One class of students was observed using laptops to explore various types and locations of volcanoes.

**Engineering.** Walking the halls of Edison STEM High School, one could observe the schoolwide engineering design process (Figure 3) hanging on walls, as well as posters of engineering careers. Patricia explained that engineering design was “expected to be integrated into lessons monthly. We have a website where teachers were expected to post their integrated STEM lessons.” Students were observed using the engineering design process in an earth science class to design and test structures (Figure 4) that could withstand shaking from a simulated earthquake. Students were given a budget and simulated money, then required to design and purchase materials to construct and test their structure.
Figure 3. *Edison STEM High School schoolwide design process.*
Mathematics. When asked about math integration in science, Grace listed several concepts that included math: “genetic variations uses a lot of fractions, cell surface to volume ratio, solution percentages, balancing equations, figuring out what molecules are going to look like and pair with, temperature ranges and looking at historical data, and graphing and plotting volcanoes and earthquake data.” Thomas added, “Physics is algebra and pushes towards calculus. Chemistry, specifically stoichiometry, is heavy algebra, so I write the chemical equations and mathematical equations, as well.” Sally described collaborating with a math teacher to use physical science formulas and situations in a math II class. Other examples of science and math integration were not readily known.
Science Instruction

Patricia and Sally described typical science lessons as including guided notes, independent and small group practice, videos, demonstrations, review games, and labs. Patricia went on to describe using inquiry-based labs in which students are given “a problem or situation to be solved instead of detailed instructions to follow.” As students are working, Patricia walks around and asks questions “to guide them to think about what they know and how they know it.” Students were observed participating in an inquiry-based simulation of protein synthesis in biology class, writing hypotheses in preparation for a lab in chemistry class, and designing earthquake-proof structures in earth science.

In addition to inquiry-based lab activities, teachers reported using project-based learning at least once per instructional unit. For example, Patricia described a genetic counseling project in which students assumed the role of genetic counselor. Additionally, Bette described a project in which students assumed the role of real estate agents who must sell property near a volcano.

Extracurricular Science Opportunities

Teachers reported that students attended field trips with their science classes. Earth science students went to the zoo to learn about biomes, biology students went to the aquarium to learn about animal behaviors and coastal habitats, physical science students went to a local chemical plant, and earth science students came to the school at night to use a telescope to explore the night sky. There was a small bus fee for these experiences. There have been students who could not pay the fee, but other students were able to pay for them.
In addition, Patricia said “All students in the school are required to participate in the school’s STEM fair annually. Students complete projects individually or in small groups based on their personal interests in STEM. The best projects are selected to participate in a districtwide STEM fair with some students advancing to the statewide science fair.” Other science related clubs or competitions were not present.

Case Three: Johnson High School

Johnson High School, a non-STEM early college, is located in a rural county in North Carolina. The county’s largest employers are the local school system, two prisons, and a small regional hospital. The median age of residents in the county is 41.5 and the poverty rate is 23.5%. The percent of students receiving free or reduced lunch is 49.2%. The school opened in 2006.

Johnson High School is split on two separate campuses that are 15 miles apart. The lower school houses freshmen, some sophomores, and older students who focus on career and technical (CTE) education, and is located in a decaying elementary school that was closed in 2009. The upper school houses some sophomores and older students who focus on college transfer classes, and is located in a two-story, brick building on a beautifully landscaped community college campus.

The science department consisted of two Caucasian females, Katherine and Dorothy, and both participated in the study. At the time of the study, Katherine had a bachelor’s degree and 17 years of teaching experience, while Dorothy had a master’s degree, seven years of experience, and began teaching at the school in January of the current school year. Katherine
and Dorothy taught at two different campuses. Katherine’s room had tables and chairs on a carpeted floor but no lab stations or running water. Dorothy’s room also had no lab stations, but it did have tile floors and bathrooms nearby with running water that could be used for labs. One each of earth science, biology, and chemistry classes were observed.

Students at Johnson High School took earth science, biology, and physical science during their first two years at the school. Some students went on to take chemistry and a college level science course. There was not a specific course pathway all students followed, but rather multiple pathways existed for students to accumulate course credits towards graduation requirements. Eighteen students participated in the student survey.

The following sections present themes within the case related to the study areas of STEM integration, science instruction, and extracurricular opportunities.

**STEM Integration**

**Technology.** Dorothy had a dedicated laptop cart in her classroom while Katherine described her access to technology as “very little” and then added:

We have two laptop carts we can check out, and they are shared among the four teachers. So we have to schedule with each other. All of them do not work. We’ve been complaining. We were going to get new computers, we had designated money for it, but the county is in financial binds and they took money from each school. Many students had cell phones that could be used in class and a few brought laptops or iPads from home. Dorothy described using technology every day for “virtual labs, research, or presentations.” Katherine says she incorporates technology “two or three times per week” in
similar ways as Dorothy with the addition of formative assessments. Students were observed using laptops in earth science to explore the lithosphere, and calculators and cell phones during chemistry lessons.

**Engineering.** Evidence for integration of engineering was limited. There was not a schoolwide engineering design process in use or evidence of engineering design projects. Katherine expressed that “the opportunities for those types of jobs are needed, but not in this area. There’s not a demand for them in this area, so the kids are not geared in to that.” Dorothy previously taught in a STEM school and described including some engineering ideas in her science classes:

> Whenever they have a problem, I coax them to think outside of the box. If there is something that isn’t the way they want it, they are encouraged to go back and fix it. I don’t call it the engineering cycle here, but I did at my previous school. Here I call it continuous improvement, but it’s really the same thing.

**Mathematics.** Katherine and Dorothy spoke of the importance of math in science but had different experiences collaborating with math teachers. On the campus where Katherine teaches, the teachers meet for a few minutes every afternoon, as she described here:

> We meet together and talk about what we’re doing and exchange ideas, talking in general about managing classrooms, but we also get into the subject matter as well. We’re good about working together, more so than at any school I’ve been at before.
As a result of this frequent communication, science and math teachers had shared resources and ideas, but they had “not formally worked together” to integrate math and science content, according to Katherine.

Dorothy was new to the school and working on a campus that did not have frequent meetings between teachers. When asked if science and math teachers collaborated she answered:

I’m sure they do, I don’t see how you couldn’t, but I don’t know them well enough yet as I am still settling in. At one time, the math teacher borrowed two of my meter sticks, so I’m hopeful some science was involved there.

**Science Instruction**

Katherine and Dorothy described a typical week in a science class as including lectures with guided notes, students researching in small groups, vocabulary instruction and quizzes, and lab activities. Katherine described her classroom as “not very conducive for labs” due to having carpet and no running water or lab stations so she tends to use virtual labs. When asked about project-based learning, Dorothy described her students presenting “Frayer models” and “projects are just the labs” in chemistry class. Katherine stated that she gets project ideas from the internet but does not use them frequently.

