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Examining the Relationship between Technology & Engineering Instruction and Technology & Engineering Literacy in K-8 Education

Tamarra L. Mitchell

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EXAMINING THE RELATIONSHIP BETWEEN TECHNOLOGY & ENGINEERING INSTRUCTION AND TECHNOLOGY & ENGINEERING LITERACY IN K-8 EDUCATION

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for the degree of Doctor of Education

By
Tamarra Mitchell

August 2017
EXAMINING THE RELATIONSHIP BETWEEN TECHNOLOGY & ENGINEERING INSTRUCTION AND TECHNOLOGY & ENGINEERING LITERACY IN K-8 EDUCATION

By

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ABSTRACT

EXAMINING THE RELATIONSHIP BETWEEN TECHNOLOGY & ENGINEERING INSTRUCTION AND TECHNOLOGY & ENGINEERING LITERACY IN K-8 EDUCATION

By

Tamarra Mitchell

August 2017

Dissertation supervised by Misook Heo, Ph.D.

The purpose of this study was to examine the relationship between technology and engineering instruction and technology and engineering literacy in grades K-8. The factors identified and used for the purpose of this study were gender, socioeconomic status, race/ethnicity, and important modes of technology and engineering instruction. These factors were evaluated to determine their relationship to student achievement scores on the National Assessment of Educational Progress (NAEP) 2014 Technology and Engineering Literacy (TEL) assessment. Eight important modes of technology and engineering instruction were identified including: (1) choices people make that affect the environment, (2) inventions changing the way people live, (3) people working together to solve community/world problems, (4) figuring out why something is not working, (5) using different tools to see which is best, (6) building or testing models to check
solutions, (7) crediting others for their ideas, and (8) judging the reliability of sources. These eight modes were analyzed in terms of exposure frequency to determine which level of exposure related to the highest level of technology and engineering literacy achievement. Multiple linear regression analyses were conducted to examine the relationship between independent variables and achievement on the NAEP TEL assessment. The study findings provided evidence to suggest that demographic predictors such as gender, socioeconomic status, and race/ethnicity have a significant relationship on student achievement in technology and engineering literacy. Additionally, evidence suggests that the more frequently students are exposed to technology and engineering modes of instruction, the higher their technology and engineering literacy achievement will be.

Limitations of the study exist due to the use of an NAEP assessment and data. US leaders, policy makers, and educators, however, can benefit from this research when determining how to best allocate funding and resources as well as developing and extending their STEM programs within schools. Additional research in this area is recommended to determine how factors can relate to technology and engineering literacy at various grade levels and across time.
DEDICATION

It is with genuine gratefulness and extreme excitement that I dedicate this work to my family. To my parents, George and Janet, without whom I would not have been able to thrive in my doctoral program or balance my studies and research along with everything else, this is for you. From taking Kayla to her many activities and caring for her when I was in class, to providing countless meals when I was too busy or tired to cook and encouraging me when I struggled to continue, thank you for stepping in and supporting me through every step of this scholarly adventure. I could not have accomplished this feat without you by my side. To my sister, Pamela, who brought me many meal deliveries when I wanted to stay focused on my work, and was often the person on the other end of the phone line when I needed a break, you provided me with many laughs and stress relief. Finally, to my daughter, Kayla, my inspiration and my motivation for starting and finishing this journey, I would not have achieved this goal without you. As my biggest fan and supporter, your patience and encouragement, especially this last year, has been invaluable to me. I hope to be able to provide the same to you one day as you follow your dreams.
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Chapter I

Introduction

A national focus on preparing United States students for global competitiveness began decades ago. One of the main goals was for the US to be able to have a competitive advantage in global markets and remain at the forefront of post-industrial trade (Barrow, 1996). Achieving that goal was predicted to be largely dependent on developing a more highly educated and diversified workforce (Thurow, 1991). The educational system in the US has changed and developed since then. Historically, in the early 20th century Industrial Age, education was largely teacher-centered within the brick and mortar walls of a school. Passive learning and memorization of three main literacies - reading, writing, and mathematics - were commonplace (Shaw et al., 2015). A pivotal turning point in 20th century education came as a result of the 1957 launch of Sputnik by the Soviet Union thus emphasizing the need for a greater focus on science and mathematics preparation in US education (Armstrong, 2006). For this reason, the US passed the National Defense Education Act of 1958 allocating over eight hundred billion dollars to revising and improving science and mathematics standards (Armstrong, 2006). Decades later, the US still exhibited the need for improvement in science and mathematics (Kimmelman, 2006). Markedly, in the 1980’s, A Nation at Risk report stated that US students were performing at a mediocre level and continued to be outperformed in mathematics and science by those in other countries thus further increasing the call for educational reform to help the US remain globally competitive (Kimmelman, 2006).
The paradigm shift to the 21st century Information Age, also known as the Knowledge or Digital Age, brought about rapid development and growth of new technologies. As such, a generation who needed a new matrix of skills and could put knowledge to work rather than machinery was sought after (Barrow, 1996). For this new generation of 21st century learners, the matrix of new competencies included critical thinking, problem solving, collaborating, and working with digital tools (US Department of Education, 2016). Furthermore, a shift to a student-centered learning environment that included project-based learning, global connections, and a focus on multiple literacies had occurred as a driving force toward achieving greater success working in a globalized millennium (McKelvey, 2001; Shaw et al., 2015).

Despite the educational reform efforts in place, an analysis and comparison of the US in relation to other countries at the beginning of the new millennium indicated that the US continued to lag behind in the areas of science and mathematics (Manzo, 2000). Consequently, the Bush administration pushed to make the US stronger in the core academic areas, including reading, science, mathematics, and writing, by developing the No Child Left Behind Act (NCLB) of 2001 placing an increased focus on student achievement (Armstrong, 2006). President Bush additionally proposed the American Competitiveness Initiative Act (ACI) in 2006 emphasizing the need for more rigorous science and mathematics courses to support national competition contributing almost six billion dollars to research, development, and strengthening of US education (Domestic Policy Council, 2006). Unfortunately, a 2012 report (Kelly et al., 2013) indicated that although US students were performing better on national assessments than they were decades ago, the US continued to fall short in comparison with other countries, ranking
35th in mathematics and 27th in science out of 64 countries. Mediocre performance in mathematics and science raised concerns about the ability of the US to be globally competitive and to properly respond to the rapidly growing Science, Technology, Engineering, & Mathematics (STEM) career demands (Thomason, 2011).

By the year 2020, STEM jobs in the US are projected to increase by over one million, placing them among the top of the fastest-growing occupations (Lockard & Wolf, 2012). There is and will continue to be an eminent need for qualified workers; however, there are not enough students pursuing STEM degrees in preparation for such technical careers (Rockland et al., 2010; Thomason, 2011). Academic skills as well as the ability to apply skills and knowledge are necessary to succeed in the 21st century workplace; unfortunately US K-12 schools have fallen short in ensuring high school graduates have attained adequate STEM skills, therefore contributing to lower enrollment and lower success rates in higher education STEM degree programs (Casner-Lotto & Barrington, 2006; Trends in International Mathematics and Science Study, 2011). As such, it is predicted that there will not be enough qualified workers in STEM fields to meet the demand of the increasing scientific and technical global economy (Thomason, 2011).

Recognizing the importance of producing college and career ready students, President Barack Obama addressed the need to improve K-12 STEM education in his State of the Union Address (Obama, 2011). Additionally, the US Chamber of Commerce reached out to businesses requesting that they assist and collaborate with schools to help influence and increase STEM education (Hess, Kelly, & Meeks, 2011). With the push to improve STEM education starting with K-12 schools, the US hopes to increase the output
of STEM literate graduates ready to pursue STEM degrees and enter the workforce, thus aiding the US in remaining globally competitive (Hess, Kelly, & Meeks, 2011; Obama, 2011).

Importance of STEM in K-12 Education

To meet the demands of the 21st Century workforce and ensure a competitive position within the global economy, policy makers, leaders, and educators are pushing for STEM initiatives and integration within US K-12 education (Hess, Kelly, & Meeks, 2011; National Research Council, 2011; Obama, 2011). Since the term STEM was coined in 2001, it has taken on a broad meaning, thus yielding numerous definitions across literature (Brown, 2012). The United States Department of Education describes STEM as programs initiated primarily to strengthen science, technology, engineering, and mathematics education at all levels from elementary through adulthood (United States Department of Education, 2007). STEM has also been described as teaching and learning approaches integrating any of the individual STEM subject areas with any other subject area (Sanders, 2009). Another common description identifies STEM education as an interdisciplinary approach where students apply rigorous academic skills in real world situations (Tsuros, Kohler, & Hallinen, 2009). Despite the different definitions across research, the common goal of providing students with skills and competencies needed to be successful contributors to the 21st century US economy seems to emerge (Lantz, 2009; National Research Council, 2012). In order to achieve this goal, a closer look at how STEM is incorporated into K-12 US education is needed.

Recent research has supported the need to attract students to STEM disciplines during their elementary and adolescent years (Myers & Pavel, 2011; Rockland et al.,
Elementary aged students, in general, acquire more positive perceptions and dispositions when they receive early exposure to STEM content (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Bybee & Fuchs, 2006). Likewise, by the time many students are 14 years old, their aspirations to pursue STEM disciplines are largely formed (Archer et al., 2012; Daugherty, Carter & Swagerty, 2014). It is therefore important that interests in STEM are encouraged and captured during the early elementary to middle school grades. As a result, students intrigued by STEM concepts in elementary and middle school may be more prepared to complete required courses throughout high school and more inclined to participate in elective courses in preparation to enter higher education STEM degree programs (Daugherty, Carter, & Swagerty, 2014).

Although evidence points to positive outcomes by starting STEM studies early in students’ school careers, formal steps toward this change have not been widespread or consistent among US schools. Consequently, elementary schools in the US are seeking assistance on how to best integrate STEM programs within their schools and initiatives to provide earlier exposure to STEM content are a growing priority (Center for Digital Education, 2010; Daugherty, Carter, & Swagerty, 2014). Options for studying STEM in high school, however, seem to be more prevalent including dual enrollment courses, early college entrance programs, residential STEM schools, online education opportunities, and specific STEM programs such as Project Lead the Way and Engineering by Design (DeJarnette, 2012). Although Merrill & Daugherty (2009) suggest STEM be taught as a fully integrated approach where the individual disciplines are not divided, but taught dynamically and fluidly, it is important to look closely at how each of the areas work in the US education system.
Science & Mathematics Literacy, Standards, and Assessment

While it is recommended that STEM areas not be taught independently, but rather integrated together to facilitate STEM literacy (Zollman, 2012), science and mathematics are typically taught as separate subjects in US K-12 public education beginning as early as Kindergarten and continuing through grade 12 (Thomasion, 2011). During middle and high school years, students are usually required to take a specific number and sequence of science and math courses in order to graduate from high school. Examples of such mathematics courses include algebra, geometry, calculus, trigonometry, and statistics. Science courses often include biology, chemistry, physics, human anatomy, and environmental science. The goal of such courses is to facilitate science and mathematics literacy among all students by the time they graduate high school. Students who are literate in science have the ability to use scientific knowledge to process, understand, solve problems, and participate in decision making related to science in real life, whereas students who are mathematically literate identify, understand, and formulate mathematical judgements to solve problems in real life contexts (National Council of Teachers of Mathematics, 2000; National Research Council, 1996; Organization for Economic Cooperation and Development, 2003; Organization for Economic Cooperation and Development, 2007).

In an effort to increase scientific and mathematical literacy, K-12 school districts in the US have adopted academic standards (Darling-Hammond et al., 2013). Teaching and learning standards have been created by experts in the field of education for the purpose of streamlining content all US students should know and skills they should be able to perform at each grade level (National Governors Association for Best Practices &
Council of Chief State School Officers, 2010). One of the primary standard sets currently used by districts to guide science and mathematics instruction is the Common Core State Standards (CCSS). The CCSS are aligned to the expectations of colleges, workforce training programs, and employers and were developed to ensure all students are equally prepared to collaborate and compete with their peers (National Governors Association for Best Practices & Council of Chief State School Officers, 2010). To assess whether US students have met the CCSS, standardized assessments in core subject areas are administered. The US is thus able to analyze the results of the CCSS assessments from each state to help determine student achievement level and identify areas of weakness that may need a stronger focus. In addition to the CCSS used nationwide in the US, large scale standardized assessments such as the National Assessment of Educational Progress (NAEP), Trends in International Mathematics and Science Study (TIMMS), and Program for International Student Assessment (PISA) have been used to measure and compare performance nationally and internationally (Bybee & Fuchs, 2006).

Unfortunately, science and mathematics achievement of US students on such standardized assessments when compared to those in other countries has been a concern for decades (Manzo, 2000). Despite overall achievement in mathematics increasing modestly, science achievement has not changed much for about 15 years (Thomasian, 2011). In an effort to become more globally competitive, the US government has provided funding to schools based on their achievement and growth on the CCSS assessments. As a result of increased accountability and funding as a motivator, schools tend to place a strong focus on improving student performance in subject areas that are included in state standardized testing (National Council of Teachers of English, 2014).
Unfortunately, schools and teachers often feel the burden of state standardized testing because their students’ achievement on such tests largely determines the amount of funding districts receive; consequently, focus on tested subjects is often required and untested areas like technology and engineering become less of a priority (Bhattacharyya, Junto, & Clark, 2013).

**Technology and Engineering Literacy, Standards, and Assessment**

Unlike science and mathematics, which are typically core courses taught in K-12 public education, technology and engineering are often incorporated as special area classes in elementary schools and elective courses at the secondary level. Technology and engineering may be found in elementary settings in the form of a weekly special area class like physical education, art, or music, as after school clubs, or integrated into classroom activities by an elementary level teacher. At the high school level, examples of courses might include robotics, computer programming, computer science, or graphic design, and are often offered as elective courses. Although US schools are making a shift and incorporating technology and engineering, there is a lack of consistency (Computer Science Teachers Association Curriculum Improvement Task Force, 2005). With this in mind there is cause for concern as technology and engineering are major components in developing STEM literacy and helping to prepare K-12 students for higher education STEM programs and STEM careers.

Technology and Engineering Literacy (TEL) is defined as understanding, evaluating, and using information and communication technologies as well as developing and achieving goals and solving problems within real-life contexts (National Assessment Governing Board, 2013). Being literate in technology and engineering allows for the
meaningful application of science and mathematics skills and prepares students for
careers in all four of the STEM areas (Carr & Strobel, 2011; Sanders, 2009). In order to
improve literacy in technology and engineering, US schools use standards of learning to
guide their instructional goals. Although technology and engineering components can be
found integrated into parts of the Common Core Standards for both Science and
Mathematics used by all US states, the focus within those standards is on science and
mathematics content (National Governors Association for Best Practices & Council of
Chief State School Officers, 2010). Separate technology standards were, however,
created by the International Society of Technology in Education, but formal assessments
to measure student proficiency were not widespread among states (International Society
for Technology in Education, 2007; Metiri Group, 2009). In order to help fill the gap and
strengthen the focus on technology and engineering integration, the Next Generation
Science Standards (NGSS) were developed in 2013. Although the NGSS included a
much greater focus on integrating science, technology, and engineering content, their use
is not yet widespread with currently less than 40% of states adopting them (Metiri Group,
2009). In addition to the lack of depth, consistency, and adoption of standards, a way to
formally assess what students know and can do in the areas of technology and
engineering has been lacking (National Assessment Governing Board, 2013). Since
technology and engineering are essential parts of STEM education and in an effort to
improve the college and career readiness of US students in the 21st century, a
standardized assessment was needed to measure US student performance to assess where
improvements can be made and to compare technology and engineering literacy
nationwide.
To meet the need for a standardized performance measure, the National Assessment Governing Board developed the 2014 NAEP Technology and Engineering Literacy (TEL) framework and assessment (2010). The NAEP is the largest nationally representative continuing assessment of what students in the US know and can do in various subject areas (National Center for Education Statistics, 2013). Accordingly, the TEL framework defined skills students should have, thus, building the foundation for the TEL assessment. The TEL assessment was developed to measure K-12 student achievement in technology and engineering literacy in a similar way that student achievement had previously been assessed by the NAEP in areas such as science, mathematics, reading, and other subjects (National Assessment Governing Board, 2013).

The TEL framework identified three major areas, Technology and Society, Design & Systems, and Information and Communication Technology, which students need to achieve proficiency in order to be considered literate in the areas of technology and engineering (National Assessment Governing Board, 2013). Additionally, the framework highlighted three overarching types of thinking and reasoning across each major assessment area including Understanding Technological Principles, Developing Solutions & Achieving Goals, and Communicating & Collaborating, of which students must demonstrate their ability to apply (National Assessment Governing Board, 2013). The TEL framework, accordingly, set the foundation for the development of the TEL assessment.

The NAEP TEL assessment is a standardized tool researchers, educators, and policymakers alike can use to analyze factors contributing to higher degrees of technology and engineering literacy so they can focus on implementing the best
approaches to increase student achievement and demonstrate growth in the future. More specifically, the TEL assessment measures students’ ability to apply technology and engineering skills in real-life computer-based scenarios (National Assessment Governing Board, 2010). The TEL reports on factors such as technology and engineering literacy achievement, instructional experiences, and a multitude of demographic characteristics of which researchers, policy makers, and educators can analyze to help identify contributors to greater achievement (National Assessment Governing Board, 2010). Accordingly, the use of such information may be able to lead to progressive changes in K-12 STEM education.

**Statement of the Problem**

K-12 students in the US are less adequately prepared for the influx of STEM careers that will be seen within the next decade (Gates & Mirkin, 2012; Kuenzi, 2008). Despite the overwhelming need for scientists, engineers, technologists, and technicians, low numbers of students are pursuing such degree programs (Daugherty, Carter, & Swagerty, 2014; Toulmin & Groome, 2007; National Science Board, 2010). For example, between the 2000-2001 and 2008-2009 academic years, the percentage of STEM field degrees awarded in the US dropped from 12.9 percent to 10.7 percent (Thomian, 2011). When national comparisons were made, the results seemed even more bleak with regard to total US growth in STEM areas. Between 1998 and 2006, the US produced a growth of 23 percent for total number of STEM degrees compared to 144 percent in Poland, 178 percent in Taiwan, and over 200 percent in China (Thomian, 2011). In order to develop and promote growth in the STEM field, analyzing factors contributing to subpar enrollment may help elucidate areas in need of improvement.
Considering the multitude of demographic characteristics that can have an effect on the substandard enrollment of STEM areas in the US, two of the more prominent dimensions that seem to emerge include gender and racial disparities (Beede, Julian, Langdon, McKittrick, & Kahn, 2011; Landivar, 2013). Notably, women currently hold nearly half of the jobs in the US; however, they hold less than 25 percent of the positions in STEM fields (Beede, Julian, Langdon, McKittrick, & Kahn, 2011). Over the last decade, more women are obtaining college degrees than men; however, women are pursuing STEM degrees at much lower rates than their male counterparts contributing to negative implications for the 21st century workforce (Legewie & DiPrete, 2014). An underrepresentation of female scientists in the field further emphasizes the need to address the gender gap within education programs as a possible solution to increase the number of graduates prepared for the workforce (Fox, Sonnert, & Nikiforova, 2011).

Similar to the gender disparity, an imbalance is also seen between some races. Historically, students of African American and Hispanic descent have been underrepresented in STEM fields (Landivar, 2013). In 2011, for example, African Americans comprised only six percent of the STEM workforce and only seven percent were Hispanic workers (Landivar, 2013). In order to remain globally competitive, it is recommended to begin emphasizing STEM and motivating students in grades K-12 including a focus on targeting underrepresented populations including females, African Americans, and Hispanics, otherwise it may be too late to prepare and attract 21st century STEM workers (Archer et al., 2012; Bottoms & Uhn, 2007; Fox, Sonnert, & Nikiforova, 2011; Freeman, 2005; Gates & Mirkin, 2012; Jeffers, Safferman, & Safferman, 2004; Landivar, 2013; Myers & Pavel, 2011).
Taking a closer look at STEM education in current K-12 US schools, additional factors such as a disconnect between STEM subjects, a lack of consistency in technology and engineering standards, and lack of an evaluation method prior to 2014 seemingly contribute to the current STEM literacy deficiencies (National Assessment Governing Board, 2013; National Governors Association for Best Practices & Council of Chief State School Officers, 2010; Zollman, 2012). Exemplifying a disconnect between STEM subjects, separate Common Core State Standards for Science and Mathematics exist; however, the engineering and technology components incorporated are not comprehensive (Metiri Group, 2009; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). To aid in increasing technology and engineering integration in standards, the Next Generation Science Standards (NGSS) were created including science, engineering, and technology domains; however, less than 40% of US states have adopted them as of today additionally signifying inconsistency (Metiri Group, 2009). Likewise, until 2014, the US lacked a consistent and widespread way to formally assess what students knew and could do in the areas of technology and engineering (National Assessment Governing Board, 2013). As of today, all 50 states are required to report on technology literacy based on the information and communication technology (ICT) standards from National Education Technology Standards (NETS) for Students (International Society for Technology in Education, 2007; Metiri Group, 2009); however, until the NAEP TEL assessment was administered, the variation in assessments used across states made it difficult to know whether students were proficient (Becker, Hodge, & Sepelyak, 2010). Consequently, very little empirical evidence exists to help guide researchers, policymakers, and school
districts in their effort to make comprehensive improvements to their STEM programs (National Research Council, 2011).

**Purpose of the Study**

The overall goal of this study was to examine how technology and engineering instruction relates to students’ technology and engineering literacy in grades K-8 by using high quality data. The first goal of this study was to identify the relationship between gender, socioeconomic status (SES), and race/ethnicity, on students’ Technology and Engineering Literacy (TEL) achievement. The next goal of the study was to determine how frequency of exposure to technology and engineering instruction in school related to students’ TEL achievement.

**Research Questions**

To achieve the aforementioned research goals, the two main research questions sought included:

RQ1. What is the relationship between gender, socioeconomic status, and race/ethnicity and student achievement on the NAEP TEL assessment?

RQ2. What is the relationship between student-perceived frequency of exposure to technology and engineering instruction and student achievement on the NAEP TEL assessment?

Through examination of the data provided by the NAEP TEL assessment, conclusions to the research questions above were drawn to contribute to the empirical evidence in order to help guide educators and policy makers toward making progressive decisions around STEM programs in K-12 education.
Significance of the Study

The rationale for this study was to contribute to the overall research on factors related to higher technology and engineering literacy achievement of US K-8 students as identified by student scores on the NAEP TEL assessment. Much research exists on student achievement in the science and mathematics areas of STEM; however, school districts, students, and researchers could benefit from further research in the areas of technology and engineering.