Students were observed performing a hands-on lab activity in which they followed instructions to learn about concentrations and molarity in a chemistry class. Students in earth science were observed creating solutions for human impacts on the lithosphere in small collaborative groups.
Extracurricular Science Opportunities

Opportunities for students to participate in science outside of the classroom were limited. Katherine and Dorothy reported that no science clubs or competition teams were available at the school and there were no science related field trips or internships. Katherine added:

The only opportunities I know of is the museum in [local city] that puts on programs every weekend, including a teen science café. I have offered extra credit if kids go and bring something back, but I have yet to have a student do that.

Case Four: Vaughan High School

Vaughan High School is located in a rural county in North Carolina. The largest employers in the county are the local school district, Wal-Mart, and a small community hospital. The median age of residents is 40 and the poverty rate is 25%. The percent of students receiving free or reduced lunch is 56.6%.

Vaughan High School is a one-story cinderblock building. The school is well maintained and clean. The school had five science teachers, and three of them participated in this study; their demographic information is recorded in Table 4. The science classrooms are deteriorating, storage shelves are broken, lab tables are pieced together and peeling, and only a few sinks are working. Teachers do not have the typical lab equipment that one would expect in a science department; there are very few microscopes, limited glassware, no hotplates, and very few chemicals. Funding for science materials has been lacking in recent years. A chemistry, earth science, and two biology classes were observed.
Table 4

Science Teacher Demographics at Vaughan High School

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Race</th>
<th>Years of experience</th>
<th>Highest degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willa</td>
<td>Female</td>
<td>Pacific Islander</td>
<td>16</td>
<td>Master’s</td>
</tr>
<tr>
<td>Abby</td>
<td>Female</td>
<td>Caucasian</td>
<td>5</td>
<td>Master’s</td>
</tr>
<tr>
<td>George</td>
<td>Male</td>
<td>Caucasian</td>
<td>5</td>
<td>Master’s</td>
</tr>
</tbody>
</table>

Students at Vaughan High School took earth science as freshmen, biology as sophomores, and physical science or chemistry as juniors. Students were advised to take chemistry if they were interested in attending college after high school, but they were free to choose between physical science and chemistry. Upon completion of the requisite science courses, students could choose to enroll in AP chemistry, anatomy and physiology, and oceanography. AP environmental science was offered at another local high school and students could elect to take the course there, with transportation provided by the school, but no students had taken advantage of the opportunity. Twenty three students participated in the student survey.

The following sections present themes within the case related to the study areas of STEM integration, science instruction, and extracurricular opportunities.

STEM Integration

Technology. Science teachers reported that the school had two computer labs they could reserve for their classes to use. George had three laptops in his room that students could use, one of those was his personal laptop. Willa had six computers received through grant funding. Most students brought smart phones to school, and they were provided access
to the school’s Wi-Fi. George described it as a “battle for the good things and not the bad things” in relation to regulating student phone use for instruction not social media. Teachers reported using technology for formative assessments, review games, and virtual labs. George mentioned that probeware used to be available, but the computers that ran the required software no longer functioned. He further explained:

The school doesn’t fund those sorts of things. I got some Donors Choose money, but that’s to restock my everyday chemical supplies.

Abby added, “You end up spending your own money for basic things that should be in a school.” Despite the lack of access, teachers were observed incorporating technology into lessons. Students were observed using computers in one biology class and cell phones in all other science classes. George attempted to use a virtual lab during earth science but the website did not work so he gave students an assignment using cell phones instead.

**Engineering.** Science teachers had not explored integrating engineering into science classes.

**Mathematics.** Science teachers easily provided examples of math use in science class and described how math is incorporated differently depending on subject.

In physical science there is a lot: formulas, radioactive decay, graphing; about half the course is math (Willa).

There’s just not a lot of focus on math in biology so incorporating it when and where you can into labs and interpreting graphs is pretty much it (Abby).
Chemistry is all math, a couple of times a week, and it does depend on the unit (George).

Collaboration with math teachers was limited to George and the teacher of discreet math as described here:

[Math teacher] comes by every now and then. He’s a smart dude, he’s application-based so he shared a strategy for getting math concepts across, an angry bird diagram.

**Science Instruction**

Willa and Abby collaboratively plan lessons since they teach the same course. Abby described a typical lesson:

We start with daily warm up. It’s an EOC based questions. Then if it’s a new lesson we start with the new lesson, mostly it’s direct instruction because I am crunching with time. If I do the questioning thing I have to wait two minutes for them to answer, and I’m looking at the time and thinking I need to hit a target and finish a topic in a certain number of days (Abby).

Then George described his typical lesson:

We take the first ten minutes to review any homework, which is how I reinforce the previous day’s lesson. So I’ll reteach or go over specific problems, then collect the homework. I try to switch into whatever our new stuff is for the day. When I first started teaching I did a lot of PowerPoints and direct instruction type things where I would try to walk through socratically what the content is like, with question and answer, but I got exposed to some modelling curriculum, so this last year I rarely use
PowerPoint at all and try to do something modelling-like to introduce ideas. Sometimes that might be a web simulator or a video. Then if there is time they can get a head start on their homework for the next day. Sometimes I will flip that and use the web simulator as the first thing and make it more inquiry based.

Although the teachers described limited use of inquiry-based practices due to “blank stares from students” (Abby) and “the kids give up” (Willa), two teachers were observed using inquiry-based practices. In addition, students were observed working in collaborative groups with manipulatives and listening to lectures.

**Extracurricular Science Opportunities**

According to the science teachers, there were limited opportunities for students to participate in extracurricular science at Vaughan High School. There were no science clubs or competition teams. Abby described that “the oceanography classes raised fish eggs and then took them to a local lake for release where they learned more about the fish life cycle.” No other field trips or field studies were reported.

**Student Experiences and Perceptions**

Student surveys included data in three domains – instructional practices; attitudes towards science, math, and engineering/technology; and STEM career interest. Tables 5, 6, and 7 show the comparisons between STEM and non-STEM students’ reported frequencies of instructional practices; attitudes towards STEM; and STEM career interest, respectively. Table 8 shows the comparisons between STEM and non-STEM science classroom observations. Mann Whitney tests were applied to determine if there were significant
differences for student surveys and classroom observations. Bonferroni corrections were used to protect against type I errors.

Table 5

*Differences in STEM and non-STEM Student Responses by Instructional Practice*

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>STEM Mean Rank n=101</th>
<th>Non-STEM Mean Rank n=41</th>
<th>Mann Whitney U</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Listen and take notes during a presentation by the teacher</td>
<td>74.54</td>
<td>66.10</td>
<td>1896.50</td>
<td>0.267</td>
</tr>
<tr>
<td>2. Watch a science demonstration</td>
<td>71.22</td>
<td>73.80</td>
<td>2072.50</td>
<td>0.728</td>
</tr>
<tr>
<td>3. Do hands-on/laboratory science activities or investigations</td>
<td>74.45</td>
<td>69.56</td>
<td>2045.00</td>
<td>0.522</td>
</tr>
<tr>
<td>4. Follow specific instructions in an activity or investigation</td>
<td>69.86</td>
<td>77.15</td>
<td>1904.50</td>
<td>0.337</td>
</tr>
<tr>
<td>5. Design or implement your own investigation</td>
<td>68.27</td>
<td>80.67</td>
<td>1777.00</td>
<td>0.101</td>
</tr>
<tr>
<td>6. Participate in field work</td>
<td>72.43</td>
<td>71.00</td>
<td>2107.00</td>
<td>0.849</td>
</tr>
<tr>
<td>7. Answer textbook or worksheet questions</td>
<td>63.02</td>
<td>92.87</td>
<td>1252.50</td>
<td>0.000*</td>
</tr>
<tr>
<td>8. Record, represent, and/or analyze data</td>
<td>68.49</td>
<td>78.42</td>
<td>1831.00</td>
<td>0.187</td>
</tr>
<tr>
<td>9. Write reflections (ex. in a journal)</td>
<td>70.47</td>
<td>77.28</td>
<td>1966.00</td>
<td>0.373</td>
</tr>
<tr>
<td>10. Make formal presentations to the rest of the class</td>
<td>67.91</td>
<td>78.81</td>
<td>1707.50</td>
<td>0.152</td>
</tr>
<tr>
<td>11. Work on extended science investigations or projects (a week or more in duration)</td>
<td>68.74</td>
<td>76.14</td>
<td>1886.00</td>
<td>0.322</td>
</tr>
<tr>
<td>12. Use computers as a tool (ex. spreadsheets, data analysis)</td>
<td>66.03</td>
<td>87.69</td>
<td>1518.5</td>
<td>0.004</td>
</tr>
<tr>
<td>13. Use mathematics as a tool in problem solving</td>
<td>70.86</td>
<td>76.36</td>
<td>2005.5</td>
<td>0.472</td>
</tr>
<tr>
<td>14. Take field trips</td>
<td>81.37</td>
<td>51.67</td>
<td>1276</td>
<td>0.000*</td>
</tr>
<tr>
<td>15. Use an engineering design process to solve problems</td>
<td>78.96</td>
<td>57.34</td>
<td>1519.5</td>
<td>0.005</td>
</tr>
</tbody>
</table>

*Note:* Mann Whitney U: Differences in two independent groups, Alpha 2-tailed, *p<0.003

Significant differences were observed for two survey items. Non-STEM students reported answering textbook or worksheet questions at a significantly higher frequency and STEM students reported taking field trips at a significantly higher frequency. It was noted
that even though non-STEM teachers reported that their schools had not offered field trips, several non-STEM students reported having attended field trips as part of their science program. The teachers speculated that the students could be recalling field trips taken during Career and Technical Education courses or during middle school.

Table 6

*Differences in STEM and non-STEM Student STEM Attitude Scores*

<table>
<thead>
<tr>
<th>Attitude Domain</th>
<th>STEM Mean Rank n=101</th>
<th>Non-STEM Mean Rank n=41</th>
<th>Mann Whitney U</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>62.39</td>
<td>73.03</td>
<td>1462.0</td>
<td>0.144</td>
</tr>
<tr>
<td>Math</td>
<td>62.28</td>
<td>73.30</td>
<td>1451.5</td>
<td>0.129</td>
</tr>
<tr>
<td>Engineering/Technology</td>
<td>63.13</td>
<td>69.49</td>
<td>1558.5</td>
<td>0.379</td>
</tr>
</tbody>
</table>

*Note: Mann Whitney U: Differences in two independent groups, Alpha 2-tailed, *p<0.017*

No significant differences were observed between STEM and non-STEM students’ STEM attitude scores.

Table 7

*Differences in STEM and non-STEM Student Career Interest*

<table>
<thead>
<tr>
<th>Career Area</th>
<th>STEM Mean Rank n=101</th>
<th>Non-STEM Mean Rank n=41</th>
<th>Mann Whitney U</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>59.40</td>
<td>76.58</td>
<td>1251.0</td>
<td>0.017</td>
</tr>
<tr>
<td>Environmental work</td>
<td>61.85</td>
<td>72.54</td>
<td>1442.5</td>
<td>0.139</td>
</tr>
<tr>
<td>Biology and Zoology</td>
<td>60.01</td>
<td>76.96</td>
<td>1274.5</td>
<td>0.019</td>
</tr>
<tr>
<td>Veterinary work</td>
<td>61.13</td>
<td>72.47</td>
<td>1407.0</td>
<td>0.114</td>
</tr>
<tr>
<td>Mathematics</td>
<td>62.19</td>
<td>68.25</td>
<td>1529.5</td>
<td>0.395</td>
</tr>
<tr>
<td>Medicine</td>
<td>58.86</td>
<td>77.86</td>
<td>1202.5</td>
<td>0.008</td>
</tr>
<tr>
<td>Earth Science</td>
<td>60.24</td>
<td>72.80</td>
<td>1356.5</td>
<td>0.078</td>
</tr>
<tr>
<td>Computer Science</td>
<td>63.16</td>
<td>64.31</td>
<td>1616.5</td>
<td>0.873</td>
</tr>
<tr>
<td>Medical Science</td>
<td>58.76</td>
<td>76.74</td>
<td>1193.5</td>
<td>0.012</td>
</tr>
<tr>
<td>Chemistry</td>
<td>61.84</td>
<td>70.80</td>
<td>1470.5</td>
<td>0.211</td>
</tr>
<tr>
<td>Energy</td>
<td>64.57</td>
<td>64.34</td>
<td>1677.5</td>
<td>0.976</td>
</tr>
<tr>
<td>Engineering</td>
<td>65.36</td>
<td>64.13</td>
<td>1695.0</td>
<td>0.865</td>
</tr>
</tbody>
</table>

*Note: Mann Whitney U: Differences in two independent groups, Alpha 2-tailed, *p<0.004*
No significant differences were observed between STEM and non-STEM students’ STEM career interests.

Table 8

*Differences in STEM and non-STEM Science Classroom Observations*

<table>
<thead>
<tr>
<th>Scoring Dimensions</th>
<th>STEM Mean Rank n=9</th>
<th>Non-STEM Mean Rank n=7</th>
<th>Mann Whitney U</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content accuracy</td>
<td>9.61</td>
<td>7.07</td>
<td>21.5</td>
<td>0.313</td>
</tr>
<tr>
<td>Meaningful and conceptual content</td>
<td>9.17</td>
<td>7.64</td>
<td>25.5</td>
<td>0.562</td>
</tr>
<tr>
<td>Inquiry-learning</td>
<td>9.17</td>
<td>7.64</td>
<td>25.5</td>
<td>0.562</td>
</tr>
<tr>
<td>Use of technology</td>
<td>8.94</td>
<td>7.93</td>
<td>27.5</td>
<td>0.711</td>
</tr>
</tbody>
</table>

*Note: Mann Whitney U: Differences in two independent groups, Alpha 2-tailed, *p<0.013*

No significant differences were observed between STEM and non-STEM classroom observations. In the following sections, themes are analyzed across the four cases to answer the research questions.