It is recommended that upon high school graduation students be equipped with foundational knowledge in science, technology, engineering, and mathematics at a level needed to participate in a 21st century digital global economy (International Society for Technology in Education, 2016; National Research Council, 2012). Much research already exists reporting on science and mathematics achievement; however, little is known about factors contributing to positive student achievement in the areas of technology and engineering. This study provides information that could serve to inform school districts when working to make improvements in their STEM instruction to benefit students. For example, school districts may identify where to best allocate funding, which course requirements may need to be added, or whether curricular changes or enhancements are needed. Likewise, this study may lead to positive implications for students because as school districts identify better ways of implementing progressive STEM integration, students will have a greater opportunity to learn skills needed to be successful in college STEM programs and/or the workforce. This study can additionally benefit future researchers by contributing to the limited body of research that currently
exists in the area of technology and engineering literacy achievement among US K-8 students, thus helping to guide them to other areas in need of study.

**Limitations of the Study**

This study was designed to address research questions using high-quality data from the NAEP. The goal of the NAEP is to ensure their assessments are developed to meet the highest standards of reliability and validity through a complex process of collaboration between experts within the National Assessment Governing Board and the National Center for Educational Statistics (National Assessment Governing Board, 2013). Limitations that were outside the control of the researcher that may have affected the study did, however, exist. First, the 2014 Technology and Engineering Literacy Assessment was the only assessment given by the NAEP, at the time of this research, to assess what students know and are able to do in the areas of technology and engineering. For this reason, the option of analyzing performance based on multiple testing dates did not exist. Likewise, the assessment had only been administered to students in grade 8. As such, it was not possible to make comparisons of student achievement to identify whether differences existed between elementary, middle, and high school students. Additionally, because the NAEP TEL assessment was so current, at the time of the study, the data was not available for export into statistical software programs. Thus, the researcher was limited to the use of the NAEP Data Explorer tool to conduct analyses.

**Definitions of Terms**

Information Age (Digital Era): a period in history also known as the Digital Age characterized as the shift from the Industrial Age to a global economy focused, technological society

Technology: a modification to natural or designed objects or application of scientific knowledge for practical purposes (National Assessment Governing Board, 2013)

Technology and Engineering Literacy: understanding, evaluating, and using information and communication technologies in addition to developing and achieving goals and solving problems within real-life contexts (National Assessment Governing Board, 2013).

Twenty-first century skills: a set of competencies taught through student centered methods including problem-based and project-based learning that include collaboration, solving authentic problems, critical thinking, effective communication of ideas, and working with digital tools to produce products (Rotherham & Willingham, 2009; United States Department of Education, 2016).
21st Century Workforce

Global competition in the 21st century has initiated a trend of economic, technological, and educational growth which has established the need for highly skilled and knowledgeable college graduates possessing job related skills, leadership qualities, and characteristics of life-long learners (Association of American Colleges, Universities, & National Leadership Council, 2007). Although basic skills are a necessity when entering the work force, thinking skills and personal skills are the primary essential qualities employers look for in perspective 21st century employees (Casner-Lotto, & Barrington, 2006). Work places today desire employees who can be flexible and adapt to the demands of multitasking, working collaboratively with colleagues, identifying possible problems, and having rapid problem solving skills (The US Department of Education, 2016). In contrast to the 20th century workforce where it was not unusual for workers to occupy a permanent career, 21st century workers tend to have more transient employment patterns. For example, recently, one in four workers in the US has been with their current employer for less than a year (Bureau of Labor and Statistics, 2004). Likewise, it is not uncommon for individuals to work 10 or more jobs in the course of their lifetime before retirement (Saratoga Institute, 2000). For this reason, 21st century workers must be confident, adaptable, life-long learners in order to be employable (Savickas, 2012). To facilitate the growth of a larger population prepared to enter the workforce, educators and business leaders should work together to ensure students are
leaving high school and college prepared with the skills and mindset to succeed in the modern workforce.

Although the United States has experienced growth in the quantity of students attending college in preparation to enter the workforce, college students’ intellectual skills are seemingly underdeveloped upon graduation (Bok, 2007). In fact, employers felt that less than 10% are prepared for work in our current global society (United States Department of Labor, 2007). In order to learn more about what employers are looking for in 21st century workers and identify their perceptions about the competency of newly hired employees, an in depth study was conducted with over 400 corporations in fields including manufacturing, businesses/professional services, financial/insurance services, entertainment, and trade (Casner-Lotto & Barrington, 2006). Desired skills that were rated the highest among employers included professionalism, work ethic, oral and written communication, teamwork and collaboration, critical thinking, and problem solving ability (Casner-Lotto & Barrington, 2006). In fact, applied skills including professional/work ethic, teamwork/collaboration, and oral communications were emphasized as three of the most important skills needed over basic skills such as reading comprehension and mathematics in the current workforce (Casner-Lotto & Barrington, 2006). Unfortunately, it was concluded that less than 25% of the professionals believed that recent college graduates were well prepared in those areas (Casner-Lotto & Barrington, 2006). It is important to consider changes and improvements that can be made starting as early as kindergarten so that schools can begin to better prepare graduates equipped with the 21st century skills necessary to be successful when entering
higher education programs and the workforce to ensure that the United States remains globally competitive.

**Preparing Students for the 21st Century STEM Workforce**

To progress toward the goal of helping students strengthen 21st century skills by becoming critical thinkers, persistent problem solvers, and effective collaborators, it is recommended that schools in the US start educating children in grades K-12 helping them reach their full potential and become successful contributors in our rapidly evolving technical global society (Bell, 2010; Pearlman, 2010). Looking at the performance of US students in comparison to those in other countries upon the turn of the century, the US appeared to be lagging behind in the areas of mathematics and science (Manzo, 2000). With mediocre performance in mathematics and science and minimal progress evident throughout the decade, leaders and policy makers have become increasingly concerned about the US's ability to remain globally competitive (Thomasian, 2011). Consequently, recent educational reforms such as implementing the Common Core State Standards were put into place responding to the call from leaders to help strengthen US students' overall core content knowledge, 21st century skills, and STEM skills (Hess, Kelly, & Meeks, 2011; Manzo, 2000; Obama, 2011). A workforce comprised of inventors, critical thinkers, and problem solvers is necessary in driving and supporting our global economy (Casner-Lotto & Barrington, 2006). As such, building STEM competencies which encompass the needed 21st century skills in K-12 students is paramount in helping to develop such innovators and encourage their entrance into higher education STEM programs in preparation for future STEM careers.
An analysis of future job growth identified STEM jobs as being among one of the fastest growing occupations projecting an increase of over one million jobs by the year 2020 (Lockard & Wolf, 2012). Additionally, STEM careers are among the highest paid, falling above the national average (Casner-Lotto & Barrington, 2006). Having a strong background in STEM education has also been found to contribute to obtaining a higher salary and a higher level of job security, even outside of STEM fields (Thomasian, 2011). It is, however, predicted that due to the low number of graduates entering higher education STEM programs, there will not be enough qualified STEM workers to meet the demands of the increasingly scientific and technical economy (Thomasian, 2011). One of the main contributing factors in the decline of graduates interested in and prepared to enter STEM fields is a breakdown of effective STEM integration and instruction within the US K-12 school system which is failing to prepare students for future careers (Rockland et al., 2010). As a result, there is a growing concern that the US may lose its competitive edge in the global economy.

The concept of STEM integration is not new; however, as recent reports of the low numbers of students pursuing STEM disciplines past high school have come to light, the need to develop and strengthen STEM skills starting in K-12 schools has gained the attention of policy makers and educational leaders (Daugherty, Carter, & Swagerty, 2014; Toulmin & Groome, 2007; National Science Board, 2010). It has thus been concluded that by working to instill an interest and build the STEM competencies starting with K-12 students, the US will have a greater chance of increasing the output of graduates prepared for higher education STEM programs to become qualified to enter the workforce.
**STEM Education**

**STEM Literacy**

To ensure the US remains competitive in the 21st century global economy, leaders, policy makers, and educators have begun integrating STEM initiatives in K-12 schools to build STEM literacy among students (Hess, Kelly, & Meeks, 2011; Obama, 2011). STEM, a term coined in 2001 by Judith Ramaley, assistant director of the Education and Human Resources Division at the National Science Foundation, refers to Science, Technology, Engineering, and Mathematics (Zollman, 2012). Numerous definitions of STEM exist across literature to attempt to describe the interrelation of the four content areas (Brown, 2012). The United States Department of Education, for example, refers to STEM with a focus on programs initiated for the purpose of strengthening science, technology, engineering, and mathematics knowledge at all educational levels (United States Department of Education, 2007). STEM has additionally been described by placing an emphasis on teaching and learning approaches through which any of the individual STEM subject areas are integrated with any one or more subject areas (Sanders, 2009). STEM is further identified as an interdisciplinary approach where students apply rigorous academic skills in real world situations (Tsupros, Kohler, & Hallinen, 2009). Regardless of the various definitions, the common goal of building STEM literacy among US K-12 students is important so that they may possess the competencies necessary to effectively contribute to the 21st century global economy (Lantz, 2009; National Research Center, 2012).

In order to build STEM literacy, it is helpful to have an understanding of what STEM literacy looks like and what skills students should have. While it is important that
the STEM areas be integrated to facilitate STEM literacy (Zollman, 2012), the individual subject areas are sometimes described independently before being analyzed as a whole. Scientific literacy, for example, often looked at within core science subjects such as physics, biology, chemistry, and earth sciences, refers to a student’s capacity to apply scientific principles and processes to build an understanding of the world around them thus being able to make contributions to the field (Thomasian, 2011). Technological literacy centers around a student’s ability to identify a modification to a natural or designed object, apply their skills and knowledge in using new technology, and demonstrate an understanding of how technology can affect humans and the world around us (National Assessment Governing Board, 2013; Thomasian, 2011).

Engineering literacy is described as having the ability to utilize a systematic approach to design, build, and use systems to meet needs or solve problems (National Assessment Governing Board, 2013; National Research Council, 2012). Mathematical literacy refers to a student’s ability to analyze, reason, and communicate for the purpose of solving mathematical problems (Thomasian, 2011). STEM literacy is thus described as a student’s ability to apply knowledge across the four interrelated subject area domains to solve problems and make sense of the world around them (Thomasian, 2011). It is further explained as having the ability to develop creative solutions to unknown future problems and being able to work flexibly and collaboratively with other individuals as well as new technologies (United States Department of Education, Office of Innovation & Improvement, 2016).

Unfortunately, many, including professionals in STEM fields, university faculty, school teachers, and school administrators lack understanding of STEM (Chiu, Price, &
Ovrahim, 2015; Sanders, 2009). Professionals in STEM related professions often linked STEM with stem cell research or plants (Bybee, 2010). Additionally, a faculty survey at a large university showed that only 25 percent had an accurate understanding of STEM (Breiner, Harkness, Johnson, & Koehler, 2010). Similarly, a study of teachers and administrators across the state of Illinois found that less than half understood or could accurately describe what STEM embodies (Brown, Brown, Reardon, & Merrill, 2011). There is a need for educators at all levels to acquire a greater awareness and understanding of STEM education in order to successfully prepare students to become more STEM literate (Tsupros, Kohler, & Hallined, 2009).

**History**

STEM skills and knowledge have been used throughout US history with scientists and inventors exemplifying implementation during the Industrial Revolution through the invention of technologies such as the light bulb, automobiles, and machinery (White, 2014). The skills and knowledge being utilized by inventors such as Thomas Edison or Henry Ford, however, were not traditionally taught and practiced within traditional schools (Butz et al., 2004). Technologies developed during World War II, such as weapons and military transportation additionally demonstrated that scientists, mathematician, and engineers worked alongside the military to use their STEM skills to help the US remain strong (Judy, 2011). Shortly after the end of World War II, the National Science Foundation was developed to promote scientific advancements, national health, and security helping the US to remain globally competitive (Mervis, 2010). A pivotal turning point in US history and STEM education came in 1957 when the Soviet Union launched Sputnik, the first man-made object successfully sent into orbit.
(Armstrong, 2006; Kelly, 2012). This event propelled the US to initiate a greater focus on science and mathematics preparation in US education (Armstrong, 2006; White, 2014). In response, the Space Act was passed by congress and the National Aeronautics and Space Administration (NASA) was formed to expand science, engineering, and technology to increase the space presence of the US (Dick, 2008). In addition to helping the US gain success in triumphs such as sending humans to the moon, NASA has contributed to STEM initiatives in US K-12 schools and colleges (NASA, 2012; White, 2014). The US also passed the National Defense Act of 1958 which funded the improvement of science and mathematics academic standards (Armstrong, 2006). Despite these efforts to increase rigorous science and mathematics programs in schools, the US exhibited a need for further advancements (Kimmelman, 2006).

While the areas of science, mathematics, technology, and engineering had been the focus of US education improvement throughout most of the 20th century, one significant point in history where US officials realized the continued need to increase STEM literacy of K-12 students was after the 1983 report of President Ronald Regan’s National Commission on Excellence in Education, A Nation at Risk (Gardner, 1983). The publication indicated that the US was performing at a mediocre level and continued to be outperformed by other countries in the areas of mathematics and science (Gardner, Larsen, Baker, Campbell, & Crosby, 1983). Alarming facts presented in the report indicated that on 19 academic tests comparing the US to other countries, American students never achieved first or second place and actually placed last seven times (Gardner, Larsen, Baker, Campbell, & Crosby, 1983). Additionally, it was reported that about 23 million adults were functionally illiterate, only one fifth of 17 year olds could
write a persuasive essay, and only one third could solve a multi-step mathematics problem (Gardner, Larsen, Baker, Campbell, & Crosby, 1983). Average achievement of high school students was reported as being lower than it was two decades prior and there had been a decline in SAT scores (Gardner, Larsen, Baker, Campbell, & Crosby, 1983). This report prompted a movement to better prepare students for a growing number of STEM related careers.

Throughout the end of the 20th century and beginning of the Digital Era, the rapid growth of new technologies contributed to the exponential growth of STEM related fields, and the need for graduates to possess 21st century skills enticed the government to provide federal grants and initiatives to promote the expansion of STEM in schools (Lockard & Wolf, 2012; Richardson, Berns, & Marco, 2010). During the late 1980s and through the 1990s, the US implemented what became known as the standards-based education movement where schools were expected to teach students to reach academic standards at certain grade levels and increased the administration of standardize measures to evaluate performance (Kuenzi, 2008). Despite changes made through the standards-based education movement, a comparison of the US and other countries upon the start of the new millennium indicated that the US continued to lag behind other countries in science and mathematics (Manzo, 2000).

The Bush Administration took several steps to facilitate increasing the strength of US students in reading, writing, science, and mathematics beginning around 2001. The No Child Left Behind Act (NCLB) was created and placed an increased focus on student achievement holding every school accountable to ensure proficiency of every child by tying standardized test results to government funding (Armstrong, 2006). Additionally,
the American Competitiveness Initiative Act (AIC) was developed in 2006 which contributed billions of dollars to initiating more rigorous science and mathematics courses to strengthen US education (Domestic Policy Council, 2006). President Obama also recognized the importance of increasing STEM literacy to prepare students to become more college and career ready thus calling for an increase in STEM education K-12 (Obama, 2011). He had an additional focus on improving teacher preparation programs and passed the American Recovery & Reinvestment Act in 2009 allocating over 77 billion dollars to improve K-12 education (Whitecomb, Borko, & Liston, 2009). Despite their efforts, reports continued to indicate that the US was failing to show competitive performance with other countries in the areas of science and mathematics and the numbers of K-12 students prepared to enter STEM related fields was not sufficient (Kelley et al., 2013; Lockard & Wolf, 2012; National Science Board, 2008). For example, in 2012, the US ranked 35th in mathematics and 27th in science out of 64 countries (Kelley et al., 2013). It was also found that the US did not have enough students upon graduation who were prepared to pursue STEM related careers although the research indicated that by the year 2020, STEM related careers will grow by over one million becoming one of the fastest growing fields (Lockard & Wolf, 2012; National Science Board, 2008). Additionally, in 2015, only 16 percent of scientists and 29 percent of the general public felt that US STEM education was average or above average and 75 percent of the American Association for the Advancement of Science members felt that a major factor contributing to the lack of scientific knowledge in the US can be attributed to a lack of STEM education in K-12 schools (PEW, 2015).
Although the US government has made multiple and major efforts to increase the performance of students in the area of STEM, it is evident that there continues to be a need to make improvements in K-12 education in order to increase the output of STEM literate students upon high school graduation (Lockard & Wolf, 2012). In order to understand the challenges to STEM integration and steps that may contribute to improving the number of STEM literate graduates in the US, it may first be helpful to understand the theory behind 21st century learning and what a 21st century learning environment consists of.

**STEM Learning Theories**

An instructional learning environment is designed and delivered according to the way individuals learn and is often based on learning theories. Learning is complex and can be influenced by a number of factors (Schunk, 2012). With advanced understanding of how individuals learn and better understanding of human cognition, learning theories have been constantly evolving (Ertmer & Newby, 1993; Schunk, 2012). Consequently, the focus of instructional design should not be to determine which learning theory is the best, but rather which will be most effective considering both the learner and the task (Ertmer & Newby, 1993; Shuell, 1986). Depending on factors such as the knowledge development of the learner as well as the level of the cognitive processing needed for learning, strategies and practices from different, and often multiple, theoretical perspectives may be effective (Ertmer & Newby, 1993). As such, it is important for STEM instructors to be knowledgeable of the main learning theories so they may design or improve their instruction to benefit 21st century learners.
Throughout the 20th century, three broad learning theories used most often included behaviorism, cognitivism, and constructivism (Ertmer & Newby, 1993; Siemens, 2005). These traditional theories were developed prior to the expansion of technology in the Digital Era and although elements of each of these theories are currently used in the instructional design process, they do not always exclusively support the evolving learning needs of the 21st century society brought on by the rapid advancements in technology (Mechlova & Malcik, 2012). In addition to the three traditional theories, connectivism, a newer proposed theory of learning, has been seen to play an important role in the digital shift that has occurred in the 21st century (Mechlova & Malcik, 2012, Siemens, 2005). Understanding basic assumptions and principles of each learning theory can yield positive implications on instructional design, best practice, and strategy selection appropriate for 21st century STEM learners (Ertmer & Newby, 1993; Mechlova & Malcik, 2012, Siemens, 2005).

**Behaviorism**

Behaviorism, one of the earliest known theories of learning, suggests that learning occurs through the arrangement of stimuli and consequences within the environment and can be measured through observable actions. The behaviorist learning theory dates back to the late 1800’s, when Russian physiologist, Ivan Pavlov developed a classical conditioning experiment using a stimulus-response method to train a dog (Mergel, 1998). In Pavlov’s classical conditioning experiment, a dog was trained to salivate (the response) upon the ringing of a bell (a stimulus substitution) which was associated with food (the stimulus). Because of the stimulus-response method, the dog would salivate
each time the bell was rung even if there was no food present because the bell acted as a stimulus substitution producing the conditioned response of salivation.

Building off of Pavlov’s classical conditioning, Edward Thorndike contributed to behaviorism through the instrumental conditioning connectionism theory (Bigge & Shermis, 2004; Mayer, 2003). Instrumental conditioning added a reinforcement or reward component following the response with the assumption that in anticipation of the reward, the correct response would be more likely to occur. For example, in training a dog to bark, the stimulus command “bark” was given. When the dog barked (response) he was given a treat (reward). The dog had been instrumentally conditioned to bark upon command in anticipation of receiving a desired reward. Instrumental conditioning can be effective with both positive and negative reinforcements to elicit desired responses or discourage undesired responses. Many behaviorists, however, disliked parts of Thorndike’s connectionism philosophy and felt the concept of reward and consequence were more psychology based than measurable observations (Bigge & Shermis, 2004).

In the early 1900’s, the term “behaviorism” was coined by John B. Watson (1928) who, like many other behaviorist, didn’t agree with certain aspects of Thorndike’s work. Watson strongly supported the classical conditioning theory, and as such began developing behaviorism based off of Pavlov’s earlier work on classical conditioning (Mechlova & Malcik, 2012). Watson believed that the fundamental principal of behaviorist learning was stimulus substitution as seen in Pavlov’s classical conditioning and expanded on his work by using more than one stimulus. Watson’s research had little impact on the academic world; however, his beliefs on the importance of environment influenced the more widely known behaviorist, B.F. Skinner (Schunk, 2012).
During the late 1930’s, behaviorist B. F. Skinner built upon the works of previous theorists thus developing the theory of operant conditioning. Operant conditioning is based on the assumption that an environment can produce consequences thus eliciting a certain response (Mechlova & Malcik, 2012). In other words, individuals behave the way they do as a result of past consequences. Whenever a particular behavior is reinforced, the chances that the behavior will be repeated are greater (Bigge & Shermis, 2004). For example, the “Skinner box” contains a rat, a lever, and food. When the rat presses the lever, it receives the food. Because the behavior of pressing the lever is reinforced by the release of food, the rat was found to increase the frequency of the behavior. Skinner’s research conducted on animals was found to be highly effective, so he was confident that the theory would transfer to children (Bigge & Shermis, 2004).

Behaviorism as a learning theory assumes that (1) learning is assessed through observable behavior, (2) learning and behavior are shaped by the environment, and (3) learning occurs through contiguity and reinforcement (Mechlova & Malcik, 2012). Behaviorist theories imply that the role of the teacher is to provide an environment that elicits desired behaviors and eliminates undesired behaviors when presented with a stimulus (Ertmer & Newby, 1993; Mechlova & Malcik, 2012). Behavioristic instructional design principles include an emphasis on observable measurable outcomes, pre-assessment of learners, mastery of foundational content, use of reinforcement, and use of cues and practice (Ertmer & Newby, 1993).

Although the behaviorist theory is not widely used within the context of 21st century STEM learning, it can be exemplified through certain instructional and assessment practices. Computer based testing, for example, where a computer measures
learning and provides rapid feedback to students is behavioristic in nature (Ally, 2008). Additionally, behavioristic methods may be used to provide foundational skills such as multiplication facts and formulas in mathematics or periodic elements in chemistry which are often recited and repeated until responses become automatic. Computerized game based learning of any academic content is another example of the behavioristic philosophy at work (Wu, Hsiao, Wu, Lin, & Huang, 2012). Examples of instruction and assessment based on the behaviorist learning theory can still be seen today mainly used for drilling and assessing the retention of basic skills and information requiring a lower level of processing; however, by the late 1950’s, a shift from the behaviorist learning theory to the theory of cognitivism occurred as educators and psychologists looked closely at more complex cognitive processes and began to challenge behaviorist perspectives (Ertmer & Newby, 1993; Schunk, 2012).