**Research Question 1**

Are there differences in integration of technology, engineering, and mathematics?

**Integration of Technology**

Of the four schools, Franklin STEM High School, had the most access to technology. However, teachers in all four schools reported integrating technology into science lessons at least weekly. Observed technology integration scores ranged from 1 to 3 on the 4 point scale used in the protocol; most of the observed lessons were rated at level 1 or 2, and one level 3 lesson was observed in each category (STEM or non-STEM) of school. Teachers at each
school discussed aging technology as a barrier to integration, as evidenced by the following statements:

A decade ago that existed here, but the computers that run the software are all Macs, but they are slow as molasses. The couple probes I have – before I came here whoever used them stopped using them and they dried up. So there weren’t a lot and the ones I have weren’t maintained. The school doesn’t fund those sorts of things (George, Vaughan High School).

We have the dreaded laptop cart back there still, it kind of works (Patricia, Edison STEM High School).

They don’t like the iPads all that much because they can be slower and it’s frustrating (Mary, Franklin STEM High School).

**Integration of Engineering**

A schoolwide engineering design process was in use at both of the STEM schools in this study. When asked how frequently engineering was incorporated into science, Patricia at Edison STEM High School responded:

I would say probably about once a month. I know that all the earth science classes do the earthquake unit, and they design a structure to withstand an earthquake and use the design process to do that. I have a photosynthesis and cellular respiration project where students design products that they can sell that runs off of photosynthesis or respiration. Physical science designs solar ovens to cook s’mores, and they’ve done rubber band cars and raced those. And then students each semester have the
opportunity to create a STEM project and enter into the STEM fair; they don’t really have the opportunity to do it, they have to do it, but they decide if it is science or STEM.

As shown in Table 5, STEM and non-STEM science students’ responses to the prompt that they use an engineering design process approached significance. This slight difference in use of an engineering design process did not result in a difference in students’ interest in careers in engineering as shown in Table 7. In addition, students’ attitude scores towards engineering and technology were 3.25 and 3.37 for STEM and non-STEM students, which was not significantly different.

**Integration of Mathematics**

All of the teachers interviewed agreed that math is important to and used frequently in science, as evidenced by the following statements from teacher interviews:

I use it as much as I can because kids struggle with the math more than the science. I get frustrated when I have a tenth grader who cannot rearrange or solve for a variable (Katherine, Johnson High School).

In earth science, there’s not a lot of calculation necessary, but lots of graph interpretation, so we have that aspect of math in all the sciences. We work on those skills…what does this graph mean, what does the trend line mean and how is it changing? (George, Vaughan High School).

As far as chemistry, there are a lot of calculations, and helping kids to see the connection between variables in an equation and how things are actually changing.
For example, we are reviewing gas laws this week, and so if you increase your pressure how is that going to increase the volume? (George, Vaughan High School)

However, integration of math was not reported as being purposeful and collaboration between math and science teachers was limited.

The only collaboration I’ve done is strategies for getting math concepts across. For example, I have kids that can’t get how to rearrange an equation, so I ask how they get them to do that (Sally, Edison STEM High School).

I have not, we have given each other some material and exchanged ideas, but we haven’t really tried to collaborate. We want to improve upon that because [the principal] wants to see that too (Katherine, Johnson High School).

I did at [previous school]. But not here (Willa, Vaughan High School).

Students’ math attitude scores were similar between STEM and non-STEM schools at 3.36 and 3.63, respectively.

Research Question 2

Are there differences in instructional methods used by science teachers?

Science teachers in the four schools used a variety of instructional practices. Many teachers interviewed described using whole class direct instruction followed by an activity, lab, or virtual investigation, as evidenced by the following statements from teacher interviews:

We start with daily warm-up. It’s an EOC test-based questions. Then if it’s a new lesson we start with the new lesson, mostly it’s direct instruction because I am
crunching with time. If I do the questioning thing I have to wait two minutes for them to answer, and I’m looking at the time and thinking I need to hit a target and finish a topic in a certain number of days. I have found after five years that the more routine the kids are in as far as what they do when they come in, the more I can get out of them, versus when they come in and have no idea what they’re in for. For me, that is pretty typical, and occasionally we’ll change it up (Abby, Vaughan High School).

If learning something new [we do] quick notes, read a science article that brings in a current event to answer questions about. I try to include lab with every topic, or two. I always have them complete some type of independent work (Patricia, Edison STEM High School).

Lecture notes, then discussion or practice (Mary, Franklin STEM High School).

They take notes that are guided notes and work through the problems (Dorothy, Johnson High School).

Inquiry-based learning was observed in every school, but it was not the dominant instructional tool teachers used. Table 8 displays inquiry-learning scores from the classroom observation protocol. There was not a significant difference between STEM and non-STEM schools in observation of inquiry, which included project-based learning. Project-based learning was observed at Franklin STEM High School and was described by teachers at Edison STEM High School. The two non-STEM schools had little evidence of project-based learning. The student survey revealed that students in the two non-STEM schools more
frequently reported spending class time answering textbook and worksheet questions, see Table 5. Other instructional practices were found to occur at similar rates.

**Research Question 3**

Are there differences in school-based extracurricular science opportunities available to students?

Franklin STEM High School offered the greatest number of extracurricular science opportunities. Although the other STEM school, Edison STEM High School, did not have as many opportunities available to students, they did offer field trips in each science class. Students in the STEM schools reported taking field trips in science class at a significantly higher frequency than students in the non-STEM schools, see Table 5. No significant differences were observed between STEM and non-STEM students’ STEM career interest, as indicated in Table 7.

**Limitations**

Though every effort was made to select comparison schools with similar characteristics and contexts, schools are inherently complex systems and natural differences will exist between them. This research was conducted through the lens of science education and programs within schools. The results could be different if another lens, for example math or engineering, was used. The extent to which the two STEM and two non-STEM schools are representative of all STEM or non-STEM schools is not known and generalizations to that effect should not be made. The duration of the study provides only a snapshot of the schools and data collected only accounted for viewpoints from science teachers and students.
Chapter 5: Discussion

This study was motivated by a desire to look beyond the rhetoric surrounding STEM education to see what happens when those ideals are put into practice. Framed within the definition of a STEM school supplied by the Department of Public Instruction in the state of North Carolina, the goal of this study was to compare science programs within STEM and non-STEM secondary schools. This chapter presents a summary of the study and important conclusions drawn from the data presented.

Summary of the Study

This multiple case study compared science programs in two STEM and two non-STEM high schools to understand the differences that define STEM programs and include the integration of technology, engineering, and mathematics into science; instructional methods and extracurricular opportunities. Teacher interviews, classroom observations, and student surveys were examined for differences in science programs. The case studies, while not broadly generalizable, provide insight into how two STEM schools enacted the ideals of STEM education within their unique contexts and communities.

From a student perspective, one could argue that the experience is very similar in STEM and non-STEM schools: similar buildings, classrooms, teachers, and instructional practices. Science course sequences and electives were similar and students took the same state required science exams. The two key differences in their experiences were in extracurricular opportunities and the use of an engineering design process. Do these two differences influence students’ career goals or knowledge of careers? Results indicated that
students from STEM and non-STEM schools are equally interested in STEM careers. However, it is not yet clear whether or not the STEM students are more prepared to enter STEM careers. Have the experiences at STEM schools better prepared students to handle the challenges of a STEM pathway? Means, et al (2016) also found no differences between STEM and non-STEM students’ self-efficacy in science and math but they did see a significant difference in students’ STEM career aspirations. The STEM schools included in that study all required students to apply to attend the school and were predominantly located in urban areas, which could play a role in the different outcomes.

**STEM Integration**

Interdisciplinary learning is not a new idea (Conderman, Crawford, & Frankenberger, 1996; Monhardt & Henriques, 1997; Roucher & Lovano-Kerr, 1995), however, in recent years the conversation has narrowed in many contexts to integrating the STEM disciplines specifically. Every state-level definition for STEM schools appears to have included an interdisciplinary component. Even the *Next Generation Science Standards* advocate for integrating technology and engineering into science lessons (States, 2013). This study showed that science teachers in all four schools were purposefully including technology in science and teachers in STEM schools were including engineering design. Science teachers in the STEM schools had some knowledge of mathematics teachers’ practices and had engaged in some collaboration but did not consider their integration of math “purposeful.” The following sections explore technology and engineering integration further.
Technology. The finding that technology integration was similar across STEM and non-STEM schools is not surprising as schools across the nation are figuring out how to produce technologically competent graduates who are prepared to enter college or the workforce. Teachers were observed using technology as a replacement support for traditional whole class direct instruction in both STEM and non-STEM schools; instead of writing on the chalk board or overhead projectors, teachers used PowerPoint to give students notes. Students were observed using technology for formative assessment (online quizzes) and virtual labs, again examples of replacing traditional modalities rather than transforming teaching and learning. None of the observed lessons received a score of four on the technology dimension of the protocol, which would have indicated that technology was used to transform the instructional method, learning process, or the subject matter. Instead, most observations earned a score of one or two on the observation rubric, indicating that technology use was limited or used to replace established instructional practices, learning processes, or content goals. Even in Franklin High School, with its increased access to technology, classroom use of technology was not transformational. Technology use outside of class time was not deeply explored in this study, however, students at Franklin High School had access to technology, like 3D printers and ROVs, after school and during study halls. How might this access impact students’ future career or hobby choices? In addition, Franklin STEM High School students participated in an Hour of Code and Girls that Code, both new programs for the school. It is not clear if continued participation in those events may impact student ideas about technology.
**Engineering.** The rhetoric surrounding STEM typically discusses engineering integration to be accomplished through the pervasive use of a schoolwide engineering design process. Both STEM schools had adopted a schoolwide engineering design process that was used in every class and teachers reported instances of engineering integrated into science classes. A lesson using engineering design was observed, however, a pervasive use of the engineering design process as a problem solving framework (Dym et al., 2005) was not observed. It is not known if using an integrated engineering design process is the best way to teach engineering or if students should take specific engineering courses. Furthermore, the quality of the engineering integration was not examined and there is no evidence that this integration enhances students’ understandings in science. With already overburdened science curricula, one could argue that adding engineering could dilute science learning.

This study did not examine what engineering integration was in math, social studies, or English classes, although the STEM schools had a schoolwide engineering design process in place. Further studies are needed to explore engineering integration in those other content areas.

Teacher professional development was not explored in this study, however, traditional science teacher preparation pathways do not prepare teachers for integrating engineering design or methodologies into science instruction. If such integration is to occur in STEM schools, teachers will need different preparation pathways and/or professional development opportunities. Teacher preparation is a complex issue and teacher preparation programs already feel pressure to include far too many components, in too short a time. Once
teachers are employed in schools, professional development opportunities may be limited due to shrinking school budgets and competing priorities. One could argue that declining salaries and prestige of the teaching profession create a talent gap among teacher candidates; it is difficult to attract and retain the best and brightest teachers, particularly in poor, rural communities, like the ones included in this study. In addition, teachers have not experienced integrated STEM methodologies as students, so it is difficult to envision what this integration could look like. In order to overcome this obstacle, teachers need time to explore and collaborate with each other. Time is costly. The STEM schools in this study did not get additional funding for becoming a STEM school, even though they were expected to teach in new ways as defined by the state’s STEM attributes rubrics.

The two STEM schools in the study existed before they added a STEM focus. Is STEM integration attainable in a traditional school with existing courses, teachers, and structures, or does the very notion of STEM integration require new designs? STEM integration may not be attainable in authentic school contexts, particularly in rural, low wealth communities that are far removed from high tech jobs and universities.

Science Instruction

Science instruction was not appreciably different between the STEM and non-STEM schools in the study. As described in chapter 4, teachers in both STEM schools reported using project-based learning and a project-based lesson was observed at Franklin STEM High School; however, this did not result in a greater frequency of inquiry-based practices as reported in Table 8. Three schools in the study are located in rural, low-wealth districts and
the drivers of instruction are more alike than different: test scores, diverse populations, and lack of money for supplies. Several teachers mentioned a lack of time as an obstacle for inquiry-based instruction. With over-packed curricula and high-stakes testing, teachers feel pressure to move quickly and disseminate information, instead of spending time enculturating students into the processes of science as Priest (2013) suggested. STEM schools and non-STEM schools alike are held to statewide testing mandates; schools are not allowed the flexibility to test out new designs in a low risk environment. The ideologies of STEM education may have the potential to improve student performance in science and math, but teachers would need time to learn and practice new strategies. Alternatively, it is not clear whether or not science instruction benefits significantly in a STEM school compared to a non-STEM school.

This study presented evidence that science lessons in STEM and non-STEM schools were very similar and did not include high frequencies of inquiry despite decades of research supporting that students learn science through inquiry. By focusing attention on STEM broadly and clustering science and engineering together, we may not be maximizing our current resources and instead missing opportunities to improve science education. Is the STEM movement just hype without substance? At least where science is concerned, it appears to be.