**Cognitivism**

In the years following World War II, the gestalt learning theories and the work of Max Wertheimer, Wolfgang Kohler, Kurt Koffa, and Kurt Lewin challenged the theory of behaviorism and criticized the belief that learning was based off of external behaviors (Mechlova & Malcik, 2012). Perception, insight, and meaning were believed to be central to learning, according to gestalt leaning theories, and learner’s use of internal mental processing enable them to makes sense of information (Mechlova & Malcik, 2012). The cognitivism theory of learning was further developed in part by Jean Piaget (1983) who proposed four stages of cognitive development for children from birth to age 11 and older with the belief that learning occurs nonlinearly at different developmental stages. Piaget additionally identified the assimilation and accommodation cognitive
learning adaptations (Deubel, 2003 & Hassan 2011). Assimilation is the process of connecting prior knowledge to new knowledge whereas accommodation is the process of modifying the existing cognitive knowledge structure in order to add to the prior knowledge (Alias, Lashari, Akasah, Kesot, 2014).

Other notable cognitive theorists including David Ausubel, Jerome Bruner, Robert Gagne, and Albert Bandura did not place emphasis on the developmental philosophy as Piaget had; however, they all contributed to the cognitive learning theory (Mechlova & Malcik, 2012). Ausubel’s work placed emphasis on the importance of prior learning, Bruner used categories and concept formation to provide models of how learners gather information from their environment, and Gagne believed learning occurred through a series of phases using cognitive steps such as coding, storing, retrieving, and transferring information (Mechlova & Malcik, 2012). Bandura’s research on social cognitive theory centered on his findings that people can learn from observation and have control over their lives by self-regulating their thoughts and actions (Schunk, 2012).

Although cognitive learning theories vary, they all centered on the belief that learning occurs from the active mental process that occurs inside a person’s brain leading up to a response (Mechlova & Malcik, 2012; Piaget, 1983). Like behaviorists, cognitivists acknowledge the role the environment plays in learning; however, they believe learning does not occur from environmental factors alone (Ertmer & Newby, 1993). Internal components such as senses, memory, motivation, and metacognition are all believed to contribute to the learning process (Ally, 2008). Because of the emphasis on mental processes, cognitive learning theories were thought to be more effective for
presenting more complex learning such as reasoning, problem solving, and information processing, unlike the behaviorist perspective (Schunk, 1991). Likewise, cognitive theories are used in 21st century instructional design to ensure that instruction is differentiated to meet the needs of learners to enable them to make connections between prior knowledge and newly gathered information in an organized and relatable way (Ally, 2008; Ertmer & Newby, 1993).

One way cognitivism is exemplified in 21st century learning is through the use of technology to account for individual learning needs (Ally, 2008). Audio, text, images, animations, and videos, for example, can be used to enhance learning in various content areas. Computer-generated presentations can include learning aids such as graphic organizers to assist students in connecting and transferring information to their working memories (Ally, 2008). Additionally, computerized game-based learning has increased in popularity throughout the 21st century and has become a more widespread method of teaching certain skills and concepts (Prensky, 2001; Van Eck, 2006). Game-based learning stimulates senses through various cognitive tasks that can occur within meaningful contexts making them effective learning tools in certain situations (Van Eck, 2006). In addition to technology, cognitivism can be exemplified in mathematics where prior knowledge plays a major role in learning and building off of already learned concepts, and in engineering as the levels of thinking, process of accommodation and assimilation, and problem solving are integral (Alias, Lashari, Akasah, & Kesot, 2014).

Elements of both behaviorism and cognitivism can be found in 21st century STEM learning; however, these theories have not been as widely used due to the passive role of the learner and the lower level learning that occurs through the use of instruction design.
based on either theory (Kaffash, Kargiban, Kargiban, & Ramezani, 2010; Mechlova & Malcik, 2012). The constructivism and connectivism learning theories better align to 21st century STEM learning goals due to the nature of student-centered authentic learning, problem solving, collaboration, active engagement, and connectivity incorporated through the practices and approaches based on such theories (Kaffash, Kargiban, Kargiban, & Ramezani, 2010; Mechlova & Malcik, 2012).

**Constructivism**

Sometimes considered a branch of cognitivism, constructivism is unique and is comprised of a variety of perspectives. Constructivist learning theories are rooted in the 20th century through the works of many theorists who built on cognitivist theories, and they began to gain much popularity in the world of education within the last few decades coming to be integral for instructional design in the 21st century (Ertmer & Newby 1993; Mechlova & Malcik, 2012). Constructivism edged its way into education through the works of several notable theorists like John Dewey, Jean Piaget, Lev Vygotsky, Ernst von Glaserfeld, and Jerome Bruner, for example (Fosnot & Perry, 1996; Matthews, 2003; Yilmaz, 2008). John Dewey, American psychologist and educational reformist, formulated constructivist beliefs long before constructivism became formally known as a learning theory. Dewey believed that the development process was unique within each child so educational development would depend on the child rather than external factors such as the teacher or environment (Stone, 1996). While Piaget and Vygotsky held their own beliefs about learning, they shared Dewey’s belief that learning occurs through the natural development of the child (Matthews, 2003). Piaget, Swiss psychologist and one of the most notable contributors to constructivism, built upon Dewey’s beliefs and his
own theory of cognitive development and determined that individuals develop at different stages and use their prior knowledge to construct meaning from new experiences (Bodner, 1986; Gillani, 2003; Matthews, 2003). Ernst von Glaserfeld would later build upon Piaget’s constructivist views through his research on radical constructivism (Mathwes, 2000). Lev Vygotsky, a Russian psychologist, helped to further shape constructivism through his research on social and cooperative learning (Slavin, 2000). He believed that through interpersonal connections and collaboration, learners could reach a higher cognitive level than by learning independently (Slavin, 2000). Jerome Bruner, American psychologist, believed that learning was an active process and learners construct knowledge based on prior knowledge (Bruner, 1961). He largely contributed to the constructivist learning theory through his research on discovery learning, an inquiry-based method of instruction (Mayer, 2004).

Diverse forms of constructivism are present across literature with some of the most notable including social constructivism and radical constructivism (Bodnar, Klobuchar, & Geelan, 2001; Matthews, 2000). Social constructivism centers on the belief that although knowledge is constructed by an individual, social effects have the ability to modify that knowledge (Bodnar, Klobuchar, & Geelan, 2001). Social factors such as politics, the economy, and power, for example, all have the ability to modify knowledge that has been constructed (Phillips, 2002). Vygotsky’s research turned the constructivist focus on the role of the community and other individuals’ impact on learning (Jones & Brader-Araje, 2002). His belief that language is interpersonal led to his conclusion that knowledge construction can be acquired through the social use of language (Van der Veer & Valsiner, 1993). Radical constructivism, influenced by
theorist Ernst von Glaserfeld, is based on the belief that prior knowledge, experiences, the role of the environment, social contexts, as well as interaction between an individual and the environment all play a role in developing understanding (Gergen, 1995). Radical constructivists believe that knowledge is constructed by an individual and is not passively received, and the role of cognition is to help construct meaningful experiences by facilitating organization (Bodnar, Klobuchar, & Geelan, 2001).

Although there are different constructivist learning theories, they all share the common belief that learning is unique to the individual learner and is constructed through an active process of building conceptual relationships or making meaning from information and experiences that lie within an individual (Bednar, Cunningham, Duffy, & Perry, 1991; Matthews, 2000; Mechlova & Malcik, 2012). Constructivists, however, do not view knowledge as something that can be acquired or transferred into their memories but rather created and built based on experiences and interactions (Ertmer & Newby, 1993). Both the learner and the environment are essential, and constructivists believe that the interaction between the two is how knowledge is created (Ertmer & Newby, 1993). Likewise, constructivists believe it is important that learning take place within a context that can form a link between the knowledge and the environment because if learning becomes decontextualized it is unlikely that transfer will occur (Bednar, Cunningham, Duffy, & Perry, 1991). This constructivist belief that learning cannot occur through isolation, segregating units of information, or division of knowledge domains according to a hierarchy, parallels current STEM philosophies discouraging the separation of each subject area (Bednar, Cunningham, Duffy, & Perry, 1991; Ertmer & Newby, 1993; Kelley & Knowles, 2016). It, however, can sometimes be difficult to
accomplish; an integrated approach to STEM instruction is beneficial for enhancing student learning, building content understanding, and facilitating application of knowledge (Bybee, 2010; Kelley & Knowles, 2016; Lantz, 2009).

As a result of the evolving needs of 21st century learners, constructivist theories have taken a more dominant role in 21st century instructional design (Ertmer & Newby, 2013). STEM learning environments, for example, can be approached differently but are commonly student-centered, collaborative, actively engaging, and reflective (Jonassen & Land, 2012; Kelley & Knowles, 2016; Wang 2013). Constructivist styles promote a learner centered classroom where the teacher plays the role of facilitator of instruction and the learning centers around the student (Froyd & Simpson, 2008; Jonassen, Marra, & Palmer, 2004). The goal of the instructor is to facilitate student growth beyond memorizing facts and encourage elaboration, interpretation, and understanding (Ertmer & Newby, 1993). Constructivist methods are used in STEM education to help build content understanding and facilitate application of knowledge (Lantz, 2009). Several constructivist-based teaching methods reflective of student-centered theories have become popular and are commonly used as best practices in 21st century STEM instruction including inquiry-based learning, project-based learning, and problem-based learning.

**Inquiry Based Learning**

Inquiry-based learning is a student centered, actively engaging educational strategy stemming from constructivist views on problem solving in which students perform methods similar to scientists in a scientific investigation (Padaste, Maeots, Leijeh, & Sarapuu, 2012). Through the process of inquiry, students are actively engaged
in a process of forming a hypothesis, testing the hypothesis through investigation or observation, and reporting on their findings (de Jong & van Joolingen, 1998; Padaste, Maeots, Leijeh, & Sarapuu, 2012). Inquiry-based learning typically occurs through a series of phases. Although the phases can vary, their purpose is to guide students through scientific discovery (Pedaste et al., 2015). Some notable models of inquiry-based instruction within K-12 US education include the 5E model where students Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 1993; Eisenkraft, 2003; Mutrofin, Nur, & Yuanita, 2016), and the Vee diagram which shows the interaction between how theoretical/conceptual elements interact with methodological elements to enhance learning (Calais, 2009; Gencer, 2014; Germann, 1989; Gowin & Alvareaz, 2005).

Depending on the specific subject area content to be learned, prior knowledge, and the learning environment, an inquiry-based learning method may be less effective than other methods, thus drawing some criticism. Providing learners with more traditional direct instruction on particular concepts, especially at a beginning stage, and providing more support as opposed to letting students engage in self-discovery can be less effective (Cronbach & Snow, 1977; Klahr & Nigam, 2004; Mayer, 2004; Shulman & Keisler, 1966; Sweller, 2003). Inquiry-based learning, however, has been found to result in better learning of some concepts compared to more traditional methods of direct instruction or unassisted discovery (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Blanchard et al., 2010; Minner, Levy, & Century, 2010; Furtak, Seidel, Iverson, & Briggs, 2012). Students more effectively understood science concepts, for example, when they become engaged in the inquiry process through generating, developing, and explaining (Furtak, Seidel, Iverson, & Briggs, 2012). The influx of technology in the
digital era has positively contributed to developing inquiry skills such as identifying problems, developing and testing a hypothesis, data collection and analysis, publishing results, and formulating conclusions (de Jong, Sotiriou, & Gillet, 2014; Maeots, Pedaste, & Sarapuu, 2008). Likewise, inquiry-based learning plays a large role in STEM learning and building scientific literacy by actively engaging students in authentic scientific research (Crippen & Archambault, 2012; Pedaste et al., 2015). Inquiry-based learning can help to develop scientifically literate students who are more prepared to enter a growing STEM workforce.

**Project Based Learning**

In current educational practice, project-based learning is a constructivist-based student-centered method of instruction that teaches a multitude of 21st century skills and strategies and allows students to drive their own learning through inquiry, working cooperatively to research, problem solve, communicate, and create, become active listeners, and use technology tools (Bell, 2010). Project-based learning derives from the works of John Dewey, American psychologist and educational reformer, who proposed that learning by doing, enriches the learning experience (Dewey, 1938). Project-based learning has sometimes been referred to by a number of alternate terms including problem-based learning, challenge-based learning, and design-based learning; however for the purpose of this research, the term project-based learning will be used.

Although each project-based lesson is different, there are some essential elements they usually have in common. Students will typically be presented with an open-ended question or task that is often multifaceted and requires students to use inquiry and independence to incorporate knowledge of multiple subjects to create an end product.
(project) to display or share their discoveries with an authentic audience (Bell, 2010). Project-based learning can be lengthy taking weeks, or sometimes months, to create a project reflective of their learning (Bell, 2010). Student choice is a key element of project-based learning that allows for differentiation, greater understanding, deeper learning, higher level thinking, and increased motivation (Bell, 2010).

One area of weakness that has been identified in implementing project-based learning is that there can often be a disconnect between the content area concepts and the project tasks which can cause projects to lose focus and direction (Blumenfeld et al., 1991). In order to prevent a disconnect, instructors can align projects to learning goals (Barron et al., 1998). Project-based instruction has become a popular method especially in the area of STEM instruction to help build a strong foundation in 21st century skills in learners for their future success in the global economy (Bell, 2010). Although standardized testing does not measure 21st century skills and measures only the specific content it is designed to measure, in analyzing basic academic subject proficiency, students engaged in project-based learning have been found to outscore their counterparts (Grier et al., 2008).

**Problem Based Learning**

Problem-based learning can fall under the umbrella of project-based learning because it has many of the same constructivist-based elements; however, it has its own history and typically follows a more structured process. Problem-based learning was developed in the 1950’s and 1960’s in the medical field to align and transfer classroom instruction to clinical practice (Barrows & Tamblyn, 1980). It then migrated into science and engineering classrooms and eventually expanded to other disciplines (Duch, Groh, &
Problem-based learning requires students to often work in teams to use an integrated, multidisciplinary knowledge base to solve real-life problems (Engle, 1999; Wood, 1994). Students work to define a problem, identify and organize ideas related to their prior knowledge, formulate questions for further research, conduct research, have discussions, and finally, present their findings (Allen, Donham, & Bernhardt, 2011).

The role of the instructor in a problem-based learning experience shifts from the presenter to the facilitator in the task of solving a problem making it a student-centered environment (Allen, 2011). As opposed to lecturing, the instructor would monitor, ask questions, and encourage participation (Mayo, Donnelly, & Schwartz, 1995). While instructors would scaffold the learning activity, students would engage in active learning and construction of knowledge (Amador, Miles, & Peters, 2006).

Problem-based learning has received criticism from a few researchers who point to evidence that the results from problem-based learning have been misrepresented and exaggerated by advocates and that small effects and inconclusive findings may be due to the complex nature of research interventions (Norman & Schmidt, 2000) or weaknesses in theory and concept development (Colliver, 2000). Problem-based learning can, however, help to strengthen knowledge in many disciplines including STEM since its student-centered approach facilitates the scientific process and helps to build skills such as conducting research and applying skills to generate solutions to problems (Savery, 2006). Positive effects on student understanding and retention of information have been observed from using problem-based learning as an instructional strategy (Dochy, Segers, Van den Bossche, & Gijbels, 2003).
**Connectivism**

The three more traditional learning theories, behaviorism, cognitivism, and constructivism, were developed prior to the digital age and the influx of technology in and out of school (Siemans, 2005). As technology became more ubiquitous, the amount of information available increased and became readily accessible instantaneously, initiating a change in the way 21st century students gain knowledge (Jones & Jo, 2004; Martin & Ertzberger, 2013). Technology is often viewed as a learning aid to expand the learning experience and to support processes previously encompassed within existing learning theories (Siemens, 2005).

As the US becomes more globally connected through new technology platforms, opportunities for communication, collaboration, and information sharing are contributing to the shift in the teaching and learning paradigm (Bell, 2011). The rapid development of technology can make it challenging for educators as they must constantly update and change their curriculums to incorporate the growth of the technological environment (Smidt, Thorton, & Abhari, 2017). Theories that assume students are gaining their knowledge solely from an instructor within the four walls of a classroom do not account for the connections that can be made through the digitally connected experiences that are possible today (Bell, 2011).

George Siemens, a writer, theorist, speaker, and researcher on learning, networks, technology, analytics and visualization, openness, and organizational effectiveness in digital environments, examined the new learning shift and discovered some gaps where existing theories may not address the learning process that occurs with some of the most current technological advances (Siemens, 2005; Technology Enhanced Knowledge
Research Institute, 2009). Such gaps included limitations in their focus on intrapersonal learning and underrepresentation of the ability to learn and make judgements through technology and organizations (Bell, 2011). Siemens proposed Connectivism as a new theory to help connect learning with technology in the digital age (Siemens, 2005).

The connectivism approach begins with the individual and posits that learning can occur outside of an individual and inside an organization, network, or database (Siemens, 2005). The knowledge gaining cycle thus begins with an individual sharing personal knowledge within a network which is then transferred into an organization, back to the network, then back to the individual making connections throughout the process (Siemens, 2005). A connectivist network has three levels including neural, conceptual, and external where a collection of nodes (individuals, groups, systems, fields, ideas, and communities) work in and among the network levels (Bell, 2011; Siemens & Tittenberger, 2009). The neural level exists within the brain developing new connections and patterns as new stimuli and experiences are added (Siemens & Tittenberger, 2009). The conceptual level exists within a certain discipline or field of knowledge where foundational concepts are organized in such a way as to develop connections between concepts (Siemens & Tittenberger, 2009). The external level exists within online technologies where networks, such as blogs or social networks, allow for learning to occur based on how one makes use of personal connections with peers, experts, and content (Siemens & Tittenberger, 2009). Depth and quality of learning within any network is important and depending on what the educator wants the learner to gain, the connections may focus more on foundational knowledge or may move towards interaction for deeper understanding (Siemens & Tittenberger, 2009). As such, the role
of an instructor in a connectivist model is to act as a facilitator and curator of quality networks learners will form (Siemens & Tittenberger, 2009).

The majority of studies conducted researching connectivism as a learning strategy occurred in higher education; however, the need for connected learning K-12 is acknowledged (Smidt, Thornton, & Abhari, 2017). Having the ability to access needed information quickly and apply it to task completion as opposed to memorizing seems to be a more desirable trait for perspective career opportunities (Bell, 2010). Connectivist pedagogy can help 21st century K-12 learners to build such skills (Siemens, 2005). As an example of connectivist learning in a K-12 setting, the learning process may begin with a research task on sustainable energy, for example. Students would use various sources such as online encyclopedias, websites, blogs, and videos to conduct research. They may then present their findings in a form such as a public service announcement which could be recorded, published, and shared on a learning network or online educational platform for others to view, learn from, and comment on creating a community of interaction and a cycle of information gathering and sharing. Additionally, learning that occurs through the use of online discussion boards, personal learning communities (e.g., Facebook groups), and collaborative sources such as Wikipedia are examples of connectivism within K-12 education.

Connectivism is not as widely known as the aforementioned traditional theories and critics have found that it does not meet the criterion to be coined a new learning theory. The proposed theory, however, has contributed to playing a role in learning with technology (Bell, 2011; Kop & Hill, 2008; Mechlova & Malcik, 2012). Recently referred to as a learning strategy, phenomenon, or pedagogical framework, connectivism
provides a promising approach to teaching and learning in the digital age (Bell, 2011; Smidt, Thornton & Abhari; 2017)

**Summary of Learning Theories**

Each learning theory has unique strengths and weaknesses. Simply because each theory seems to build off of previously established theories does not necessarily indicate that the most recent theory will meet the needs of every learner in every educational situation. Successful instruction can result from an integration and overlap of practices from multiple learning theories (Ertmer & Newby, 1993). Depending on the level of the learner and the nature of the content/task, instructional design may be based on a single theory or a combination of perspectives. Behaviorist strategies, for example, can be used to instruct “what” by building a foundation of content through facts or tasks that require a lower degree of processing (Ertmer & Newby, 1993). Cognitive strategies can be used to address “how” by teaching processes and principles of learning that often have a stronger cognitive emphasis (Ertmer & Newby, 1993). Constructivist strategies facilitate “why” promoting higher level thinking, processing, building meaning, and application within context (Ertmer & Newby, 1993). Connectivist strategies integrate the notion of “where” by building knowledge of where information can be found and how to filter it based on need (Mechlova & Malcik, 2012). Regardless of the theoretical perspective, principles are often shared between theories for the main purpose of enhancing learning and facilitating progression (Schunk, 2012). STEM instructors will benefit from being knowledgeable about each of the discussed theories so they may adapt if and when their instructional design is not effective or to improve, enhance, and advance their practices (Ertmer & Newby, 1993).
STEM in K-12 Schools

STEM education in today’s K-12 schools is taught primarily through constructivist methods focused on building competencies such as critical thinking skills, collaboration skills, content knowledge, application of knowledge, and making real-world connections using inquiry based instruction (Chiu, Price, & Ovrahim, 2015; Lantz, 2009; Siemens, 2005; Siemens & Tittenberger, 2009; Schlechty, 2008). Student-centered instructional strategies and techniques including active learning, cooperative learning, guided research, and discussion groups are important in achieving effective STEM learning outcomes (Bruce-Davis et al., 2014; Smith, Douglas, & Cox, 2009).

A large body of recent research concludes that STEM is best learned through an interdisciplinary integrative approach (Basham, Israel, & Maynard, 2010; Brown, Brown, & Merrill, 2011; Chiu, Price, & Ovrahim, 2015; DePaul Science Working Group, 2013; National Academy of Engineering and the National Research Council, 2014; Stohlmann, Moore, & Roehrig, 2012; Wang, Moore, Roehrig, & Park, 2011). Regardless of their content area specialty, all teachers, given proper training, can implement STEM integration into their curriculum (Chiu, Price, & Ovrahim, 2015). Additionally, rather than segregate STEM instruction within individual classrooms, it would be beneficial for teams of teachers to work together to implement authentic STEM integration (Basham, Israel, & Maynard, 2010). STEM challenges and projects have characteristics that lend themselves to collaborative opportunities for subject specific science, mathematics, engineering, and technology content area instructors to work together in integrating STEM into their regular curricula (Brown, Brown, & Merrill, 2011; Wang, Moore, Roehrig, & Park, 2011). This type of interdisciplinary collaboration helps teachers adapt
their instruction to avoid and correct preconceptions and misconceptions of their students more effectively (Chiu, Price, & Ovrahim, 2015). It can additionally provide students with the opportunity to work within authentic real-world contexts (Basham, Israel, & Maynard, 2010).