**Implications for Further Study**

This study was unique from other studies because it used a science lens to look at how STEM was enacted in schools and focused on science programs specifically. The study
only considered the views of science teachers and students. School and district administration, community members, parents, and teachers in other departments also take part in the implementation of STEM education within schools and their viewpoints and stories require further study. The political drivers for the push to become STEM schools is missing from this study. While science, technology, and mathematics are present, to some extent, in every school, non-STEM schools are missing the engineering domain. Where is the push for more engineering coming from and should all students learn engineering? There have been arguments presented for a lack of qualified U.S. workers to fill engineering sector jobs, which represent only a small portion of our economy, but arguments to the contrary have also been made (Kelly, Butz, Carroll, Adamson, & Bloom, 2004).

The two STEM schools included in this study have had a STEM focus for three years. Presumably, their implementation of STEM could deepen over time, producing differences in student attitudes and dispositions that were not observed in this study. Alternatively, since staff within these schools have not been stable, teachers and administrators have moved to other positions and been replaced with new staff members, the champions of STEM could transition out of the schools and the STEM focus could stagnate. What sustains and motivates schools and teachers to continue in pursuing a STEM focus? There was no additional compensation received for being a STEM school, so what triggers a school to stay on this path? Does the community view a school differently if it is STEM? Are there benefits to a school district for encouraging schools to focus on STEM? Do participants in the school feel unique or different about school because their school is special?
Results indicated that students’ attitudes toward STEM were similar between STEM and non-STEM students. Does this pattern continue with age? Student achievement in science and math was not studied, is it different in STEM schools? If it is different, do STEM students achieve higher in one or more of the STEM domains in college and does this impact their attitudes towards their work?

These questions suggest that more research is needed to provide evidence about the degree to which STEM schools make a genuine differences in the quality of educational programs. As this cohort of students graduates and enters the workforce there may be additional evidence of the impact of STEM schools on students’ knowledge, skills, and career goals.
REFERENCES


Retrieved from http://catalog.lib.ncsu.edu/record/NCSU2697912


https://doi.org/10.1016/j.sbspro.2014.09.362

https://doi.org/10.1016/j.sbspro.2014.05.371

https://doi.org/10.1002/sce.20414


Guzey, S. S., Harwell, M., Moreno, M., Peralta, Y., & Moore, T. J. (2017). The Impact of Design-Based STEM Integration Curricula on Student Achievement in Engineering,


https://doi.org/10.1080/02783190903386561


Appendix A: Teacher Interview Protocol

1. Can you start by giving an overview of the science curriculum at the school? What science courses and in what sequence do students complete? What elective science courses are available and how many students enroll in those courses?

2. How do you or your students use technology in your science classes?
   a. What technology is available in the school for you to use? (Do you have a 1:1 environment? BYOD? Check out carts? Is it available?)
   b. How frequently do you incorporate technology into science lessons?
   c. How do the students use technology during class, can you give a few specific examples?
   d. Do you assign work that requires students to use technology outside of the class? Do they have access and connectivity outside of the class?
   e. What barriers do you encounter when considering technology use in science lessons?

3. Do you incorporate engineering into science lessons?
   a. Do you use a schoolwide or department-wide engineering design process? Can I get a copy of it? Do teachers in other departments use it?
   b. How frequently are engineering ideas or methodologies integrated into science lessons? Can you give some examples of what that looks like?
   c. In thinking about technology and engineering integration, would you expect course-specific differences? Would you expect more or less integration in chemistry, for example?

4. Do you incorporate math into science lessons?
   a. Can you give some specific examples?
   b. How frequently is math integrated into your science lessons?
   c. Would you expect course-specific differences in math integration?
   d. Do you know if the math teachers in your school integrate science into their lessons? Do you ever collaborate to make that happen? Can you give specific examples?

5. What does a typical science lesson look like? Think about a typical week – what would happen?
   a. What would students be doing? (taking notes, completing a lab, reading texts, writing lab reports or essays, making presentations, analyzing data)
   b. Do you use inquiry-based practices? How frequently? Can you describe what that looks like? What are you doing, what are students doing?
   c. Do you use project-based learning? How frequently? Can you describe what that looks like? What are you doing, what are students doing?
   d. Would you expect course-specific differences in instructional practices?

6. What extracurricular science opportunities are available to students?
   a. Prompt if needed – clubs, competitions, internships, field trips
b. Are field studies incorporated into science lessons or available outside of school for students? Can you give examples?
c. How many students participate in extracurricular science opportunities?
d. How are these experiences funded? Do students pay fees? Do you do fundraisers?
e. Is there parent support for these opportunities? What does that look like?
f. Is transportation provided for students or do they arrange their own transportation?
Appendix B: Teacher Survey

Please enter your school name
What science classes are you currently teaching?
How long have you been a science teacher?
How long have you been a science teacher at your current school?
What is the highest level of education you have completed?

In your current science classes, how often do students participate in the following:
<table>
<thead>
<tr>
<th>Activity</th>
<th>Never (1)</th>
<th>Rarely (ex. a few times a semester (2)</th>
<th>Sometimes (ex. once or twice a month) (3)</th>
<th>Often (ex. once or twice a week) (4)</th>
<th>All or most science lessons (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listen and take notes during a presentation by the teacher (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watch a science demonstration (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do hands-on/laboratory science activities or investigations (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow specific instructions in an activity or investigation (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design or implement your own investigation (5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participate in field work (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Answer textbook or worksheet questions (7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Record, represent, and/or analyze data (8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Write reflections (ex. in a journal) (9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make formal presentations to the rest of the class (10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work on extended science investigations or projects (a week or more in duration) (11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Use computers as a tool (ex. spreadsheets, data analysis) (12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use mathematics as a tool in problem solving (13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Take field trips (14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use an engineering design process to solve problems (15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**DIRECTIONS:**

For each of the following statements, please indicate the degree to which you agree or disagree.

Even though some statements are very similar, please answer each statement. There are no "right" or "wrong" answers. The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help make your choice.

**Science Teaching Efficacy and Beliefs**

Directions: Please respond to these questions regarding your feelings about your own teaching.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am continually improving my science teaching practice.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I know the steps necessary to teach science effectively.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I am confident that I can explain to students why science experiments work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I am confident that I can teach science effectively.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I wonder if I have the necessary skills to teach science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I understand science concepts well enough to be effective in teaching science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Given a choice, I would invite a colleague to evaluate my science teaching.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I am confident that I can answer students' science questions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. When a student has difficulty understanding a science concept, I am confident that I know how to help the student understand it better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. When teaching science, I am confident enough to welcome student questions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. I know what to do to increase student interest in science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Science Teaching Outcome Expectancy

**Directions:** The following questions ask about your feelings about teaching *in general*. Please respond accordingly.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>When a student does better than usual in science, it is often because the teacher exerted a little extra effort.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>The inadequacy of a student’s science background can be overcome by good teaching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>When a student’s learning in science is greater than expected, it is most often due to their teacher having found a more effective teaching approach.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>The teacher is generally responsible for students’ learning in science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>If students’ learning in science is less than expected, it is most likely due to ineffective science teaching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Students’ learning in science is directly related to their teacher’s effectiveness in science teaching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>When a low achieving child progresses more than expected in science, it is usually due to extra attention given by the teacher</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child’s teacher</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Minimal student learning in science can generally be attributed to their teachers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Student Technology Use

Directions: Please answer the following questions about how often students use technology in settings where you instruct students. If the question is not applicable to your situation, please select “Not Applicable.”

During science instructional meetings (e.g. class periods, after school activities, days of summer camp, etc.), how often do your students...

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Occasionally</th>
<th>About half the time</th>
<th>Usually</th>
<th>Every time</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Use a variety of technologies, e.g. productivity, data visualization, research, and communication tools.</td>
<td>☐</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td>2. Use technology to communicate and collaborate with others, beyond the classroom.</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td>3. Use technology to access online resources and information as a part of activities.</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td>4. Use the same kinds of tools that professional researchers use, e.g. simulations, databases, satellite imagery.</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td>5. Work on technology-enhanced projects that approach real-world applications of technology.</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td>6. Use technology to help solve problems.</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td>7. Use technology to support higher-order thinking, e.g. analysis, synthesis and evaluation of ideas and information.</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td>8. Use technology to create new ideas and representations of information.</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
</tr>
</tbody>
</table>
Science Instruction

Directions: Please answer the following questions about how often students engage in the following tasks during your instructional time.

During science instructional meetings (e.g. class periods, after school activities, days of summer camp, etc.), how often do your students...

<table>
<thead>
<tr>
<th>Task</th>
<th>Never</th>
<th>Occasionally</th>
<th>About half the time</th>
<th>Usually</th>
<th>Every time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Develop problem-solving skills through investigations (e.g. scientific, design or theoretical investigations).</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Work in small groups.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Make predictions that can be tested.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Make careful observations or measurements.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Use tools to gather data (e.g. calculators, computers, computer programs, scales, rulers, compasses, etc.).</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Recognize patterns in data.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Create reasonable explanations of results of an experiment or investigation.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Choose the most appropriate methods to express results (e.g. drawings, models, charts, graphs, technical language, etc.).</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Complete activities with a real-world context.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Reason quantitatively.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13. Critique the reasoning of others.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14. Learn about careers related to the instructional content.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
### 21st Century Learning Attitudes

**Directions:** Please respond to the following questions regarding your feelings about learning *in general*.

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

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lead others to accomplish a goal.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2. Encourage others to do their best.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>3. Produce high quality work.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>4. Respect the differences of their peers.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>5. Help their peers.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>6. Include others’ perspectives when making decisions.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>7. Make changes when things do not go as planned.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>8. Set their own learning goals.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>9. Manage their time wisely when working on their own.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>10. Choose which assignment out of many needs to be done first.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>11. Work well with students from different backgrounds.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Appendix C: Student Survey

1. Name of science course currently enrolled in:

2. How many other science courses have you completed in high school?

3. In your current science class, how often do you take part in the following types of activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Never (ex. A few times a semester)</th>
<th>Rarely (ex. Once or twice a month)</th>
<th>Sometimes (ex. Once or twice a week)</th>
<th>Often (ex. Once or twice a week)</th>
<th>All or most all science lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listen and take notes during presentation by teacher</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watch a science demonstration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do hands-on/laboratory science activities or investigations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow specific instructions in an activity or investigation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design or implement your own investigation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participate in field work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Answer textbook or worksheet questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Record, represent, and/or analyze data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Write reflections (ex. In a journal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make formal presentations to the rest of the class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work on extended science investigations or projects (a week or more in duration)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use computers as a tool (ex. Spreadsheets, data analysis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use mathematics as a tool in problem solving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Does your school provide opportunities for students to be involved in science-related experiences outside of class time (Ex. Science clubs, competitions, summer camps, or externships)?

5. If yes, have you participated in any science related experiences outside of your regular science class time? If yes, please list. Why or why not?
### Math

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Math has been my worst subject.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I would consider choosing a career that uses math.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Math is hard for me.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I am the type of student to do well in math.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I can handle most subjects well, but I cannot do a good job with math.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I am sure I could do advanced work in math.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I can get good grades in math.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I am good at math.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Science

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. I am sure of myself when I do science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I would consider a career in science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. I expect to use science when I get out of school.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Knowing science will help me earn a living.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I will need science for my future work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. I know I can do well in science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Science will be important to me in my life’s work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. I can handle most subjects well, but I cannot do a good job with science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. I am sure I could do advanced work in science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Engineering and Technology**

Please read this paragraph before you answer the questions.

Engineers use math, science, and creativity to research and solve problems that improve everyone’s life and to invent new products. There are many different types of engineering, such as chemical, electrical, computer, mechanical, civil, environmental, and biomedical. Engineers design and improve things like bridges, cars, fabrics, foods, and virtual reality amusement parks. Technologists implement the designs that engineers develop; they build, test, and maintain products and processes.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. I like to imagine creating new products.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. If I learn engineering, then I can improve things that people use every day.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. I am good at building and fixing things.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. I am interested in what makes machines work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Designing products or structures will be important for my future work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. I am curious about how electronics work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. I would like to use creativity and innovation in my future work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Knowing how to use math and science together will allow me to invent useful things.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. I believe I can be successful in a career in engineering.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Your Future

Here are descriptions of subject areas that involve math, science, engineering and/or technology, and lists of jobs connected to each subject area. As you read the list below, you will know how interested you are in the subject and the jobs. Fill in the circle that relates to how interested you are.

There are no "right" or "wrong" answers. The only correct responses are those that are true for you.