Due to variations in demographics, budgets, challenges, and needs, schools often implement STEM integration differently (Chiu, Price, & Ovrahim, 2015). Despite challenges, however, schools are working to help support students in developing higher-order learning skills such as analyzing, synthesizing, making connections, hypothesizing, and explaining ideas, competencies that are highly sought after in the 21st century workforce (Toulmin & Groome, 2007). To accomplish this goal, schools often look at other schools with successful models of STEM integration in place (Chiu, Price, Ovrahim, 2015). Although no single model has been identified as the best, several models have had positive effects in elementary, middle, and high school education.

**STEM in Elementary Education**

Elementary age students in particular develop more positive perceptions about STEM learning when they are immersed in STEM integration early on rather than waiting until later into their adolescence (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Bybee & Fuchs, 2006). By the time students reach the middle school level, their opinions are already largely formed, so it is therefore important that students’ interests are captured during their early years so they are more likely to be motivated to continue their STEM learning through the upper grades (Archer et al., 2012; Daugherty, Carter, & Swagerty, 2014). Despite the evidence for earlier intervention, a smaller body of research and variation in STEM models at the elementary level exists due to the self-
contained nature of elementary schools, where a single classroom teacher provides instruction of all content areas within a day (Hansen, 2014). Common elements such as professional capacity of teachers and staff, parent-community ties, a student-centered learning environment, and instructional guidance, have been found to help facilitate improved student learning in elementary schools (National Research Council, 2011). Since the nature of most elementary schools includes self-contained classrooms, one attempt to introduce STEM at an earlier age is to introduce STEM through a “special” class in a weekly rotation similar to that of an art, music, or physical education class (Epstein & Miller, 2011). Through this model, students would receive instruction by a teacher who specializes in STEM, as a special class, usually once or twice a week. Although this seems to be an excellent idea, budgetary constraints can make this type of arrangement difficult for some schools to initiate and difficult to maintain (Epstein & Miller, 2011). For this reason, much of STEM integration at the elementary level falls to the classroom teachers, and their responsibility of fostering motivation as well as providing a solid foundation of skills is necessary (Cotabish, Robinson, Dailey, & Hughes, 2013).

One method classroom teachers have tried involves students participating in interdisciplinary project-based learning. This method can be beneficial to student learning as it presents STEM in a more connected fashion and often in contexts that simulate real-life authentic experiences (National Academy of Engineering and the National Research Council, 2014). In this format, however, it can be difficult for the classroom teacher to integrate projects and challenges into an already full day of teaching each of the core subject areas they are responsible for (Epstein & Miller, 2011).
Additionally, the time required for student engagement in such a learning method requires flexible scheduling which is sometimes difficult to arrange (DeJarnette, 2012). Training teachers to effectively integrate STEM learning into their curriculum instead of adding it on top of what they would typically teach may make this method more successful thus becoming more widespread (Daugherty, 2013).

Virtual learning experiences for elementary students are another way to help build STEM knowledge (Moss, 2003). One such project, known as The JASON Project, was implemented with elementary students and provided connections between students, scientists, and researchers, both virtually and in person, to enrich STEM learning (Moss, 2003). It was concluded, however, that the experience was beneficial for short-term learning of concepts and that the technology component and access to scientists was not used to their fullest capacity due to ineffective professional development intended to aid in delivering this program (Moss, 2003). A project like this has the potential to create deep STEM learning given proper professional development and planning (Moss, 2003). Opportunities for STEM learning outside of school are available for students as well through summer programs, for example. One such program, the Blue STEM Camp in Kentucky, offers a summer activity to students in grades 5-8 where they can engage in hands-on project-based STEM learning (Mohr-Schroeder et al., 2014). Programs like this are fun and engaging for students and help to build their interest and motivation for STEM learning (Mohr-Schroeder et al., 2014). Students’ interest and motivation actually increased by 3% after participating in the Blue STEM summer camp (Mohr-Schroeder et al., 2014).
To further contribute to the STEM education of young children, federally funded and non-profit community organizations have started programs geared towards elementary students, families, and teachers. The 21st Century Community Learning Centers, for example, is a federally funded program started to provide STEM enrichment activities in after school programs for students in primarily high-poverty low-performing schools (Thomasian, 2011). A number of states have adopted similar after school programs for children as well. For example, the California Department of Education formed partnerships with businesses and private foundations to help bring STEM learning to approximately 1 million students (Thomasian, 2011).

Museums and Science Centers have joined in the effort as well providing informal education to teachers, students, and families (National Research Council, 2009). The Illinois Chicago Museum of Science and Industry, for example, offers courses in STEM for teachers and nearly 1,000 educators have taken advantage of the professional development over the last decade (Chiu, Price, Ovrhim, 2015). Additionally, the Exploratorium in California offers exhibit, literature, films, and camps for both kids and families (Thomasian, 2011).

Although schools and organizations in the US have made positive strides in bringing STEM learning to young children, a movement for more widespread integration in K-12 schools is needed (Daugherty, Carter, & Swagerty, 2014). Elementary schools across the US continue to seek input on how to best integrate STEM into their current programs in order to facilitate earlier exposure to young students (Center for Digital Education, 2010; Daugherty, Carter, & Swagerty, 2014). If students’ interests are captured in elementary school, they will be more likely to achieve success in completing
necessary coursework throughout middle and high school in preparation to enter STEM fields (Bybee & Fuchs, 2006).

**STEM in Middle & High School Education**

Students who wish to pursue a STEM degree or career need extensive preparation throughout their middle and high school years. At the middle school level, students begin making course path choices that will impact their desire and ability to succeed in STEM careers (Wyss, Heulskamp, & Siebert, 2012). Obtaining a strong academic foundation can lead to a higher rate of success in higher education programs (Thomasian, 2011). One approach that has been successful among middle school students is providing exposure to role models and mentors working in STEM fields (Brody, 2006; Wyss, Heulskamp, & Siebert, 2012). Exposing students to STEM professionals and career opportunities through video interviews was found to positively impact students’ interests (Wyss, Heulskamp, & Siebert, 2012). Also found to be beneficial in building middle schoolers’ STEM skills and positive dispositions toward STEM include cross-curricular cooperative learning opportunities (Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013). For example, several schools across four states participated in the Middle Schoolers Out to Save the World Project (MSOWP) (Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013). Sixth and seventh graders measured power output of appliances around their homes, gathered data in spread sheets, and created energy saving plans, which were shared with fellow project participants in other states (Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013). Middle schools across the US are beginning to integrate projects like MSOWP to help build the STEM skills and interests of their students.
Options for studying STEM in high school are seemingly more prevalent than at the elementary or middle levels (Chiu, Price, & Ovrahim, 2015). Students have options such as attending specially designed STEM schools, taking dual enrollment courses, entering early college preparatory programs, engaging in online programs, and participating in clubs and organizations in and out of school (DeJarnette, 2012).

In a 2007, Rising Above the Gathering Storm, a report published by the National Academy of Science, requested to identify the most urgent challenges and recommend specific steps to help the US remain globally competitive moving forward, called to expand statewide specialty STEM high schools (National Academy of Science, 2007). Providing students with challenge, stimulation, and instruction from highly qualified educators, STEM specialty schools would be beneficial to students with interest and talent in STEM areas thus making them more likely to pursue STEM programs in higher education (Tai, Liu, Maltese, & Fan, 2006; Subotnik, Tai, Rickoff, & Aldmarode, 2010). A growing number of states have begun developing specialty STEM schools intended to provide rigorous focused curriculums (Thomasian, 2011). The spectrum is quite diverse, however, with some full-time residential facilities and some part-time establishments. Specialty STEM schools have been developed in many states, for example, The Bronx High School of Science in New York, Montgomery Blair Science, Mathematics, and Computer Science Magnet Program in Maryland, Thomas Jefferson High School in Virginia, the Illinois Mathematics and Science Academy, and the North Carolina School for Science and Mathematics (Subotnik, Tai, Rickoff, & Aldmarode, 2010). The creation of specialty STEM high schools is becoming more widespread; however, there still is a need for expansion (Subotnik, Tai, Rickoff, & Almarode, 2010).
In addition to STEM specialty schools, early college preparatory programs have started to expand as well. This type of program allows students to earn college credits in conjunction with courses and credits required for high school graduation (Thomasian, 2011). The Wake North Carolina State STEM Early College High School and the Metro Early College High School in Ohio are examples of such programs. Students who attend early college high schools can attend school and earn a high school diploma plus up to two years of college credits at the same time (Thomasian, 2011). These schools have not been known to have strict admissions requirements and have been shown to improve high school and college achievement of diverse student populations (Thomasian, 2011).

Online learning opportunities for high school students provide access to STEM learning options that they may not have access to within their school. Examples of online STEM learning programs include the North Carolina Virtual Public School, which is available to North Carolina students, as well as Apex Learning, which is available to students across the US (Thomasian, 2011). Online programs hold affordances such as giving students access to AP and advanced courses that may not be available at their current high schools, test preparation services and career planning services (Thomasian, 2011).

Another example of a STEM approach for high school students is Project Lead the Way. Project Lead the Way was an initiative that started in New York in 1997 as a program to build engineering integration in high schools and has progressively grown to integrate STEM in all states (Project Lead the Way, 2017). The goal of Project Lead the Way is to increase interest and knowledge in STEM through a project-based, hands-on curriculum in US secondary schools (Robbins, Sorge, Helfenbein, & Feldhaus, 2014).
number of studies have concluded that schools that implement Project Lead the Way have seen increased scores in mathematics and science and produced a greater number of students who were prepared for and interested in STEM programs in college (Van Overschelde, 2013; Robbins, Sorge, Helfenbein, & Feldhaus, 2014; Starobin, Schenk, Laanan, Rethwisch, & Moeller, 2013). One comparison study found when comparing STEM specialty schools that used the Project Lead the Way curriculum to those who did not, regardless of the curriculum used, students’ mathematics scores increased (Bicer, Boedeker, Kopparla, Capraro, & Capararo, 2015).

Competitions are another way high schools are involving students in STEM learning. For example, the Pennsylvania Department of Education holds an annual competition aimed at providing exposure to STEM areas that students will need for future careers (Commonwealth of Pennsylvania, 2016). Given a theme for the competition, teams of high school students research, design, and present a device or project that matches the theme. In 2016, the theme was “Making Our Lives Better Through STEM”. Winning student projects included a device that allows homeowners to monitor energy consumption, a helmet that identifies head trauma and alerts emergency responders, and an electric robot that shovels and salts driveways (Pennsylvania Department of Education, 2016).

Opportunities to build STEM knowledge exist outside of school time as well. For example, many states and schools offer after school, weekend, or summer programs and classes for high school students. One such program, Fostering Interest in Information Technology, for students in an urban Michigan high school setting was designed to increase STEM learning of underrepresented high school students and formed a
collaborative partnership among schools and a variety of community participants (Duran, Hoft, Lawson, Medjahed, & Orady, 2014). Learning projects, strategies, and curriculum models were implemented after school, on weekends, and throughout summer months, and utilized online learning to provide students with a more informal approach to STEM learning (Duran, Hoft, Lawson, Medjahed, & Orady, 2014). Results of a study analyzing the program indicated that students’ technology skills including using computers, internet, productivity tools, Web 2.0 tools, and robotics programming improved (Duran, Hoft, Lawson, Medjahed, & Orady, 2014). Additionally, participants gained a greater understanding of what information technology is and how STEM scientists utilize it; however, mixed results were provided related to changes in attitude about STEM learning (Duran, Hoft, Lawson, Medjahed, & Orady, 2014).

Student clubs and competitions inside and outside of school help to facilitate STEM learning by engaging students in authentic hands-on experiences as well. Clubs such as MATHCOUNTS, American Mathematics Competition, Science Olympian, University Interscholastic League, and Science DEMO are some examples of clubs and competitions that high school students can become involved with (Sahin, 2013). One multi-charter school system, Harmony Public Schools (HPS), serving more than 20,000 students in Texas, encouraged students to participate in after school programs such as those aforementioned clubs and take part in completing a science fair project (Sahin, 2013). A study was then conducted to analyze the impact HPS programs had on students’ entrance to post-secondary STEM programs. Findings indicated that HPS students were above the national average in terms of admission to post-secondary STEM
programs and multiple years of participation in HPS science fairs and/or participation in multiple clubs yielded even higher results (Sahin, 2013).

There have yet to be any conclusive studies as to the best approach for STEM learning for students at the secondary level (Subtonik, Tai, Rickoff, & Almarode, 2010); however, much of the literature points to a need for students to engage in interdisciplinary integrated STEM learning experiences (Frykholm & Glasson, 2005; Asgar, Ellington, Rice, Johnson, & Prime, 2012). By providing students in high school with a strong foundation and building an interest, students will be more likely to enter post-secondary STEM programs (Thomasian, 2011). Accordingly, the output of qualified students prepared to enter STEM careers should increase thus preparing the US to compete in the 21st century global economy (Rockland et al., 2010). Although the US government and school systems have made many improvements and implemented many programs and changes to increase STEM learning K-12, there continue to be various challenges that exist and areas that are in need of improvement to further the progress of the US and increase the number of STEM literate graduates.

**STEM Challenges & Areas in Need of Improvement**

Over the years the movement to add STEM programs in and out of school for US K-12 students has grown to include a variety of programs and different methods of integration. Despite recent growth and advancements, there are currently a few areas that stand out across the literature which have contributed to barriers for success in US K-12 education. It may be helpful to understand certain challenges to successful STEM integration a little better so that steps may be taken in the future to facilitate improvements within K-12 schools. Challenges such as difficulty obtaining and retaining
qualified STEM educators, targeting STEM instruction toward a diverse population, and lack of unified STEM curriculum and assessments are among some of the greatest challenges (Thomasian, 2011). Understanding the scope of these challenges, may lead to developing progressive changes.

**Obtaining & Retaining Qualified Educators**

A factor contributing to the challenge of improving STEM education for K-12 students directly relates to a lack of qualified STEM instructors in the US. The success of students in gaining STEM skills and the potential for them to succeed and have an interest in post-secondary programs and STEM careers is directly related to the ability of K-12 educators to engage them in quality STEM learning (Nadelson, Seifert, & Hendricks, 2015). Unfortunately, many K-12 educators have negative perceptions or misconceptions about STEM learning and do not have adequate training to be able to integrate STEM learning effectively into their classrooms (Daugherty, 2013; Nadelson, Pluska, Moorcroft, Jeffery, & Woodward, 2014).

When asked, educators indicated elements such as a lack of training, time constraints, pedagogical uncertainty, and limited knowledge in content areas as factors which make it difficult for them to be able to integrate STEM activities in their classrooms (Epstein & Miller, 2011). Some elementary teachers also felt that engineering concepts in particular can be difficult to understand by students at their level (Swift & Watkins, 2004). This misconception can be related back to a lack of training to educate in-service teachers about what STEM is and how to implement STEM-oriented curricula (Thomasian, 2011; Tucker, 2012; Swift & Watkins, 2004). Elementary teachers additionally believed that it can be difficult to add technology and engineering
components to their already seemingly structured curriculum divided into core academic subjects including mathematics, science, language arts, and social studies (Epstein & Miller, 2011). To alleviate this way of thinking about STEM as an “add-on”, more extensive training for teachers would be helpful so they can better understand how to modify their curriculum to incorporate STEM as opposed to trying to add it on top of what they currently teach (Rockland et al., 2010). The structure of many elementary schools where students are often taught by one teacher would be a seemingly more feasible set-up than perhaps departmentalized middle and high school settings. Unfortunately, elementary educators lack the training and knowledge of incorporating STEM through an interdisciplinary approach (Thomasian, 2011; Tucker, 2012; Swift & Watkins, 2004).

At the secondary level, often times individuals who are highly skilled and knowledgeable in STEM areas find that they can make a better living putting their skills to use outside of K-12 public education which is another contributing factor to the lower pool of highly qualified STEM educators (Thomasian, 2011). Due to the lack of highly qualified instructors of STEM areas, out-of-field teaching, or teaching without a major, minor, and/or certification in a subject, has been occurring in the upper grades (Ingersoll, 1999; Gruber, Broughman, Strizek, & Burian-Fitzgerald, 2002). According the a Schools & Staffing Survey, for example, about 68 percent of middle grade (5-9) teachers and about 31 percent of upper grade (10-12) teachers were teaching mathematics without a major or certification in mathematics (NCES, 2002). In the area of the sciences, about 57 percent of middle grade (5-9) teachers and about 27 percent of upper grade (10-12) teachers were teaching science courses without a major or certification in science (NCES,
There is an even greater shortage of STEM teachers in school districts with a larger population of low-income students (Thomasion, 2011). When educators teach outside their field, students are not always receiving the highest quality of instruction as the educators have not had extensive training and education in the field in which they are instructing (Ingersoll, 1999).

The US has made efforts to increase the pool of highly qualified STEM instructors in K-12 schools. For example, in recognizing that the most important factor to building STEM literacy K-12 is obtaining and maintaining highly qualified STEM educators (PCAST, 2010), President Obama started the Educate to Innovate campaign which focused on training new teachers (Office of the Press Secretary, 2009). Another proposed solution to the shortage of qualified STEM educators is to hire highly qualified STEM educators who can engage students as well as provide professional development to other educators within the school (Rittmayer & Beire, 2008). An additional possible solution, which many institutions are implementing, includes a focus on improving the STEM programs at post-secondary schools to better prepare preservice teachers to enter STEM positions within schools (Thomasion, 2011). Although efforts have been made, more widespread professional development and training for in-service K-12 educators to support the integration of STEM learning may be beneficial in helping to correct misconceptions and build more positive attitudes for progressive change to build the pool of highly qualified educators (Geijsel, Sleegers, van den Berg, & Kelchtermans, 2001).

**Targeting Diverse Populations**

In addition to obtaining and maintaining highly qualified educators, for the US to remain globally competitive, a commitment to ensuring equitable education and ensuring
all students are provided with the opportunity to develop their STEM knowledge and skills is important (Clewell, Anderson, & Thorpe, 1992; Margolis & Fisher, 2002). There is a nationwide epidemic of declining student interest in STEM degree programs (Daugherty, 2013). In a 2010-2012 ACT report, just one in 10 graduates indicated an interest in pursuing a STEM major or occupation (American College Testing, 2013). A focus on targeting currently underrepresented populations in STEM fields could potentially facilitate a growth in the output of graduates interested in and prepared for higher education programs and careers in STEM (Allen-Ramdial & Campbell, 2014).

Due to limited exposure to STEM topics, particularly the area of engineering, during their K-12 education, many students, especially the female population, have a lack of interest in pursuing higher education in preparation to enter STEM fields (Daugherty, 2013). Additionally, certain populations such as individuals of lower socioeconomic status and racial and ethnic minorities are currently under performing in the areas of science and mathematics and are underrepresented in the current STEM field. If this trend continues, an increasing number of students will be unprepared to succeed through college and career STEM programs (Thomasian, 2011).

Despite the narrowing achievement gap between genders in middle and high school mathematics and science scores, there continues to be a loss of STEM interest and confidence in the female population (American Association of University Women, 2004; American Association of University Women, 2010; NCES, 2009). Interest levels of American females often begin to fade after elementary school (Thomasian, 2011). Barriers for females who wish to pursue STEM education and careers often begin at the earliest stages of academia (Sadker, Sadker, & Zittleman, 2009). For example, both in
the classroom and in their homes, females experience a greater lack of encouragement compared to males, fewer STEM activities have been offered for them outside of school, and female STEM role models are underrepresented (American Association of University Women, 2010; Andre, Whigam, Henderson, & Chambers, 1999; Herbert & Stipek, 2005). As a result, fewer females are enrolling in science and mathematics courses in middle school (Burke & Mattis, 2007). These barriers that occur for females early on contribute to the diminishing pool of females in STEM careers. In 2000, for example, only about 11 percent of engineers were female and although there has been an increase over the last two decades, women still represent a small percentage of physical science careers (American Association of University Women, 2010). Women of color often face an even greater psychological and structural challenge in science fields because they often experience a combination of both racism and sexism barriers (Fenema, 2000).

Unfortunately, the gender gap seems to increase with age. Low self-confidence is a factor that contributes to females dropping out of or not enrolling in STEM classes as they get older (Gilligan, Goldberger, & Ward, 1994). For example, 81 percent of females reported enjoying mathematics in elementary school which dropped to 68 percent by middle school, and 61 percent by high school, and when asked whether they felt they were good at mathematics, only 14 percent of females in high school perceived themselves as such (Gilligan, Goldberger, & Ward, 1994). Policy makers and educational leaders have attempted to bridge the gap to build interest and experience in STEM, but the gap continues to widen (United States Department of Education, Office of Innovation & Improvement).
Similar to general education, socioeconomic status (SES) is strongly associated with STEM interest and achievement (Xie, Fang, & Shauman, 2015). A STEM achievement and participation gap exists between students from lower SES families and those from higher SES families (Schneider, Swanson, & Riegle-Crumb, 1998; Muligan, Hastedt & McCarroll, 2012; National Science Board, 2014). Minority students, including African Americans, Hispanics, and those from lower socioeconomic neighborhoods are largely underrepresented in post-secondary STEM programs and careers (Xie, Fang, & Shauman, 2015). Unfortunately these lower numbers are often a result of factors associated with lower socioeconomic status (Estrada, Woodcock, Hernandez, & Schultz, 2011). Students who live in lower-income neighborhoods experience segregation by family income and are at a disadvantage for educational attainment (Reardon, 2011). Students with a socioeconomic disadvantage are at a greater risk for cognitive deficits and lower academic achievement (Brooks-Gunn, Duncan, Klebanov, & Sealand, 1993; Sastry & Pebly, 2010; Sharkey & Elwert, 2011). As racial and ethnic minorities such as African Americans or Hispanics often come from financially disadvantaged neighborhoods, racial and ethnic segregation puts them at an academic disadvantage as well (Massey, 1993). Unfortunately, the effects are shown in the numbers of minorities represented in STEM fields. Comprising only about 13 percent of the STEM workforce, racial and ethnic minorities continue to be underrepresented (National Science Foundation, 2014).

Minorities and students of lower socioeconomic status face additional barriers which have a negative impact on their success and interest in such fields. For example, while it is not uncommon for schools in all areas to assign teachers to instruct areas
outside of their expertise, the inequity of this practice is alarming. Students in schools with a large minority and low SES population are unfortunately more likely to have teachers who are teaching out of their degree and certification areas and are often underqualified to teach STEM areas (Jerald & Ingersol, 2002). Compared to schools in more affluent areas, students in high-poverty schools are 77 percent more likely to have a class taught by an out-of-field teacher and students attending schools with a high population of non-white students are 40 percent more likely to have classes taught by underqualified teachers (Jerald & Ingersol, 2002).

Another barrier that has contributed to narrowing the population of students entering STEM programs is that the primary focus of STEM integration in the US has been geared toward secondary education; however, it has become increasingly evident that STEM integration needs to move down the pipeline beginning with the youngest students in elementary schools (Epstein & Miller, 2011; National Research Council, 2012). Earlier integration and building a strong STEM foundation at a young age will facilitate greater student participation in STEM learning through middle school and high school education programs (DeJarnette, 2012). One step taken to correct this issue was a national K-12 initiative recommending the addition of 1000 STEM focused schools by the year 2020 with 800 consisting of elementary and middle schools (President’s Council of Advisors on Science & Technology, 2010).

Despite efforts made to increase funding and programs, minorities and females continue to be underrepresented in the STEM workforce (Duran, Hoft, Lawson, Medjahod, & Orady, 2014). Due to the changes in demographics and evolving educational systems in other countries, it has become more important than ever before to
expand opportunities for underrepresented minorities (National Research Council, 2011). Starting with the youngest students in grades K-12, the US can address targeting underrepresented populations (Duran, Hoft, Lawson, Medjahod, & Orady, 2014).

**STEM Learning Standards and Assessments**

The lack of consistently defined learning standards and common assessments for students in the US is considered as a challenge of K-12 STEM integration (Carr, Bennett, & Strobel, 2012; Rose, 2007; Thomasian, 2011). A separation seems to occur in the way STEM subjects are presented through curriculums in K-12 US schools; for example, science, mathematics, and computer classes are often separate school subjects with a focus on the natural sciences and a lack of attention being placed on technology and engineering which in turn can cause a disconnect for students (Thomasian, 2011). The government at the federal, state, and local level, as well as community organizations, have all combined their efforts in order to promote the growth of STEM programs in K-12 schools; however, continued efforts are necessary (Thomasian, 2011). In 2010, for example, the US began implementing the Common Core State Standards (CCSS), a new set of more rigorous academic standards which are evidence-based and are aligned with college and work expectations (National Governors Association for Best Practices and Council of Chief State School Officers, 2010). Currently forty-two states, the District of Columbia, four territories, and the Department of Defense Education Activity have adopted the CCSS which cover what students in grades K-12 should know and be able to do in mathematics and language arts.

The mathematics CCSS include a number of standards to help ensure student growth in STEM proficiency including a strong focus on foundational mathematics skills.
in grades k-5, higher level conceptual understanding, application to real-world problem solving, and college and career readiness for high school students (Thomasian, 2011). The Next Generation Science Standards (NGSS) were released to answer a call for a new set of rigorous academic science standards that contain a stronger technology and engineering presence (Thomasian, 2011). The NGSS helps to provide a stronger foundation of content but also integrates application of real-world challenges and problem solving (National Research Council, 2011). Although many states have shown interest, as of 2016, only 18 states and the District of Columbia have formally adopted the NGSS standards. Other states have academic standards for science and technology; however, many of them are older. For example, Pennsylvania’s academic standards for Science and Technology and Engineering Education were updated in 2012 at the K-2 level, 2009 at the grade 3-8 level and 2010 at the secondary level; and Arizona’s State Science Standards were last updated in 2005.

In addition to the need for a more unified adoption of STEM academic standards, there is a need for improved assessments. Until a new set of assessments were released during the 2014-2015 school year, many states’ assessments were not fully aligned to the CCSS nor did they assess the level of problem solving ability the newer assessments were designed to measure (Thomasian, 2011). These assessments, however, only cover mathematics and language arts. As such, assessments to measure science, technology, and engineering are still lacking. While technology and engineering elements exist among both the science and mathematics academic standards and assessments, they receive less of a focus and are weakly defined (Car, Bennett, & Strobel, 2012).
Until the National Assessment of Student Progress (NAEP) developed and administered the Technology and Engineering Literacy Assessment (TEL) in 2014, there had been no standardized assessment that could be used for a large-scale study to measure growth and proficiency of the technology and engineering components of STEM. The lack of such an assessment could have contributed to the limited pool of research examining student growth and performance of STEM through integrated and interdisciplinary approaches (Mahoney, 2010; Stohlman, Moore, & Roerig, 2012).

**Summary of STEM in K-12 Schools**

Although there has been a lack of consistency on how to best integrate STEM into the K-12 curriculum nationwide, there is agreement that an integrated approach may provide more promising results (Meyrick, 2011). It has been concluded that regardless of their grade level, more time for teacher preparation and training in STEM can help facilitate more effective integration K-12 (National Research Council, 2012). In addition, it is evident that a greater focus be placed on integrating STEM education with all student populations, especially those previously underrepresented in STEM career areas starting with students at the elementary level (Myers & Pavel, 2011; Robelen, 2011). Diversifying the target population may, in fact, help to increase the number of students graduating prepared to take their STEM learning to a higher level in post-secondary education programs. The need to unify curricular standards and assessment continues to be area in need of improvement within the US K-12 education system as well (Carr, Bennett, & Strobel, 2012; Rose, 2007; Thomasian, 2011). Although steps have been taken to integrate technology and engineering components through the Common Core
Standards and the Next Generation Science Standards, the US education system could benefit from more unified participation in such standards.

The NAEP has taken important steps in developing an assessment to measure the performance and growth of K-12 students in the areas of Technology and Engineering in a similar way to how they have evaluated science and mathematics performance and growth through the creation of the NAEP TEL assessment. Such an assessment may provide valuable information on students’ technology and engineering literacy and help to identify factors associated with greater performance outcomes thus helping provide input for informed decisions to improve STEM learning K-12.

**National Assessment of Educational Progress (NAEP)**

Assessments to measure academic progress and growth began before the 1960s; however, during that era declining performance of K-12 students in the US as well as a need for a quality standardized assessment of students at all levels brought about the development of the National Assessment of Educational Progress (NAEP) (Beaton et al., 2011). After the launch of Sputnik in 1957 and development of the National Defense Act of 1958, the concern that US schools were not producing enough scientists to continue to be globally competitive led to the development of several assessments that could be used to analyze performance and focus on making improvements in education (Armstrong, 2006). Once such assessment was Project Talent, a national longitudinal study, which was the largest and most comprehensive assessment administered to high school students beginning in 1960 surveying over 440,000 students (American Institute for Research, 2016). The Project Talent assessment design required students to take the test over multiple days, and could not identify minority performance as questions about one’s race
and ethnicity were not asked during that time period, leaving much room for improvement (Beaton et al., 2011). After the Civil Rights Act of 1964, the Equality of Educational Opportunity Survey (EEOS or the Coleman Report), another large-scale national assessment, was developed and administered to students in grades 1, 3, 6, 9, and 12 (Beaton et al., 2011). Improvements upon the EEOS were necessary due to the low sample size and lack of appropriate technology to compute reliable statistics (Beaton et al., 2011). In addition to Project Talent and the EOSS, both the Scholastic Aptitude Test (SAT) and the American College Testing Program (ACT) taken by US college-bound students during their high school years, measured performance for the purpose of providing colleges with a common criterion for comparing applicants for admission (Princeton Review, 2017). The decline of scores for US college-bound students between the 1960s and 1970s along with the need to improve the quality of national performance indicators of all students helped shape the development of the NAEP.

The NAEP, also known as the Nation’s Report Card, is the largest nationally representative measure of students’ academic performance in a multitude of content areas as of today (National Center for Educational Statistics, 2017). The NAEP is an indicator of academic achievement for students grades K-12 nationwide (Fields, 2014). NAEP assessments are standardized, where one identical test is given to all test takers in the same format, thus providing a common measure of student proficiency and progress so that comparisons can be made between demographic subgroups, states, as well as analyzing the nation as a whole (Fields, 2014; NCES, 2009). Indicators such as achievement, instructional experiences, school environment demographics, and population demographics are reported based on samples of students in grades 4, 8, and 12.
for the main content area assessments (National Center for Educational Statistics, 2017). When results from NAEP assessments are collected, they are published in a report known as The Nation’s Report Card. Educators, parents, policymakers, and researchers can then use the data to assist with improving the quality of education.

When the NAEP assessments were first administered in 1969, they focused on measuring the performance of citizenship, science, and writing (Beaton et al., 2011). Historically, samples of students were comprised of age cohorts from both public and private schools and were reported by national regions (Beaton et al., 2011). The assessment took approximately one hour with the use of tape recorders to present instructions, read aloud parts of the assessment, and ensure standardization (Beaton et al., 2011). In 1983, the NAEP made some significant changes moving forward in a new era. Accordingly, reading and writing assessments were added, sampling was reported in terms of both age and grade, and a questionnaire reporting a reason special needs students were excluded from the assessment was added (Beaton et al., 2011). The Nation’s Report Card: Improving the Assessment of Student Achievement was published in 1987 suggesting changes in the governance of the NAEP (Alexander, James, and Glaser, 1987). As such, The Governing Board was developed and was responsible for setting NAEP policies and developing frameworks for the NAEP assessments (Beaton et al., 2011). Over the years, the Governing Board developed new frameworks, built new assessments based on the frameworks, initiated the addition of achievement level (Basic, Proficient, Advanced), added open-ended responses that could be hand graded, and developed new guidelines for the participation of students with disabilities and English language learners (Beaton et al., 2011). When the No Child Left Behind Act (NCLB) of
2001 was enacted, the NAEP mathematics and reading assessments became required in the US in grades 4 and 8 every other year and as often as they had in the past for grade 12 with a minimum requirement of every 4 years (Beaton et al., 2011). By comparing state results, the Governing Board identified the need to report urban districts separately so they created the Trial Urban District Assessment (TUDA) (Beaton et al., 2011).

Currently, the NAEP administers main content assessments and long-term trend assessments. There are a total of 12 main subject assessments including the Arts, Civics, Economics, Foreign Language, Geography, Mathematics, Reading, Science, US History, World History, Writing, and Technology and Engineering Literacy (TEL). While most of these assessments are taken with paper and pencil, the writing assessment for grades 8 and 12 began being administered digitally in 2011. Additionally, the TEL assessment was administered electronically in 2014 (National Center for Educational Statistics, 2017).

Although an assessment specifically designed to measure STEM proficiency and growth does not exist yet, standardized assessments such as Common Core Assessments, TIMMS, and NAEP have all been used to measure mathematics and science performance and growth thus providing data that could be used to improve those areas within schools. Until NAEP developed the TEL, a large-scale universal tool to measure technology and engineering proficiency and growth did not exist. In order to help schools determine exactly what US K-12 students know and what skills they possess, analysis of the TEL indicators compared to performance may help educators identify where improvements can be made to help their students grow and become more literate.
Technology and Engineering Literacy (TEL)

Framework

Each NAEP assessment is based on a unique assessment framework. The frameworks guide assessment builders on content to include, processes to follow, question types, and test administration procedures that can be used for each individual assessment. Due to the rapid expansion and integration of technology in schools, the National Assessment Governing Board developed the Technology and Engineering Literacy (TEL) framework as a guide to describe what students at various grade levels should know and be able to do with regard to technology and engineering in a similar way to the existing NAEP science and mathematics assessments. Although the TEL framework highlights expectations of students at certain grade levels, it is important to note that it was developed as an assessment framework to serve as a basis for the TEL assessment as opposed to a curriculum framework and does not describe how, when, or what content should be taught in classrooms (National Assessment Governing Board, 2013).

To aid in designing the TEL framework, the development committee utilized the research and guidelines from various resources including existing standards from US states and other countries such as the United Kingdom, the National Education Technology Standards (International Society for Technology in Education, 2007), Standards for Technological Literacy: Content for the Study of Technology (International Technology Education Association, 2007), the Framework for 21st Century Learning (Partnership for 21st Century Skills, 2007), the Science Framework for the 2009 NAEP (National Assessment Governing Board, 2008), Benchmarks for Science Education
Standards (National Research Council, 1996), the No Child Left Behind Act of 2001 (No Child Left Behind, 2001), the American Recovery & Reinvestment Act of 2009 (American Recovery and Reinvestment Act, 2009), and a number of notable research studies and reports (National Assessment Governing Board, 2013). One of the challenges in developing the framework was the varying definitions of technology, engineering, and technology and engineering literacy across the literature, so one of their first steps was to create an umbrella definition for the purpose of framework and assessment design (National Assessment Governing Board, 2013). The NAEP describes technology as a modification to natural or designed objects or the application of scientific knowledge for practical purposes (National Assessment Governing Board, 2013). Engineering is defined as an approach taken to design, build, and use systems that meet human needs and solve problems (National Assessment Governing Board, 2013; National Research Council, 2012). In order to be considered literate in technology and engineering, one must be able to understand, evaluate, and use information and communication technologies in addition to developing and achieving goals while solving problems within real-life contexts (National Assessment Governing Board, 2013).

In order to address each assessment area 21st century students need to be knowledgeable in to determine their level of technology and engineering literacy, the NAEP TEL assessment framework was developed. The framework contains three areas of technology and engineering literacy, each of which were assessed and reported on separately, including Technology & Society, Design & Systems, and Information & Communication Technology (ICT). Although they are described individually here,
overlap between the three areas is evident due to the nature of technology and engineering (National Assessment Governing Board, 2013).

**Assessment Area 1: Technology & Society**

The assessment area Technology & Society addresses the reciprocal effects of technology and society along with ethical decisions that must be made in accordance to those effects and consists of four sub areas including Interaction of Technology and Humans, Effects of technology on the Natural World, Effects of Technology on the World of Information and Knowledge, and Ethics Equity, and Responsibility (National Assessment Governing Board, 2013; Zhang et al., 2016). Table 1 describes each of the sub-areas, identifies principles of understanding, and provides an example of how a student in 8th grade would demonstrate their technology and engineering literacy related to factors associated with technology and society in the context of providing a sustainable energy source.
Table 1

Technology & Society sub-areas, principles of understanding, and examples (National Assessment Governing Board, 2013).

<table>
<thead>
<tr>
<th>Technology &amp; society sub-areas</th>
<th>Description</th>
<th>Principles students should understand</th>
<th>Example of 8th grade assessment task to demonstrate TEL</th>
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| Interaction of technology and humans                | Relates to society’s influence on the creation and use of new technologies and technology’s influence back on society | • The reciprocal relationship between technology and society  
• Cost, benefits, and trade-offs when making technology decisions  
• Use of technology may have unanticipated consequences  
• Development and evaluation of technology solutions are based on criteria | Provided a scenario that wind turbines will be placed in residential neighborhoods, describe positive and negative effects they may have on society. |
| Effects of technology on the natural world          | Relates to whether technology has a positive or negative impact on the world around us | • Technology use can have both positive and negative effects on the environment and economy  
• Some technologies can help reduce negative effects of other technologies  
• Sustainable solutions should meet needs without negatively impacting future generations | In order to make the best decision for a city, compare and contrast wind turbines with other sources of energy in relation to their impact on the environment and economy. |
Table 1 (Continued)

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<tr>
<th>Technology &amp; society sub-areas</th>
<th>Description</th>
<th>Principles students should understand</th>
<th>Example of 8\textsuperscript{th} grade assessment task to demonstrate TEL</th>
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| Effects of technology on the world of information and knowledge | Focuses on the vast expansion and rapid changes to the ways in which ICT stores, organizes, and accesses data and how that correlates with positive and negative effects on society | • Vast amounts of data can be stored, managed, and accessed on a variety of devices in many different formats  
• ICT connects individuals and helps them create and modify information  
• Such capabilities are transforming the world of education and having large effects on society | Provided with two persuasive presentations on different wind turbine designs, compare the designs and develop an educated opinion. |
| Ethics, equity, and responsibility | Focuses on the effects technology can have, responsibilities of digital citizens, and consequences of decisions | • Technology affects others  
• There are differences to the type, amount, and availability of technologies in various countries | Describe a process for citizens of a community to evaluate the effects that wind turbines might have on the community. |

Assessment Area 2: Design & Systems

The assessment area of Designs & Systems addresses how students maintain and use technology tools along with the engineering process behind technology and consists of four sub areas including Nature of Technology, Engineering Design, Systems Thinking, and Maintenance & Troubleshooting (National Assessment Governing Board, 2013). Table 2 describes each of the sub-areas, identifies principles of understanding, and provides an example of how a student in 8th grade would demonstrate their technology and engineering literacy related to factors associated with design and systems in the context of providing a sustainable energy source.
Table 2

*Design & Systems sub-areas, principles of understanding, and examples (National Assessment Governing Board, 2013).*

<table>
<thead>
<tr>
<th>Design &amp; systems sub-areas</th>
<th>Description</th>
<th>Principles students should understand</th>
<th>Example of 8th grade assessment task to demonstrate TEL</th>
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| Nature of technology       | Focuses on being able to identify products, processes, and systems created by humans to meet human needs | • There are natural constraints than can affect technology  
• Scientists and engineers have different roles  
• Creative processes are needed for technology development  
• Technology tools designed for a specific purpose can help build efficiency, accuracy, and safety | Given a scenario where a homeowner must choose between wind power and other alternative energy sources, identify constraints that might exist. |
| Engineering and design     | Focuses on creating solutions to problems and meeting needs | • The engineering process is systematic, creative, and typically requires model development to represent solutions to challenges  
• There are multiple ways to solve a problem  
• The goal is to find the best possible solution given a set of set of constraints | Compare aesthetic properties of vertical versus horizontal wind turbine designs. |
Table 2 (Continued)

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<thead>
<tr>
<th>Design &amp; systems sub-areas</th>
<th>Description</th>
<th>Principles students should understand</th>
<th>Example of 8th grade assessment task to demonstrate TEL</th>
</tr>
</thead>
</table>
| Systems and thinking       | Centers on a way of thinking about interactions between causes and consequences of various problems and solutions | • Parts of systems work together and/or interact with parts of other systems to meet specific purposes  
• More complex systems often require more energy making them more susceptible to errors and breakdown | Provided with a simulation model of a wind turbine, identify goals, processes, inputs/outputs, feedback, and control features. |
| Maintenance and troubleshooting | Focuses on ways to prevent technological problems and what students can do when problems arise | • Technology tools need routine maintenance to maintain their highest capability of functioning  
• Identify and fix a problem when it does occur | Using a simulation model of a wind turbine, identify parts that may require the most maintenance. |

Assessment Area 3: Information & Communication Technology (ICT)

The third assessment area, ICT, involves students’ knowledge of tools, systems, protocols, and devices for creating and communicating individually or as a team and is comprised of five sub areas including Construction and Exchange of Ideas and Solutions, Information Research, Investigation of Problems, Acknowledgement of Ideas and Information, and Selection and Use of Digital Tools. Table 3 describes each of the sub-areas, identifies principles of understanding, and provides an example of how a student in 8th grade would demonstrate their technology and engineering literacy related to factors associated with ICT in the context of providing a sustainable energy source.
Table 3

*Information and Communication Technology sub-areas, principles of understanding, and examples (National Assessment Governing Board, 2013).*

<table>
<thead>
<tr>
<th>Information and communication technology sub-areas</th>
<th>Description</th>
<th>Principles students should understand</th>
<th>Example of 8th grade assessment task to demonstrate TEL</th>
</tr>
</thead>
</table>
| Construction and exchange of ideas                 | Focuses on being equipped with an ITC skill set needed to communicate and collaborate effectively | - Digital tools can be used for formal and informal expression  
- Choose appropriate tools for a specific purpose | Design a presentation on positive and negative impacts of wind turbines in residential areas. |
| Information research                               | Focuses on using technology tools to aid in research and information collection from different sources | - Electronic resources increase the quantity of information available  
- Strategies should be used to evaluate and verify that sources are reliable | Compare and contrast wind turbines to other green energy alternatives. |
| Investigation of problems                          | Focuses on using ICT within content areas and real-life situations to diagnose and solve problems | - Digital tools can be used for simulations, tests, and experiments to help solve problems in and out of the school setting | Determine which US state would be most appropriate for installing wind turbines. |
Table 3 (Continued)

<table>
<thead>
<tr>
<th>Information and communication technology sub-areas</th>
<th>Description</th>
<th>Principles students should understand</th>
<th>Example of 8th grade assessment task to demonstrate TEL</th>
</tr>
</thead>
</table>
| Acknowledgement of ideas and information              | Based on understanding intellectual property and the importance of crediting others’ work appropriately | • It is important to abide by copyright laws and fair use guidelines  
• properly cite all sources | Give appropriate credit to cite research and images used. |
| Selection and use of digital tools                     | Focuses on the ability to choose appropriate tools for specific purposes | • Certain tools may be more efficient for a specific task  
• Foundational skill set for a variety of tools | Choose an appropriate multimedia technology tool to create a persuasive presentation on wind turbines for homeowners. |

These three broad assessment areas outline what students at grade levels 4, 8, and 12 should know and be able to do and they detail the areas that the NAEP TEL assessment was developed to evaluate. Grade 8 examples of how students would demonstrate proficiency were chosen above since the TEL has only been administered to 8th grade students upon conducting this research. In addition to the three main assessment areas, there are three general overarching practices that are also expected of students that span all three assessment areas.

**Overarching Practices**

In all three assessment areas of technology and engineering literacy, students are expected to demonstrate thinking and reasoning skills referred to as “practices” (National Center for Educational Statistics, 2017). The three overarching practices that complement each of the three areas should be applied and carried out by students across each of the assessment areas. These practices include Understanding Technology Principles, Developing Solutions & Achieving Goals, and Communicating & Collaborating.

The first practice, Understanding Technology Principles, focuses on students’ ability to organize their thoughts and apply reasoning skills from a level of foundational knowledge to higher order thinking and reasoning (National Assessment Governing Board, 2013). For example, students might identify examples of ethical and equality disparity, describe how technology affects the world around them, and analyze positive and negative effects of technology tools (National Assessment Governing Board, 2013). The second practice, Developing Solutions and Achieving Goals focuses on students’ ability to apply their knowledge and skills combined with the use of technology to
achieve goals and engage in the problem solving process in and out of the school setting (National Assessment Governing Board, 2013). The NAEP TEL assessment requires students to respond to tasks and solve a multi-step problem to demonstrate their understanding in this area. The third practice, Communicating and Collaborating centers on the students’ ability to use various technology tools to work effectively individually, with a group, or with an expert to solve a problem or complete a task (National Assessment Governing Board, 2013).