<table>
<thead>
<tr>
<th></th>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physics: is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. (aviation engineer, alternative energy technician, lab technician, physicist, astronomer)</td>
<td><img src="image" alt="Circle Not at all Interested" /></td>
<td><img src="image" alt="Circle Not So Interested" /></td>
<td><img src="image" alt="Circle Interested" /></td>
<td><img src="image" alt="Circle Very Interested" /></td>
</tr>
<tr>
<td>2. Environmental Work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. (pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technician)</td>
<td><img src="image" alt="Circle Not at all Interested" /></td>
<td><img src="image" alt="Circle Not So Interested" /></td>
<td><img src="image" alt="Circle Interested" /></td>
<td><img src="image" alt="Circle Very Interested" /></td>
</tr>
<tr>
<td>3. Biology and Zoology: involve the study of living organisms (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. (biological technician, biological scientist, plant breeder, evrop lab technician, animal scientist, geneticist, zoologist)</td>
<td><img src="image" alt="Circle Not at all Interested" /></td>
<td><img src="image" alt="Circle Not So Interested" /></td>
<td><img src="image" alt="Circle Interested" /></td>
<td><img src="image" alt="Circle Very Interested" /></td>
</tr>
<tr>
<td>4. Veterinary Work: involves the science of preventing or treating disease in animals. (veterinary assistant, veterinarian, livestock producer, animal caretaker)</td>
<td><img src="image" alt="Circle Not at all Interested" /></td>
<td><img src="image" alt="Circle Not So Interested" /></td>
<td><img src="image" alt="Circle Interested" /></td>
<td><img src="image" alt="Circle Very Interested" /></td>
</tr>
<tr>
<td>5. Mathematics: is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. (accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)</td>
<td><img src="image" alt="Circle Not at all Interested" /></td>
<td><img src="image" alt="Circle Not So Interested" /></td>
<td><img src="image" alt="Circle Interested" /></td>
<td><img src="image" alt="Circle Very Interested" /></td>
</tr>
<tr>
<td></td>
<td>Not at all Interested</td>
<td>Not So Interested</td>
<td>Interested</td>
<td>Very Interested</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------</td>
<td>-------------------</td>
<td>------------</td>
<td>-----------------</td>
</tr>
<tr>
<td><strong>6.</strong> Medicine: involves maintaining health and preventing and treating disease. (physician's assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>7.</strong> Earth Science: is the study of earth, including the air, land, and ocean. (geologist, weather forecaster, archaeologist, geoscientist)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>8.</strong> Computer Science: consists of the development and testing of computer systems, designing new programs and helping others to use computers. (computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>9.</strong> Medical Science: involves researching human disease and working to find new solutions to human health problems. (clinical laboratory technologist, medical scientist, biomedical engineer, epidemiologist, pharmacologist)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>10.</strong> Chemistry: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves. (chemical technician, chemist, chemical engineer)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>11.</strong> Energy: involves the study and generation of power, such as heat or electricity. (electrician, electrical engineer, heating, ventilation, and air conditioning (HVAC) technician, nuclear engineer, systems engineer, alternative energy systems installer or technician)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>12.</strong> Engineering: involves designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through the use of math, science, and computers. (civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
About Yourself

DIRECTIONS: In the following series of questions, you will skip certain questions based on how you answered previous questions.

1. How well do you expect to do this year in your:

<table>
<thead>
<tr>
<th></th>
<th>Not Very Well</th>
<th>OK/Pretty Well</th>
<th>Very Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>English/Language Arts Class?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Math Class?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Science Class?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

2. In the future, do you plan to take advanced classes in:

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Science?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

3. Do you plan to go to college?
   ○ Yes
   ○ No
   ○ Not Sure

Displayed only if answer to Question 3 was “Yes.”

4. If so, please list what college(s) you are interested in attending.

Displayed only if answer to Question 3 was “Yes.”

5. Are you planning on going to a community college or four-year college/university first?
   ○ Community College
   ○ Four-year College

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you know any adults who work as scientists?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Do you know any adults who work as engineers?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Do you know any adults who work as mathematicians?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Do you know any adults who work as technologists?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Appendix D: STEM Classroom Observation Protocol

Observer: If you don’t know how to rate a particular indicator, or the rating is non-applicable, leave it blank in the online form.

1. Mathematics and Science Content Accuracy and Presentation

Select one from scale: 0 = not observed to 4=very descriptive of the observation.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Math and science content information was accurate. Teacher used accurate and appropriate mathematics or science vocabulary.</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1b. Teacher’s presentation or clarification of mathematics or science content knowledge was clear.</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1c. Student mistakes or misconceptions were clearly addressed (emphasis on correct content).</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Summary: All three indicators should contribute equally to the overall rating.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Record specific examples below.
2. Meaningful and Conceptual Mathematics and Science Content

Select one from scale: 0 = not observed to 4=very descriptive of the observation.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2a. Teacher/students emphasized meaningful relationships among different facts, skills, and concepts within a discipline.</td>
<td>(0)</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>2b. Teacher connected information to previous knowledge and experience of students.</td>
<td>(0)</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>2c. Appropriate connections were made to other areas of mathematics/science or to other disciplines or real-world contexts.</td>
<td>(0)</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>2d. Lesson time spent on memorizing, practicing algorithms/basic skills, and procedures/vocabulary.</td>
<td>(0)</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Summary: Element 2a must be rated high (3 or 4) for an overall high rating. Elements 2b, 2c contribute to/are examples of the overall rating, but don’t need to be high. High 2d negatively affects summary rating.

Record specific examples below.
### 3. Inquiry Learning; Project-Based Learning; and Problem-Based Instruction

Select one from scale: 0 = not observed to 4 = very descriptive of the observation.

| 3a. Students were engaged in open-ended tasks. | (0) | (1) | (2) | (3) | (4) |
| 3b. Students engaged in hands-on or real-life problem-solving activities or a lab experiment. | (0) | (1) | (2) | (3) | (4) |
| 3c. Students engaged in scientific inquiry process (i.e., developed their own questions and/or hypotheses, tested them, and made inferences). | (0) | (1) | (2) | (3) | (4) |
| 3d. Students had (or prepared) to present or explain results of project. | (0) | (1) | (2) | (3) | (4) |
| 3e. Students worked on a project requiring creativity and/or their own design. | (0) | (1) | (2) | (3) | (4) |

**Summary:** High rating (3 or 4) on any one of the elements 3a-3e warrants a high summary rating. Element 3d contributes to the summary rating, but alone cannot justify a high summary rating.

Record specific examples below.
4. Use of Technology

Select one from scale: 0 = not observed to 4 = very descriptive of the observation.

| 4a. Technology was used to a high extent (i.e., as a proportion of time of the lesson and intensity of use). | (0) | (1) | (2) | (3) | (4) |
| 4b. The use of technology provided a significant added benefit to instructional process and/or student learning. | (0) | (1) | (2) | (3) | (4) |
| 4c. Students used technology to explore or confirm relationships, ideas, hypotheses, develop conceptual understanding, or to generate or manipulate one or more representations of a given concept or idea. | (0) | (1) | (2) | (3) | (4) |
| 4d. Students used technology to practice skills or reinforce knowledge. | (0) | (1) | (2) | (3) | (4) |
| 4e. Students used technology as a tool for purposes not related to the lesson’s goals. | (0) | (1) | (2) | (3) | (4) |
| 4f. Teacher, but not students, used technology. | (0) | (1) | (2) | (3) | (4) |

Summary: The summary rating denotes the quality and appropriateness of technology use (elements 4b - 4e), but also considers the extent of use (element 4a). Elements 4a and 4b must be rated high (3 or 4) for this dimension to receive a high summary rating. Elements 4c - 4f contribute to the summary.

Record specific examples below.