By assessing students on the three overarching practices within each assessment area through a variety of contexts, the NAEP TEL assessment will identify the level of proficiency each student is at with regard to their technology and engineering literacy. By closely analyzing students’ proficiency in these areas in comparison with where and how STEM learning is being integrated within US K-12 schools, leaders in education may gain information that will be helpful in making future improvements to their policies and instructional design.

Assessment

The TEL framework was created to identify skills and information students should know, understand, and be able to do with technology and engineering at specific grade levels for the purpose of designing the 2014 TEL assessment (National Assessment Governing Board, 2013). As a new test, the TEL was administered to grade 8 students only in 2014, however, future assessments will be administered to students in grades 4 and 12 as well (National Center for Educational Statistics, 2017).

The TEL assessment was administered by computer and was comprised of a discrete item section that took students approximately 25 minutes to complete and
included selected response items and constructed response items. The assessment also included 2 scenario type performance tasks. The longer scenario performance task took students about 25 minutes and the shorter scenario performance tasks took about 15 minutes. Because the nature of technology and engineering is unique, the TEL utilized interactive scenario based tasks where students could use a set of technology tools to solve real-life problems through interaction with multimedia (National Center for Educational Statistics, 2017). In addition to the TEL assessment items, background demographic data was also collected by students, teachers, and schools including gender, race/ethnicity, eligibility for free/reduced lunch, English language learners, and students with disabilities. Additionally, students and schools reported on variables related to their opportunities to learn technology and engineering skills and concepts such as modes of instruction they engage in while at school.

The rapid growth of technology in our world led the National Assessment Governing Board’s curiosity as to whether students were adequately prepared to use such tools to meet a goal or solve a problem, so they worked to develop the NAEP TEL assessment as a way to measure exactly what students know about technology and engineering on a national scale (National Assessment Governing Board, 2013). The collection and analysis of this data can help support improvements in instructional policy and design in order to increase student growth and achievement.

**Chapter Summary**

In order to remain globally competitive in the 21st century, a generation with a matrix of skill competencies including critical thinking, problem solving, collaborating, and working with digital tools is highly sought after in preparing individuals for 21st
century careers (US Department of Education, 2016). Science, Technology, Engineering, and Mathematics (STEM) fields are among the fastest growing 21st century career areas with a projected increase of over one million jobs by the year 2020 (Lockard & Wolf, 2012). Low numbers of graduates pursuing post-secondary STEM degree programs, however, indicate that there will not be a sufficient amount of STEM workers to meet the demands of the growing scientific and technical US economy (Thomasian, 2011). To ensure the US maintains a competitive edge in the global economy, leaders, policy makers, and educators have begun integrating STEM initiatives into K-12 education to help build STEM literacy among students (Hess, Kelly, & Meeks, 2011; Obama, 2011).

With the advancements in understanding how 21st century students learn and a greater understanding of human cognition, constructivist teaching practices are primarily used to facilitate 21st century learning and to build strong STEM competencies (Ertmer & Newby, 2013). Parallel to constructivist learning theories, STEM integration is often student-centered, collaborative, actively engaging, and reflective (Jonassen & Land, 2012; Kelley & Knowles, 2016; Wang, 2013). Instructional practices such as inquiry-based learning, project-based learning, and problem-based learning are often used to help build a strong foundational skill set as well as to promote application of knowledge in real-life challenges and scenarios (Ertmer & Newby, 2013; Lantz, 2009).

A trend in today’s K-12 STEM education programs is to facilitate building 21st century skills while providing a strong foundation of content knowledge (Lantz, 2009; Siemens, 2005; Schlechty, 2008). This is particularly important at the elementary level as younger children are more likely to develop positive perceptions and interest in STEM when immersed in integration early on (Bagiati, Yoon, Evangelou, & Ngambeki, 2010;
A variety of methods have been used to incorporate STEM learning at the elementary level. STEM is sometimes added as a “special” class and attended as part of a weekly rotation (Epstein & Miller, 2011). Often times, due to budgetary and/or scheduling constraints, classroom teachers at the elementary level are responsible for STEM integration (Epstein & Miller, 2011). The government as well as community partners have sponsored STEM programs and activities for elementary students as well (Thomason, 2011). STEM learning opportunities at the middle school level are important as well since students begin to make course path choices at this level (Brody, 2006; Wyss, Heulskaemp, & Siebert, 2012). Although opportunities for students at the elementary and middle levels have expanded in recent years, STEM programs in high school are more prevalent. For example, students can attend specialized STEM schools (Subotnik, Tai, Rickoff, & Aldmarode, 2010), participate in early college preparatory programs and earn college credits while still in high school (Thomason, 2011), take online courses that may not be offered through their school (Thomason, 2011), or participate in after-school clubs or contests (Sahin, 2013). Although schools and organizations in the US have made efforts to increase STEM learning, a more widespread integration is needed and addressing some of the barriers of implementation will be helpful in making progressive instructional design decisions (Daugherty, Carter, & Swagerty, 2014, Thomason, 2011).

Some of the greatest challenges in building STEM literate graduates include the ability for US K-12 schools to obtain and retain qualified instructors (Nadelson, Seifert, & Hendricks, 2015), making a commitment to ensure equitable STEM education for underrepresented populations such as minorities and females (National Research Council,
2011), and building a consistent, defined, rigorous STEM curriculum and set of common assessments (Carr, Bennett, & Strobel, 2012; Rose, 2007; Thomasian, 2011). Despite the challenges, leaders, policy makers, and educators continue to work towards making improvements.

The National Assessment of Educational Progress recently took a large step in a positive direction towards assessing the STEM proficiency of students with the development of the Technology and Engineering Literacy (TEL) assessment published and administered in 2014. The TEL assessment may provide valuable information on students’ technology and engineering literacy that leaders, policy makers, and educators can use to help identify factors associated with greater performance outcomes thus helping provide input for informed decisions to improve the instructional design of STEM learning K-12.
Chapter III

Methodology

The overall purpose of this research study was to examine how technology and engineering instruction relates to students’ technology and engineering literacy achievement in grades K-8. The first objective was to discover how gender, socioeconomic status (SES), and race/ethnicity related to student achievement on the NAEP Technology and Engineering Literacy (TEL) assessment. The second objective of the study was to discover how the frequency of exposure to technology and engineering instruction related to TEL achievement.

The original de-identified pre-existing data used in this study were collected by the National Assessment of Educational Progress (NAEP), the largest nationally representative provider of assessments that evaluate what students in the US know and can do in various subject areas (National Center for Education Statistics, 2017). The first and most current TEL assessment was conducted in 2014. Due to the nature of the technology and engineering content and skills that needed to be assessed, this assessment was administered via a computer rather than a paper and pencil format. Data from this assessment was analyzed through the use of the NAEP Data Explorer, which is accessible online through the Main NAEP database, a web-based data analysis tool provided by the National Center for Education Statistics.

This study used data collected from cognitive and non-cognitive components of the TEL assessment. The cognitive component of the NAEP TEL included scenario based questions, short answer questions, and multiple choice questions designed to measure students’ technology and engineering literacy. The cognitive component
measured student achievement in three interconnected areas of technology and engineering: Technology & Society, Design & Systems, and Information & Communication Technology. The cognitive component additionally measured students’ ability to demonstrate the following three practices across the three interconnected assessment areas: Understanding Technological Principles, Developing Solutions & Achieving Goals, and Communicating & Collaborating. Non-cognitive instruments included questionnaires that were given to both students and schools. These questionnaires helped to provide contextual background information about the students who were assessed and the schools in which they attended. They were designed to give insight into their demographics as well as technology and/or engineering learning opportunities students may have had inside and outside of school (National Center for Education Statistics, 2017).

**Research Questions**

In an effort to achieve the research goals, answers to research questions were sought after. Each research question was answered by analyzing students’ overall performance on the TEL assessment.

The first main research question was: “What is the relationship between gender, socioeconomic status (SES), and race/ethnicity and student achievement on the NAEP TEL assessment?” To answer this question, non-cognitive questions from the NAEP TEL assessment were analyzed along with student achievement from cognitive question data. The independent variables included gender, eligibility for free/reduced price lunch to describe socioeconomic status, and race/ethnicity. These variables are explained more
completely in Table 4. The dependent variable was student achievement on the NAEP TEL assessment.

The second main research question was “What is the relationship between student-perceived frequency of exposure to technology and engineering instruction and student achievement on the NAEP TEL assessment?” To answer this question, non-cognitive questions from the NAEP TEL assessment were analyzed along with student achievement from cognitive question data. The independent variables included eight modes of technology and engineering instruction students may or may not have been exposed to within school courses throughout grades K-8. The eight modes of instruction included learning about/discussing the following: (1) choices people make that affect the environment, (2) inventions changing the way people live, (3) people working together to solve community/world, (4) figuring out why something is not working, (5), using different tools to see which is best, (6) building or testing models to check solutions, (7) crediting others for their ideas, and (8) judging reliability of sources. These instructional modes were explained more completely in Table 4. The dependent variable was student achievement on the NAEP TEL assessment.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Short name</th>
<th>Full title</th>
<th>Values/Measures</th>
</tr>
</thead>
</table>
| IV1      | Gender     | Gender of student as taken from school records | • Male  
• Female |
| IV2      | National School Lunch Program eligibility (SES) | Student eligibility for National School Lunch Program based on school records | • Eligible  
• Not eligible  
• Info not available |
| IV3      | Race/ethnicity using 2011 guidelines, school-reported | School-reported race/ethnicity organized according to OMB guidelines introduced in the 2011 assessment, with an option to choose more than one race and a Native Hawaiian/Other Pacific Islander category that is separate from Asian | • White  
• Black  
• Asian  
• American Indian/Alaska Native  
• Native Hawaiian/Other Pacific Islander  
• Two or more races |
| IV4      | Choices people make that affect environment | In school, how often have you learned about or discussed choices people make that affect the environment? | • Never  
• Rarely  
• Sometimes  
• Often |
| IV5      | Inventions changing the way people live | In school, how often have you learned about or discussed inventions that change the way people live? | • Never  
• Rarely  
• Sometimes  
• Often |
| IV6      | People working together to solve community/world problems | In school, how often have you learned about or discussed the ways people work together to solve problems in their community or the world? | • Never  
• Rarely  
• Sometimes  
• Often |
Table 4 (Continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Short name</th>
<th>Full title</th>
<th>Values</th>
</tr>
</thead>
</table>
| IV7      | Figured out why not working in order to fix it | In school, how often have you ever figured out why something is not working in order to fix it? | • Never  
• Once or twice  
• Three to five times  
• More than five times |
| IV8      | Use different tools to see which are best | In school, how often have you ever used different tools, materials, or machines to see which are best for a given purpose? | • Never  
• Once or twice  
• Three to five times  
• More than five times |
| IV9      | Built/tested model to check solution | In school, how often have you ever built or tested a model to see if it solves a problem? | • Never  
• Once or twice  
• Three to five times  
• More than five times |
| IV10     | Learn to credit others for their ideas | In school, how often do you learn about or discuss how to credit others for their ideas? | • Never  
• Rarely  
• Sometimes  
• Often |
| IV11     | Learn to judge reliability of sources | In school, how often do you learn about or discuss how to judge reliability of sources? | • Never  
• Rarely  
• Sometimes  
• Often |

Note. Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Hypotheses

This study investigated how gender, socioeconomic status (SES), and race/ethnicity relate to students’ technology and engineering literacy achievement. This study further investigated the relationship between frequency of student exposure to technology and engineering instruction and students’ technology and engineering literacy achievement. To address the aforementioned objectives, the following alternative hypotheses were tested:

H_{a1}: There will be significant differences between student achievement on the NAEP TEL assessment based on gender, socioeconomic status as described by eligibility for free/reduced lunch, and race/ethnicity.

H_{a2}: Students’ overall scores will be significantly higher on the NAEP TEL assessment when students perceive their frequency of exposure to technology and engineering instruction to be higher.

Expected Outcomes

Regarding the first hypothesis, it was expected that the male gender group would produce significantly higher achievement scores than females. This prediction was supported by a body of literature pointing to a gender gap in college STEM programs and STEM careers (Fox, Sonnert, & Nikiforova, 2011; Legewie & DiPrete, 2014). Additionally, females continue to be an underrepresented population in STEM fields (Daugherty, 2013). Studies further indicated a SES and race/ethnicity divide identifying an underrepresentation of individuals from lower SES as well as African Americans and Hispanics in STEM fields (Landivar, 2013; Xie, Fang, & Shauman, 2015). As such, it was expected that those populations would have lower achievement on the TEL
assessment. Coinciding with underrepresentation in STEM programs and fields, achievement gaps in science and mathematics exist among genders, SES groups, and race/ethnicities (Morgan, Farkas, Hillmeier, & Maczuga, 2016; Muligan, Hastedt, & McCarroll, 2012; Schneider, Swanson, & Riegle-Crumb, 1998; Department of Education, 2016), further contributing to the predicted outcome of student performance on the TEL assessment.

For the second hypothesis, it was expected that students with more exposure to technology and engineering instruction would have higher achievement; therefore, the more frequently students are exposed to the eight modes of technology and engineering instruction, the higher their achievement will be. Higher curricular standards are related to higher achievement; however, failure to provide STEM exposure starting at an early age can lead to attrition (Bybee & Fuchs, 2006; Han & Buchmann, 2016). To achieve competencies that 21st century learners need to succeed in the workforce, competencies such as critical thinking skills, problem solving skills, ability to collaborate with others, and working with digital tools are beneficial (US Department of Education, 2016). Student-centered active learning strategies such as the 8 identified modes of technology and engineering instruction can be a driving force toward achieving greater success working in a globalized millennium (Bruce-Davis et al., 2014; McKelvey, 2001; Shaw, 2015; Smith, Douglas, & Cox, 2009). Aligned to the Technology and Engineering Literacy Framework, each mode of instruction relates to building student skills in technology and engineering literacy. It was, therefore, predicted that more frequent exposure to technology and engineering instruction would yield more positive achievement results.
Research Design

This study was an exploratory correlational study involving secondary analysis designed to evaluate demographic factors and instructional factors that may relate to technology and engineering literacy achievement among kindergarten through eighth grade students. To address each research question and determine whether the independent variables had statistically significant relationships on student achievement, multiple linear regression analyses were used because the values of the predictive variables allowed for the prediction of future outcomes (Field, 2009).

Pre-existing data from the NAEP TEL’s 2014 assessment were utilized to discover whether there were overall differences in TEL achievement between groups of students categorized by gender, socioeconomic status as determined by eligibility for free/reduced lunch, and race/ethnicity. Additionally, the data was used to discover whether there were overall differences in TEL achievement based on exposure frequency in technology and engineering instruction in grades K-8.

Participants

Participants in this study included a national sample of students in grade 8 who completed the TEL assessment in 2014. While the original data set had a total of 21,500 students from a total of 840 schools (19,100 students from 710 public schools and 2,400 students from 120 private schools), only data from students attending public schools were used in this study.

Instrumentation

The NAEP created the TEL to understand students’ ability to apply technology and engineering skills to real-life problems (National Center for Education Statistics,
The TEL assessment provides data that can help researchers and the public understand what US students in 8th grade know and can do. The data came from both cognitive and the non-cognitive instruments containing survey questions for students and schools as well as scenario-based cognitive assessment sets and discrete item sets. Survey questions from the non-cognitive instruments were administered to both students and school representatives. These survey questions were designed to provide background variables and identify various subgroups that may be helpful to researchers or the public in understanding demographics and educational opportunities (National Assessment Governing Board, 2013). For example, questions relating to gender, race/ethnicity, eligibility for free or reduced-price lunch, courses taken, learning opportunities, and other relevant information to TEL achievement were asked on the non-cognitive student and school questionnaires. An example of a question from the student questionnaire can be seen in Figure 1 below.
The cognitive component of the TEL assessment included computer-based sets of scenario-based performance tasks and discrete items. Two scenario-based assessment sets of varying complexity were presented to students, one longer taking about 25 minutes to complete and one shorter taking about 12 to 15 minutes to complete (National Assessment Governing Board, 2013). The scenarios began by providing a setting for the student, asking a question or stating a goal, and presenting a storyline that prompted the student to engage in attempting to solve the problem or reach the goal (National Assessment Governing Board, 2013). Students then responded to the task by completing what was considered an extended constructed response which was developed and contributed to as the student completed all of the tasks needed to achieve the scenario-based problem or goal (National Assessment Governing Board, 2013). Students used a variety of multimedia resources or tools such as spread-sheets, word-processing programs, or presentation tools, to help solve problems and demonstrate their skills and

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**Figure 1.** Example of questions from Student Questionnaire of 2014 NAEP TEL assessment. Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. How to judge reliability of sources (for example, how a website might be biased or inaccurate)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>b. How to credit others for their ideas (for example, citing sources, using endnotes and footnotes in reports)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
</tbody>
</table>
understanding on extended constructed response tasks (National Assessment Governing Board, 2013).

The scenario-based assessment portion may contribute to a higher level of validity since the scenarios were designed to parallel real-life situations students may face; however, it also reduces the number of independent measures in the assessment (National Assessment Governing Board, 2013). As a result, the NAEP TEL included discrete items that produced independent measures to ensure reliability (National Assessment Governing Board, 2013). This discrete item set included about 10-15 stand-alone selected response items and short constructed response items and was designed to take about 25 minutes to complete. Selected response items, where students select a correct answer, were used in both the scenario-based sets as well as the discrete sets. Short constructed response items were also used in both the discrete item set and the scenario-based set; however, they generally required the student to identify cause and effect relationships, provide examples of something, or explain a certain situation (National Assessment Governing Board, 2013).

Based on the recommendations of the TEL framework, the assessment questions were developed according to specifications created by the National Assessment Governing Board (NAGB) (National Center for Educational Statistics, 2009). The questions are reviewed by a national committee of teachers, subject specialists, and measurement experts to ensure the assessment components were aligned to the framework (National Center for Educational Statistics, 2009). To protect the integrity of the assessment, the assessment was kept confidential and any questions published to the public are then discontinued (National Center for Educational Statistics, 2009). The
NAGB was responsible for ensuring that NAEP assessments were reliable, valid, and free of bias (Ravitch, 2009). In order to ensure validity, the American Institutes for Research were hired to work with the NAEP (NAEP Validity Studies Panel, 2009).

**Variables**

Variables used for this study were extracted from the cognitive instrument and the non-cognitive instrument. These variables included eleven independent variables and one dependent variable.

**Independent Variables**

For research question one, three demographic variables from NAEP TEL were used in this study to describe student groups including gender, socioeconomic status (SES), which is identified as high or low based on whether students qualify for free/reduced price lunches through the National School Lunch Program at school, and race/ethnicity. These variables were taken from the demographic information on the TEL assessment school questionnaire. For research question two, eight variables were taken from the TEL assessment student questionnaire and include specific modes of technology and engineering instruction describing what students have learned, discussed, or done in grades K-8. Each instructional mode included four measures of frequency. The measures of frequency for five of the eight modes include ‘never’, ‘rarely’, ‘sometimes’, and ‘often’. The measures of frequency for three of the eight modes include ‘never’, ‘once or twice’, ‘three to five times’, and ‘more than five times’. For consistency of terminology in this study, the measures ‘once or twice’, ‘three to five times’, and ‘more than five times’ will be referred to as ‘rarely’, ‘sometimes’, and ‘often’, respectively. Each independent variable was summarized in Table 4.
**Dependent Variable**

The dependent variable reflects student performance on the NAEP TEL assessment. Performance was analyzed based on overall achievement on the TEL assessment. This variable was taken from the NAEP TEL cognitive instrument and was measured by analyzing average scale scores of student groups.

**Data Analysis**

To conduct the analysis, data reports were extracted from the NAEP Data Explorer, made available through the Main NAEP database. Regarding research question one, for the first three predictor variables (gender, school lunch eligibility (SES), and race/ethnicity), a multiple linear regression analysis was conducted to model the relationship between multiple predictor variables and the dependent variable (achievement). Average scale scores, \( p \)-values, standardized regression coefficients, \( R \) values, and \( R^2 \) values were calculated and used to analyze the data.

To answer research question two, for each of the eight modes of instruction (IV 4 through IV 11 in Table 4), multiple regression analyses were conducted for the instructional modes to model the relationship between multiple predictor variables (frequency of exposure to the modes of instruction) and the dependent variable (achievement). Average scale scores, \( p \)-values, standardized regression coefficients, \( R \) values, and \( R^2 \) values were calculated and used to analyze the data. As the NAEP Data Explorer tool limits statistical analyses to the selection of only 3 independent variables at a time, instructional modes were grouped according to the assessment area in which they related, to (Technology & Society, Design & Systems, or Information and Communication Technology), to identify the modes of instruction that would most
strongly predict highest scale scores. Steps were first taken to ensure that no pairwise multicollinearity existed (considering that .70 suggests about 50% shared variance, r-squared less than 0.7 would cause minimum adverse impact of multicollinearity in regression analysis). Standardized regression coefficients were compared for the frequency measures of each mode of instruction variable.

For each of the research questions, populations were determined to be different when the difference in population means was statistically significant at an alpha level of 0.05. It is important to note that the NAEP Data Explorer tool automatically used a multi-stage sampling design where students from groups are not considered strictly independent (e.g., where sampled students were located within the same schools and/or schools are located within the same geographic regions) (U.S. Department of Education, 2015). When comparing multiple groups in a single analysis (e.g., when analyzing White student performance versus Black, Hispanic, Asian, etc.) error rates are controlled to ensure that comparisons made using NAEP data are as accurate as possible (U.S. Department of Education, 2009). The NAEP Data Explorer tool also automatically creates dummy variables when conducting a regression analysis using 0-1 contrast coding when testing for significance. The first subgroup of the independent variable is used as the reference group. Except for the reference group, each subgroup is contrasted (code 1) in a separate dummy variable against all other subgroups of the variable (code 0) (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment).
The NAEP Data Tool also automatically adjusts for multiple pairwise comparisons according to the Benjamini-Hochberg false discovery rate (FDR) procedure to increase the statistical power (U.S. Department of Education, 2009). Using the FDR procedure, with an alpha level of 0.05, about 95% of the hypothesis tests rejected the null hypothesis correctly with about 5% rejecting the null hypothesis incorrectly. The FDR procedure is used for multiple comparisons in NAEP data because familywise procedures are considered conservative for large families of comparisons thus making it more suitable than other procedures (Williams, Jones, & Tukey, 1999). Family size is the number of significance tests performed simultaneously. The larger the family size, the more the significance level is reduced in order to reduce the chance that significant differences are due to chance alone (U.S. Department of Education, 2009).

One way the NAEP reports achievement is through estimates of scale score distributions for groups of students. For the 2014 NAEP TEL assessment, the scale was 0-300 points. Scale scores were reported with standard errors and confidence intervals. NAEP scales were produced using the Item Response Theory (IRT) methods to summarize response patterns and analyze students’ correct answers (U.S. Department of Education, 2009.) Scale scores were used in this study to analyze student achievement.

Reports were created in the NAEP Data Explorer through four main steps: select criteria, select variables, edit reports, and build reports. Multiple linear regression analyses were conducted to answer the research questions.

*Select Criteria.* This study used four main criteria to begin building reports including subject, grade, jurisdiction, and measure. The subject criterion was “Technology and Engineering Literacy,” the grade criterion was “Grade 8,” and the
jurisdiction was “National Public” which remained constant throughout all reports. The fourth criterion, measure, included “Overall Technology and Engineering Literacy scale”. This was illustrated in Figures 2 and 3.
Figure 2. Select Criteria. The criteria “Technology and Engineering Literacy” and “Grade 8” will be selected. Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 3. Select Criteria continued. The criteria “Jurisdiction” and “Measure” will be selected. Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.

Select Variables. There were 271 variables available in the Main NAEP dataset, organized into categories and subcategories. Since data for the year 2014 was the only data collected thus far, the year 2014 will be selected by default. Independent variables for this study were selected from the category “Student Factors” and in the subcategory “Modes of Instruction” under the category “Instructional Content and Practice”. Figure 4 provides an example of the variable selection screen.
Figure 4. Select Variables. Independent and control variables will be selected. Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.

Edit Reports. Once variables were selected, the edit report screen was used to create customized reports, set format, and statistic options. Customized reports were created for each variable that was used. Options for editing and customizing reports can be seen in Figures 5 and 6.
Figure 5. Edit Reports. The edit option will be used to set format and statistic options.

Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 6. Edit Report Menu. Statistics options to be used include average scales. Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.

Build Reports. The final step was to build reports. Once built, choices such as Chart, Significance Test, and Regression analysis were available to view. For this study, cross-tabulated multiple regression analyses were used.

The multiple regression analyses were analyzed to determine if the $p$-values were significant indicating that it is probable that the independent variable predicts significant differences in achievement level on the TEL assessment. The $p$-value was determined to be significant when $p < 0.05$ as that is the customary level used when identifying
statistical significance (Krawthel & Anderson, 2001). If significance was identified, the standardized regression coefficients and $R^2$ values for each of the measures were analyzed to determine the magnitude of the effect the measures of frequency have on the dependent variable, student achievement.

**Chapter Summary**

This study explored students’ technology and engineering literacy achievement in relation to technology and engineering instruction in grades K-8. It explored student groups based on gender, SES as determined by student enrollment in the National School Lunch program, and race/ethnicity as they related to student achievement on the TEL. It additionally explored the relationship frequency of exposure to technology and engineering instruction, identified by analyzing the eight specific modes of technology and engineering instruction, had on TEL achievement. The implications of these relationships are presented in the following chapters.
Chapter IV

Results

Introduction

In an effort to examine how technology and engineering instruction in grades K-8 relates to students’ technology and engineering literacy proficiency by using high quality data, this study sought to answer two main research questions. The first research question was to explore the relationship between gender, socioeconomic status (SES), and race/ethnicity and student achievement on the NAEP TEL assessment. A multiple linear regression analysis was conducted to compare male achievement to female achievement, achievement between students of lower SES and students of higher SES (as determined by eligibility for free/reduced lunch), and achievement between each of the seven race categories.

The second research question in this study was to explore the relationship between student-perceived frequency of exposure to technology and engineering instruction and student achievement on the NAEP TEL assessment. Multiple regression analyses were conducted to compare exposure frequency levels of eight technology and engineering instructional modes to student achievement. The eight instructional modes measure frequency by levels referred to as: never, rarely, sometimes, and often.

This chapter will discuss the findings related to the following research hypotheses:

$H_{a1}$: There will be significant differences between student achievement on the NAEP TEL assessment based gender, race/ethnicity, and socioeconomic status as described by eligibility for free/reduced lunch.
Hₐ₂: Students’ overall scores will be significantly higher on the NAEP TEL assessment when students’ perceive their frequency of exposure to technology and engineering modes of instruction to be higher.

**Descriptive Statistics**

Participants in this study included a national sample of 19,100 eighth grade students from 710 public schools who completed the TEL assessment in 2014. Due to the size of the sample used for this study, a power analysis was not necessary and, therefore, not performed. There was a fairly even distribution of male and female students with a 49% female population and a 51% male population. The distribution of socioeconomic status as determined by free/reduced lunch eligibility was fairly even as well with 48% of the population not eligible, 51% of the population eligible, and 1% with that information not recorded. That 1% of the population was eliminated as a measure by the researcher because it did not prove to be significant. The race/ethnicity groups are more varied, as seen in Table 5 below.
Table 5

Race/Ethnicity demographics of sample

<table>
<thead>
<tr>
<th>Race represented in sample</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>53</td>
</tr>
<tr>
<td>Black</td>
<td>17</td>
</tr>
<tr>
<td>Hispanic</td>
<td>22</td>
</tr>
<tr>
<td>Asian</td>
<td>5</td>
</tr>
<tr>
<td>Two or more races</td>
<td>2</td>
</tr>
<tr>
<td>American Indian/Alaska Native</td>
<td>1</td>
</tr>
<tr>
<td>Native Hawaiian/Other Pacific Islander</td>
<td>0</td>
</tr>
</tbody>
</table>

**Inferential Statistics**

**First Research Question**

The first main research question was: “What is the relationship between gender, socioeconomic status (SES), and race/ethnicity and student achievement on the NAEP TEL assessment?” To answer this question, a multiple linear regression analysis was conducted to compare (1) gender and achievement on the NAEP TEL assessment, (2) socioeconomic status and achievement on the NAEP TEL assessment, and (3) race/ethnicity with achievement on the NAEP TEL assessment. This analysis was conducted to determine if these three demographic predictors have significant relationships on student achievement on the 2014 NAEP TEL assessment. The results indicated significant differences between genders, socioeconomic status groups, and between some of the race/ethnicity groups but not all. Full reports can be viewed in Appendix A.
**Gender (IV1)**

The female gender population has a significantly higher mean scale score ($\bar{x} = 150$) compared to that of the male gender population, which has a difference in the average mean scale score of -3 points ($\bar{x} = 147$) (Table 6). The standardized regression coefficient indicates that being a female ($\beta = 0.0474$) more strongly predicts higher scale scores.

**Socioeconomic Status (IV2)**

The findings of the study showed that the higher SES population related to a significantly higher mean scale score ($\bar{x} = 163$) compared to that of the lower SES population which has a difference in the average mean scale score of -28 points ($\bar{x} = 135$) (Table 6). The standardized regression coefficient indicates that being of lower SES ($\beta = 0.3023$) more strongly predicts lower scale scores.

**Race/Ethnicity (IV3)**

Race/ethnicity group differences showed that the White population group yielded significantly higher mean scale score when compared to the Black, Hispanic, and Native Hawaiian/Other Pacific Islander populations (Table 6). No significant differences were found between the White population and the Asian, American Indian/Alaska Native, or two or more races populations.

Both the Black and the Hispanic population groups correlate with a significantly lower mean scale score than all of the other population groups. The standardized regression coefficients indicate that being of the Black minority ($\beta = -0.239$) and being of the Hispanic minority ($\beta = -0.1524$) more strongly predicts lower scale scores.
From the data analyzed from the NAEP TEL assessment, it can be concluded that there are significant differences in technology and engineering literacy achievement based on gender, race/ethnicity, and socioeconomic status. SES and Race/ethnicity have a stronger effect than gender, however. Model statistics, as seen in Table 7, report significance in the model ($p < 0.0001$) and indicate that gender, SES, and race/ethnicity account for 22 percent ($r^2=0.22$) of the variance in the model. Further discussion and conclusions of this finding will be presented in Chapter 5.
Table 6

Gender, SES, and Race/ethnicity Comparison Statistics

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Average scale score</th>
<th>Standard error</th>
<th>Confidence interval</th>
<th>p</th>
<th>Standardized regression coefficient</th>
<th>Difference in average mean scale score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>147</td>
<td>0.7</td>
<td>146-149</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Female</td>
<td>150</td>
<td>0.6</td>
<td>149-151</td>
<td>&lt; 0.0001</td>
<td>0.0474</td>
<td>3</td>
</tr>
<tr>
<td>SES (National school lunch program)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (eligible)</td>
<td>135</td>
<td>0.7</td>
<td>134-137</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>High (not eligible)</td>
<td>163</td>
<td>0.5</td>
<td>162-164</td>
<td>&lt; 0.0001</td>
<td>0.3023</td>
<td>28</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>159</td>
<td>0.8</td>
<td>157-161</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Black</td>
<td>128</td>
<td>1.2</td>
<td>125-130</td>
<td>&lt; 0.0001</td>
<td>-0.2390</td>
<td>-32</td>
</tr>
<tr>
<td>Hispanic</td>
<td>137</td>
<td>0.6</td>
<td>136-138</td>
<td>&lt; 0.0001</td>
<td>-0.1524</td>
<td>-22</td>
</tr>
<tr>
<td>Asian</td>
<td>160</td>
<td>2.0</td>
<td>156-165</td>
<td>0.1146</td>
<td>0.0187</td>
<td>1</td>
</tr>
<tr>
<td>American Indian/Alaska Native</td>
<td>146</td>
<td>4.8</td>
<td>135-156</td>
<td>0.0941</td>
<td>-0.0156</td>
<td>-14</td>
</tr>
<tr>
<td>Native Hawaiian/Other Pacific Islander</td>
<td>142</td>
<td>3.1</td>
<td>136-148</td>
<td>0.0007</td>
<td>-0.0225</td>
<td>-17</td>
</tr>
<tr>
<td>Two or more races</td>
<td>153</td>
<td>2.8</td>
<td>147-159</td>
<td>0.3038</td>
<td>-0.0114</td>
<td>-6</td>
</tr>
</tbody>
</table>

Note. The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant. The symbol * indicates the reference group in the multiple linear regression analysis.
Table 7

*Gender, SES, and Race/ethnicity Regression Model Statistics*

<table>
<thead>
<tr>
<th>Multiple correlation</th>
<th>$R^2$</th>
<th>F ratio</th>
<th>$Df_1$</th>
<th>$Df_2$</th>
<th>Mean square</th>
<th>$p$-value</th>
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<tr>
<td>0.46</td>
<td>0.22</td>
<td>242.93</td>
<td>9</td>
<td>7944.59</td>
<td>101892145.55</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

**Second Research Question**

The second main research question was: “What is the relationship between student-perceived frequency of exposure to technology and engineering instruction and student achievement on the NAEP TEL assessment?” To answer this question, the frequency rates of eight different modes of instruction were analyzed. Multiple linear regression analyses for the modes of instruction were conducted to demonstrate whether differences in achievement were reflected based on frequency of exposure (never, rarely, sometimes, or often) to technology and engineering instruction. Full reports used for analysis can be seen in Appendix B. Table 8 summarizes the eight modes of instruction. Model statistics, as seen in Table 9, report significance for each model ($p < 0.0001$) and indicate that modes of instruction relating to Technology & Society account for 9 percent of variance, modes of instruction relating to Design & Systems account for 6 percent of variance, and modes of instruction relating to Information & Communication Technology account for 12 percent of variance. Further discussion and conclusions of this finding will be presented in Chapter 5.
## Table 8

**Modes of Instruction Comparison Statistics**

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Average scale score</th>
<th>Standard error</th>
<th>Confidence interval</th>
<th>p</th>
<th>Standardized Regression Coefficient</th>
<th>Difference in average mean scale score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choices people make that affect environment (IV 4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>125</td>
<td>1.3</td>
<td>122-127</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>143</td>
<td>0.8</td>
<td>141-144</td>
<td>&lt; 0.0001</td>
<td>0.0886</td>
<td>18</td>
</tr>
<tr>
<td>Sometimes</td>
<td>153</td>
<td>0.6</td>
<td>152-154</td>
<td>&lt; 0.0001</td>
<td>0.1762</td>
<td>28</td>
</tr>
<tr>
<td>Often</td>
<td>153</td>
<td>0.8</td>
<td>152-155</td>
<td>&lt; 0.0001</td>
<td>0.1305</td>
<td>28</td>
</tr>
<tr>
<td>Inventions changing the way people live (IV 5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>123</td>
<td>1.1</td>
<td>121-125</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>140</td>
<td>0.7</td>
<td>139-142</td>
<td>&lt; 0.0001</td>
<td>0.1408</td>
<td>17</td>
</tr>
<tr>
<td>Sometimes</td>
<td>154</td>
<td>0.7</td>
<td>152-155</td>
<td>&lt; 0.0001</td>
<td>0.3509</td>
<td>31</td>
</tr>
<tr>
<td>Often</td>
<td>157</td>
<td>0.8</td>
<td>155-159</td>
<td>&lt; 0.0001</td>
<td>0.3674</td>
<td>34</td>
</tr>
<tr>
<td>People working together to solve community/world problems (IV 6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>132</td>
<td>1.1</td>
<td>130-134</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>147</td>
<td>1.0</td>
<td>145-149</td>
<td>0.0194</td>
<td>0.0368</td>
<td>15</td>
</tr>
<tr>
<td>Sometimes</td>
<td>152</td>
<td>0.6</td>
<td>151-154</td>
<td>0.0375</td>
<td>0.0365</td>
<td>20</td>
</tr>
<tr>
<td>Often</td>
<td>151</td>
<td>0.7</td>
<td>150-153</td>
<td>0.5012</td>
<td>-0.0131</td>
<td>19</td>
</tr>
<tr>
<td>Independent variable</td>
<td>Average scale score</td>
<td>Standard error</td>
<td>Confidence interval</td>
<td>$p$</td>
<td>Standardized Regression Coefficient</td>
<td>Difference in average mean scale score</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>---------------------</td>
<td>---------</td>
<td>--------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Figured out why not working in order to fix it (IV 7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>152</td>
<td>0.6</td>
<td>151-154</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>151</td>
<td>0.8</td>
<td>149-152</td>
<td>&lt; 0.0001</td>
<td>-0.0854</td>
<td>-1</td>
</tr>
<tr>
<td>Sometimes</td>
<td>144</td>
<td>1.0</td>
<td>141-146</td>
<td>&lt; 0.0001</td>
<td>-0.1607</td>
<td>-8</td>
</tr>
<tr>
<td>Often</td>
<td>140</td>
<td>0.9</td>
<td>138-142</td>
<td>&lt; 0.0001</td>
<td>-0.2064</td>
<td>-12</td>
</tr>
<tr>
<td>Use different tools to see which are best (IV 8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>141</td>
<td>1.1</td>
<td>139-143</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>148</td>
<td>0.7</td>
<td>147-150</td>
<td>&lt; 0.0001</td>
<td>0.1031</td>
<td>6</td>
</tr>
<tr>
<td>Sometimes</td>
<td>152</td>
<td>0.7</td>
<td>151-154</td>
<td>&lt; 0.0001</td>
<td>0.1531</td>
<td>11</td>
</tr>
<tr>
<td>Often</td>
<td>154</td>
<td>1.0</td>
<td>152-156</td>
<td>&lt; 0.0001</td>
<td>0.1612</td>
<td>13</td>
</tr>
<tr>
<td>Built/tested model to check solution (IV 9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>143</td>
<td>0.9</td>
<td>142-145</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>149</td>
<td>0.7</td>
<td>147-150</td>
<td>&lt; 0.0001</td>
<td>0.0730</td>
<td>6</td>
</tr>
<tr>
<td>Sometimes</td>
<td>152</td>
<td>0.8</td>
<td>150-153</td>
<td>&lt; 0.0001</td>
<td>0.1089</td>
<td>9</td>
</tr>
<tr>
<td>Often</td>
<td>155</td>
<td>1.1</td>
<td>153-157</td>
<td>&lt; 0.0001</td>
<td>0.1371</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 8 (Continued)

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Average scale score</th>
<th>Standard error</th>
<th>Confidence interval</th>
<th>$p$</th>
<th>Standardized Regression Coefficient</th>
<th>Difference in average mean scale score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn to credit others for their ideas (IV 10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>125</td>
<td>1.1</td>
<td>123-128</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>139</td>
<td>1.0</td>
<td>136-141</td>
<td>&lt; 0.0001</td>
<td>0.1001</td>
<td>14</td>
</tr>
<tr>
<td>Sometimes</td>
<td>148</td>
<td>0.7</td>
<td>147-150</td>
<td>&lt; 0.0001</td>
<td>0.2386</td>
<td>23</td>
</tr>
<tr>
<td>Often</td>
<td>160</td>
<td>0.8</td>
<td>159-162</td>
<td>&lt; 0.0001</td>
<td>0.3795</td>
<td>35</td>
</tr>
<tr>
<td>Learn to judge reliability of sources (IV 11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>131</td>
<td>0.9</td>
<td>130-133</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rarely</td>
<td>144</td>
<td>0.9</td>
<td>143-146</td>
<td>&lt; 0.0001</td>
<td>0.0921</td>
<td>13</td>
</tr>
<tr>
<td>Sometimes</td>
<td>153</td>
<td>0.7</td>
<td>151-154</td>
<td>&lt; 0.0001</td>
<td>0.1641</td>
<td>22</td>
</tr>
<tr>
<td>Often</td>
<td>161</td>
<td>0.9</td>
<td>159-163</td>
<td>&lt; 0.0001</td>
<td>0.1760</td>
<td>30</td>
</tr>
</tbody>
</table>

*Note.* The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant. The symbol * indicates the reference group in the multiple linear regression analysis.
Table 9

Modes of Instruction Regression Model Statistics

<table>
<thead>
<tr>
<th></th>
<th>Multiple correlation</th>
<th>$R^2$</th>
<th>F ratio</th>
<th>$Df_1$</th>
<th>$Df_2$</th>
<th>Mean square</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV 4 – IV 6</td>
<td>0.3</td>
<td>0.09</td>
<td>113.68</td>
<td>9</td>
<td></td>
<td>10164.73</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>IV 7 – IV 9</td>
<td>0.24</td>
<td>0.06</td>
<td>69.95</td>
<td>9</td>
<td></td>
<td>10082.12</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>IV 10 – IV 11</td>
<td>0.34</td>
<td>0.12</td>
<td>169.17</td>
<td>6</td>
<td></td>
<td>7700.15</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
**Choices people make that affect the environment (IV 4)**

Regarding the independent variable 4, learning about/discussing choices people make that affect the environment, students indicating their frequency of exposure as ‘sometimes’ gained significantly higher scale scores than others. Compared to the group indicating their frequency of exposure as ‘never’, those who indicated ‘rarely’, ‘sometimes’, and ‘often’ gained significantly higher scale scores (18, 28, and 29 more points, respectively, at p < 0.001). Although there is no significant difference between those who indicated ‘often’ and ‘sometimes’ when looking at p-values, the standardized regression coefficients of ‘sometimes’ ($\beta = 0.1762$) was higher than ‘often’ ($\beta = 0.1305$). The standardized regression coefficients for ‘rarely’ ($\beta = 0.0886$), ‘sometimes’ ($\beta = 0.1762$), and ‘often’ ($\beta = 0.1305$) show a greater effect with the frequency ‘sometimes’.

**Inventions changing the way people live (IV 5)**

For independent variable 5, learning about/discussing inventions changing the way people live, students indicating their frequency of exposure as ‘often’ gained significantly higher scale scores than others. Compared to the group indicating their frequency of exposure as ‘never’, those who indicated ‘rarely’, ‘sometimes’, and ‘often’ gained significantly higher scale scores (17, 31, 34 more points, respectively, at p < 0.001). As seen by the data, a trend exists with this variable where higher frequency correlates with significantly higher scale scores. The standardized regression coefficients for ‘rarely’, ($\beta = 0.1408$), ‘sometimes’, ($\beta = 0.3509$), and ‘often’, ($\beta = 0.3674$), show the greatest positive effect with a frequency of ‘often’.
**People working together to solve community/world problems (IV 6)**

With independent variable 6, learning about/discussing people working together to solve community/world problems, students indicating their frequency of exposure as ‘sometimes’ gained significantly higher scale scores than others. Compared to the group indicating their frequency of exposure as ‘never’, those who indicated ‘rarely’, ‘sometimes’, and ‘often’ gained significantly higher scale scores (15, 20, 19 more points, respectively, at p < 0.001). Interestingly, when comparing ‘often’ to ‘sometimes’, there is no significant difference in scale scores. The standardized regression coefficients for ‘rarely’, (β = 0.0368), ‘sometimes’, (β = 0.365), and ‘often’, (β = -0.0131), show the greatest positive effect with a frequency of ‘sometimes’.

**Figured out why not working in order to fix it (IV 7)**

For the independent variable 7, figuring out why something is not working in order to fix it, students indicating their frequency of exposure as ‘never’ gained significantly higher scale scores (p < 0.0001) than others. Compared to the group indicating their frequency of exposure as ‘never’, those who indicated ‘rarely’, ‘sometimes’, and ‘often’ had significantly lower scale scores (-1, -8, -12 points respectively). A frequency of ‘never’ relates to higher achievement and the more frequently students were exposed to this mode of instruction, the lower their achievement scores were.

**Use different tools to see which are best (IV 8)**

With the independent variable 8, using different tools to see which are best, students indicating their frequency of exposure as ‘often’ gained significantly higher scale scores than all others. Compared to the group indicating their frequency of
exposure as ‘never’, those who indicated ‘rarely’, ‘sometimes’, and ‘often’ gained
significantly higher scale scores (7, 11, 13 more points, respectively, at p < 0.001). As
seen by the data, a trend exists with this variable where higher frequency correlates with
significantly higher scale scores. The standardized regression coefficients for ‘rarely (β =
0.1031), ‘sometimes (β = 0.1531), and ‘often (β = 0.1612) show the greatest positive
effect with a frequency of ‘often’.

*Built/tested model to check solution (IV 9)*

Regarding the independent variable 9, *participating in building/testing a model to
check a solution*, students indicating their frequency of exposure as ‘often’ gained
significantly higher scale scores than others. Compared to the group indicating their
frequency of exposure as ‘never’, those who indicated ‘rarely’, ‘sometimes’, and ‘often’
gained significantly higher scale scores (6, 9, and 12 more points respectively, at p <
0.001). A trend exists with this variable where higher frequency correlates with
significantly higher scale scores. The standardized regression coefficients for ‘rarely’ (β
= 0.0730), ‘sometimes’ (β = 0.1089), and ‘often’ (β = 0.1371) show the greatest positive
effect with a frequency of ‘often’.

*Learn to credit others for their ideas (IV 10)*

With independent variable 10, *learning about/discussing crediting others for their
ideas*, students indicating their frequency of exposure as ‘often’ gained significantly
higher scale scores than others. Compared to the group indicating their frequency of
exposure as never, those who indicated ‘rarely’, ‘sometimes’, and ‘often’ gained
significantly higher scale scores (14, 23, 35 more points, respectively, at p < 0.001). A
trend that higher frequency correlates with significantly higher scale scores exists with
this variable. The standardized regression coefficients for ‘rarely’, ($\beta = 0.1001$), ‘sometimes’, ($\beta = 0.2386$), and often, ($\beta = 0.3795$) show the greatest positive effect with a frequency of ‘often’.

**Learn to judge reliability of sources (IV 11)**

Regarding independent variable 11, *learning about/discussing judging reliability of sources*, individuals indicating their frequency of exposure as ‘often’ gained significantly higher scale scores than others. Compared to the group indicating their frequency of exposure as ‘never’, those who indicated ‘rarely’, ‘sometimes’, and ‘often’ gained significantly higher scale scores (13, 22, and 30 more points respectively, at $p < 0.001$). As seen by the data, a trend exists with this variable where higher frequency correlates with significantly higher scale scores. The standardized regression coefficients for ‘rarely’ ($\beta = 0.0921$), ‘sometimes’ ($\beta = 0.1641$), and often ($\beta = 0.1760$) show the greatest positive effect with a frequency of ‘often’.

**Chapter Summary**

This chapter presented the statistical analyses of the NAEP TEL assessment data. First, descriptive statistics were presented for the sample population’s gender, race/ethnicity, and socioeconomic status. Inferential statistics to answer each research question were collected from conducting multiple linear regression analyses.

Results indicate that there were overall statistically significant differences between gender groups and socioeconomic status groups in relation to student achievement on the 2014 NAEP TEL assessment. Female and higher SES populations correlated with significantly higher overall average mean scale scores when compared to male and lower SES populations. Additionally, statistically significant differences were
found between some race/ethnicity populations, but not all. The most significant differences were found when comparing the Black population with White and Asian groups, as well as the Hispanic population with White and Asian groups. Although all three variables yield significant differences in achievement, socioeconomic status and race/ethnicity were shown to have the greatest effect.

The study results further indicated that for the majority of technology and engineering modes of instruction, students reporting their frequency of exposure as ‘often’ gained higher student achievement on the NAEP TEL assessment. Only one of the eight technology and engineering instructional modes does not significantly predict higher average scale scores, which was ‘figuring out why something wasn’t working in order to fix it’. Conclusions from the analyses of the data are discussed further in Chapter Five.
Chapter V

Conclusions

Summary of Purpose

The purpose of this study was to examine how technology and engineering instruction relates to students’ technology and engineering literacy achievement in grades K-8 by using high quality data. The first goal of this study was to identify the relationship between gender, socioeconomic status (SES), and race/ethnicity, on students’ Technology and Engineering Literacy (TEL) achievement. The next goal of the study was to determine how the frequency of exposure to technology and engineering instruction in school related to students’ TEL achievement.

Summary of Procedures

Pre-existing de-identified data from the 2014 National Assessment of Educational Progress (NAEP) TEL assessment were used to discover whether there were overall differences in TEL achievement between groups of students categorized by gender, socioeconomic status as determined by eligibility for the National School Lunch Program for free/reduced lunch, and race/ethnicity. Additionally, the data were used to discover whether there were overall differences in TEL achievement based on exposure frequency to technology and engineering instruction in grades K-8.

Data from 19,100 public school students in 8th grade were used. The data utilized came from the cognitive instrument, which included computer-based sets of scenario-based performance tasks and discrete items. Scenario-based assessment sets included a question or goal followed by a storyline that prompted the students to engage in attempting to solve the problem or reach the goal (NAGB, 2010). Students respond to
such tasks by completing extended constructed responses and using a variety of multimedia resources or tools such as spread-sheets, word-processing programs, or presentation tools, to help solve the problems and demonstrate their skills and understanding (NAGB, 2010). Non-cognitive instruments were also used in the form of questionnaires completed by the students and schools. Survey questions on the questionnaires were designed to provide background variables and identify various subgroups that may be helpful to researchers or the public in understanding demographics and educational opportunities (NAGB, 2010). For example, questions relating to gender, race/ethnicity, eligibility for the National School Lunch Program, courses taken, learning opportunities, and other relevant information to TEL achievement were answered. Three variables from the demographic information on the TEL school questionnaire were used to describe student groups including gender, socioeconomic status described as high or low based on whether students qualified for the National School Lunch Program for free/reduced price lunches at school, and race/ethnicity. Eight variables from the TEL student questionnaire were utilized and included specific modes of technology and engineering instruction describing what students have learned, discussed, or done in grades K-8. The NAEP Data Explorer, made available through the Main NAEP database, was then used to create multiple regression analyses to analyze the student data.

**Participant Demographics**

Participants in this study included a national sample of 19,100 eighth grade students from 710 public schools who completed the NAEP TEL assessment in 2014. The gender populations were fairly even (male-female ratio of 51-49). The distribution of socioeconomic status as determined by National School Lunch Program eligibility was
fairly even as well (high-low SES ratio of 48 and 51; note that 1 percent of data was with unidentified SES). The race/ethnicity groups were more varied; with the majority being White (53 percent), Hispanic (22 percent), and Black (17 percent).

**Summary of the Findings and Response to Hypotheses**

The goal of this study was to examine the relationship between technology and engineering instruction and technology and engineering literacy achievement on the NAEP TEL. Factors that could possibly relate to differences in achievement scores were examined including student demographics and frequency of technology and engineering instruction. The student demographics examined in this study included gender, socioeconomic status, and race/ethnicity. The frequency of exposure for eight modes of technology and engineering instruction were examined and measured by the rates ‘never’, ‘rarely’, ‘sometimes’, and ‘often’. The modes of technology and engineering instruction examined included learning about/discussing (1) choices people make that affect the environment, (2) inventions changing the way people live, (3) people working together to solve community/world problems, (4) figuring out why something is not working, (5), using different tools to see which is best, (6) building or testing models to check solutions, (7) crediting others for their ideas, and (8) judging the reliability of sources.

In response to the first hypothesis, there will be significant differences between student achievement on the NAEP TEL assessment based on gender, socioeconomic status as described by eligibility for free/reduced lunch, and race/ethnicity, convincing evidence was found that student achievement differed based on their gender, SES, and race/ethnicity. Therefore, the first hypothesis was accepted.
The female gender population had significantly higher achievement compared to that of the male gender population. This result did confirm the hypothesis predicting significant differences in gender group scores; however, not in the same direction as expected. It was expected that the male gender group would produce significantly higher scale scores than females based on prior research related to gender achievement gaps (Fox, Sonnert, & Nikiforova, 2011; Legewie & DiPrete, 2014). Finding female scale scores significantly higher on the TEL assessment suggests that female ability and achievement in technology and engineering through 8th grade is not a predictor of whether females will continue their STEM education throughout their high school years, college, or careers.

Minority groups including the lower SES and Black and Hispanic race/ethnicity groups yielded significantly lower achievement compared to that of the higher SES, White, and Asian populations. This finding is in line with the body of literature identifying achievement gaps among minorities (Morgan, Farkas, Hillmeier, & Maczuga, 2016; Muligan, Hastedt, & McCarroll, 2012; Schneider, Swanson, & Reigle-Crumb, 1998; Department of Education, 2016). This outcome was also supported by the research identifying an underrepresentation of minority groups in STEM programs and fields (Landivar, 2013; Xie, Fang, & Shauman, 2015).

The second hypothesis asserted that students’ overall scores would be significantly higher on the NAEP TEL assessment when the frequency of exposure to technology and engineering instruction is higher. Convincing evidence was found that more time spent exposed to technology and engineering instruction related to higher achievement as the majority of the instructional modes predicted significantly higher
achievement when students reported frequency of exposure as ‘often’. Subsequently, the second hypothesis was accepted.

Overall, in the majority of technology and engineering modes of instruction, students reporting their exposure as ‘often’ gained higher student achievement on the NAEP TEL assessment. More specifically, with five out of the eight modes of instruction, students indicating their frequency of exposure as ‘often’ gained significantly higher achievement than others. Those five modes included 1) learning about inventions that change the way people live, 2) using different tools to see which are best, 3) building/testing a model to check a solution, 4) learning to credit others for their ideas, and 5) learning to judge the reliability of sources. With two out of eight modes of instruction, students indicating their frequency of exposure as ‘sometimes’ gained significantly higher achievement than others; however, for those modes, ‘often’ also gained significantly high scores with only a slight difference from the rate of ‘sometimes’. Those two modes included: 1), choices people make that affect the environment, and 2) learning to judge the reliability of sources. One mode of instruction, figuring out why something does not work in order to fix it, contributed negatively to achievement influencing lower scores if used in K-8 instruction. This was an unforeseen finding as it was predicted that the more time spent exposed to technology and engineering instruction, the higher student achievement would be. Additionally, this instructional mode seems to relate to hands-on active learning and higher order thinking/problem-solving skills, which are highly sought after 21st century skills (Bell, 2010; McKelvey, 2001; Han & Buchmann, 2016; Pearlman, 2010; Shaw, 2015; US Department of Education, 2016).
Findings Related to Literature and Implications

To ensure that the US remains globally competitive in our increasingly technical and scientific economy, the push toward the goal of helping students strengthen 21st century skills by becoming critical thinkers, persistent problem solvers, and effective collaborators is increasing starting with the youngest students (Bell, 2010; Pearlman, 2012). When comparing the performance of US students to those in other countries upon the turn of the century, the US appeared to be lagging behind in the areas of mathematics and science (Manzo, 2000). To address the need to improve, STEM education has received increased attention from policy makers and educational leaders with the goal of increasing the output of STEM literate graduates ready to pursue STEM degrees and enter the workforce, thus aiding the US in remaining globally competitive (Hess, Kelly, & Meeks, 2011; Obama, 2011).

The current study was designed to expand the existing research on technology and engineering literacy, two areas of STEM, by examining factors related to student achievement on the National Assessment of Educational Progress (NAEP) 2014 Technology and Engineering Literacy (TEL) assessment. The current study further contributed to existing research by analyzing the performance of student groups in addition to frequency of exposure to technology and engineering instruction as factors contributing to technology and engineering literacy achievement. In this section, the findings related to the research questions are discussed and connected with the existing research.

Building STEM competencies which encompass the needed 21st century skills in K-12 students is paramount in helping to develop innovative students and encouraging
their entrance into higher education STEM programs in preparation for future STEM careers. Jobs in STEM fields among the fastest growing occupations predicted to increase by over one million career opportunities by the year 2020 (Lockard & Wolf, 2010). Due to the low number of graduates entering higher education STEM programs, however, there will not be enough qualified STEM workers to meet the demands of the increasingly scientific and technical economy (Thomasian, 2011). In order for the US to remain globally competitive, a commitment to ensuring equitable education and ensuring all students are provided with the opportunity to develop their STEM knowledge and skills is important (Clewell, Anderson, & Thorpe, 1992; Margolis & Fisher, 2002).

**NAEP TEL Assessment and Demographics**

As the 2014 NAEP TEL assessment was the first nationally representative measure of what students know and can do in technology and engineering, this study examined populations identified through the literature as underrepresented in STEM fields including females, those of lower socioeconomic status, and the African American and Hispanic populations. Findings from this research study indicated significant differences between gender groups, SES groups, and some race/ethnicity groups.

Results identified that the female population had significantly higher achievement in technology and engineering literacy than their male counterparts. This finding was unexpected as the literature shows that males continue to outperform females in the sciences (Fox, Sonnert, & Nikiforova, 2011; Legewie & DiPrete, 2014). The NAEP TEL assessment results have shown that females have not only closed the achievement gap, but have significantly outperformed males. Despite these results, there continues to be a loss of STEM interest and confidence in the female population (American Association of
University Women, 2004; American Association of University Women, 2010; US Department of Education 2016; National Center for Education Statistics, 2009). For example, only about 11 percent of engineers were female and although there has been an increase over the last two decades, women still represent a small percentage of physical science careers (American Association of University Women, 2010). In connection with the literature (Thomasian, 2011; Sadker, Sadker, & Zittleman, 2009), the findings from this study point to the conclusion that ability and achievement in females does not predict interest or motivation to continue STEM learning beyond eighth grade. In fact, lack of exposure to engineering topics, lack of interest, lack of confidence are often reported as barriers for females who wish to pursue STEM education and careers; and a lack of female STEM role models often begin at the earliest stages of academia (American Association of University Women, 2004; Andre, Whigam, Henderson, & Chambers, 1999; Daugherty, 2013; Herbert & Stipek, 2005; Sadker, Sadker, & Zittleman, 2009). Low self-confidence is also reported as a factor contributing to females dropping out of or not enrolling in STEM classes as they get older (Gilligan, Goldberger, & Ward, 1994). For example, 81 percent of females reported enjoying mathematics in elementary school, which dropped to 68 percent by middle school, and 61 percent by high school, and when asked whether they felt they were good at mathematics, only 14 percent of females in high school perceived themselves as such (Gilligan et al., 1994). Continued efforts are, thus, needed to reduce such barriers to help build interest, motivation, and confidence in the female population at the earliest stages of academia so that their future participation in STEM fields increases. The implications from this study can serve to support the need for schools to provide more widespread opportunities for females to participate in STEM
programs geared toward the interest of young girls as well as provide opportunities to collaborate with, observe, or read about successful women in the STEM field. Programs such as Middle Schoolers Out to Save the World Project (MSOWP) and Project Lead the Way have shown positive implications for improving student interest, thus coordinating in school and such out of school STEM programs may help increase female interest and motivation (Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013; PLTW, 2017).

Socioeconomic status is strongly associated with STEM interest and achievement as well (Xie, Fang, & Shauman, 2015). A STEM achievement and participation gap exists between students from lower SES families and those from higher SES families (Muligan, Hastedt, & McCarroll, 2012; Schneider, Swanson, & Riegle-Crumb, 1998; National Science Board, 2014). The findings from this research study coincide with the literature indicating that students from a higher SES group are more likely to earn higher achievement in technology and engineering literacy and students with a socioeconomic disadvantage are at a greater risk for cognitive deficits and lower academic achievement (Brooks-Gunn, Duncan, Klebanov, & Sealand, 1993; Sastry & Pebly, 2010; Sharkey & Elwert, 2011). Barriers exist within lower-income area schools that play a role in student achievement as well. While it is not uncommon for schools in all areas to assign teachers to instruct areas outside of their expertise, the inequity of this practice is alarming and schools with a larger population of lower SES students are unfortunately more likely to have teachers who are teaching out of their degree and certification areas and are often underqualified to teach STEM areas (Jerald & Ingersol, 2002). Lower performance in technology and engineering can thus be connected to the underrepresentation of students from a lower SES group in STEM fields.
In addition, minority students including African Americans and Hispanics are largely underrepresented in post-secondary STEM programs and careers (Xie, Fang, & Shauman, 2015). Contributing to similar findings, this research study found both African American (Black) and Hispanic groups scoring significantly lower than other groups such as Whites, Asians, and two or more races. As racial and ethnic minorities such as African Americans or Hispanics often come from financially disadvantaged neighborhoods, racial/ethnic as well as socioeconomic segregation puts them at an academic disadvantage as well (Massey, 1993). Unfortunately, the effects are shown in the numbers of minorities represented in STEM workforce where they comprise only about 13 percent (National Science Foundation, 2014).

As was reported above, females, the lower SES population, and students of the African American and Hispanic race/ethnicity groups have barriers to overcome. All three groups have previously underperformed in the areas of science and mathematics and are also largely underrepresented in current STEM fields; however, females have proven to outperform males on the NAEP TEL. Unless policy makers, educational leaders, and teachers start to break down the barriers, an increasing number of students will be unprepared to succeed in college and career STEM programs (Thomasian, 2011). A focus on targeting currently underrepresented populations in STEM fields could potentially facilitate a growth in the output of graduates interested in and prepared for higher education programs and careers in STEM (Allen-Ramdial & Campbell, 2014). The findings from this research study contribute to the current body of research and indicate a further need to increase STEM education opportunities for students of underrepresented populations including females, the lower SES population, and
minorities such as African Americans and Hispanics. Implications of this study can serve to inform US leaders in charge of allocating funding. If the US is to increase the output of students prepared for STEM careers and remain globally competitive, a focus on providing funding and resources to schools that serve a large population of lower SES and minority students is necessary as SES and race/ethnicity are stronger predictors of achievement than gender. Furthermore, it would be worthwhile for leaders and educators to create more widespread STEM opportunities for females starting at a young age to make greater strides in building their confidence and motivation.

In addition to equitable education and ensuring all students are provided with the opportunity to develop their STEM knowledge and skills, another area of concern for the US includes having unified STEM standards for instruction. As global competition in the 21st century has initiated a trend of economic, technological, and educational growth, the need for highly skilled and knowledgeable college graduates possessing job related skills, leadership qualities, and characteristics of life-long learners is growing (Association of American Colleges, & National Leadership Council, 2007). To facilitate the growth of a larger population prepared to enter the workforce, educators and business leaders can work together to ensure students are leaving high school and college prepared with the skills and mindset to succeed in the modern workforce. Although basic skills are a necessity when entering the work force, employers today desire employees who can be flexible and adapt to the demands of multitasking, working collaboratively with colleagues, identifying possible problems, and having rapid problem solving skills (US Department of Education, 2016). Constructivist styles promote learner-centered classrooms where the teacher facilitates instruction and the learning centers around the
student (Froyd & Simpson, 2008; Jonassen, Marra, & Palmer, 2004). STEM learning environments, for example, can be approached differently but are commonly student-centered, collaborative, actively engaging, and reflective (Jonassen & Land, 2012; Kelley & Knowles, 2016; Wang, Moore, Roehrig, & Park, 2011). Eight technology and engineering instructional modes that coincide with the NAEP Technology and Engineering Framework are all indicative of instructional activities that would be observed in a 21st century constructivist-based STEM learning environment.

**NAEP TEL Assessment and Frequency of Exposure**

On the 2014 NAEP TEL, students were asked to rate the frequency in which they were exposed to the eight different modes of technology and engineering instruction which involved active student-centered learning, collaboration, critical thinking, problem-solving skills, use of leadership skills, and life-long learning skills. Student frequency ratings were compared to their achievement scores on the TEL to determine whether more frequent exposure to technology and engineering instruction resulted in more positive achievement results. The finding that the majority of the instructional modes (seven out of eight) contributed to higher overall achievement with greater exposure is consistent with the literature indicating a need for exposure to STEM skills (Bell, 2010; McKelvey, 2001; Han & Buchmann, 2016; Pearlman, 2010; Shaw, 2015; US Department of Education, 2016). Each of the instructional modes identified as having a positive influence on student TEL achievement can be beneficial for educators to focus on when making improvements to their STEM programs. Incorporating a greater emphasis on these skills can contribute to higher student achievement in technology and
engineering literacy thus providing a greater opportunity for success in college STEM programs and STEM careers.

These results are seemingly consistent with literature pointing to higher curricular standards being related to higher achievement; with failure to provide STEM exposure starting at an early age leading to attrition (Bybee & Fuchs, 2006; Han & Buchmann, 2016). It is worth noting that with the two out of eight modes where scores were higher at a rate of ‘sometimes’, the scores at ‘often’ were only slightly lower. It is possible that students underestimated the frequency with which they were exposed to a specific instructional mode or that they were unsure of the difference between the terms ‘sometimes’ and ‘often’.

One unexpected finding of the study included that the mode of instruction, *figuring out why something does not work in order to fix it*, contributed negatively to achievement influencing lower scores the more frequently used in K-8 instruction. It is important to note that this instructional mode is categorized by the NAEP as “Design & Systems Assessment Areas”. This assessment area addresses how students maintain and use technology tools along with the engineering process behind technology and consists of four sub areas including Nature of Technology, Engineering and Design, Systems Thinking, and Maintenance & Troubleshooting (National Assessment Governing Board, 2010). The sub areas that the aforementioned instructional mode addresses includes Engineering and Design (i.e., creating solutions to problems and meeting needs), Systems Thinking (i.e., a way of thinking about interactions between causes and consequences of various problems and solutions), and Maintenance & Troubleshooting (i.e., ways to prevent technological problems and what students can do when problems arise) (National
Assessment Governing Board, 2010). The inconsistent results related to this mode of instruction could be attributed to an error in the testing design/process. Implications of these results can serve to help NAEP test creators identify a testing area in need of closer analysis. It could also be speculated that students in 8th grade may not yet have the background knowledge needed to benefit from time spent on such Design & Systems tasks, as the literature on constructivism would support; learning is an active process and learners construct knowledge based on prior knowledge (Bruner, 1961). This information can serve to inform school leaders when developing or improving their curriculums.

Another plausible conclusion could relate to individual or geographical characteristics or preferences of the specific student population who spent a greater amount of time on figuring out why something does not work in order to fix it. This population of students may have focused too much time on that one particular instructional mode inhibiting their exposure and growth in the other areas thus limiting their knowledgebase causing them to underperform. It is possible that this group of students prefers more technical hands-on activities and do not have as much confidence in other areas such as Information and Communication Technology or Technology and Society topics/skills. Students exposed in this mode for a greater amount of time are engaging in a form of self-discovery which can often be seen through inquiry-based or project-based learning. An area of weakness that has been identified related to project-based learning is that there can be a disconnect between the content area concepts and the project tasks which can cause projects to lose focus and direction (Blumenfeld et al., 1991; Padaste, Maeots, Leijeh, & Sarapuu, 2012). It is possible that when more time is
spent figuring out why something isn’t working, students are losing their focus on the bigger picture or project they are working on. In order to prevent a disconnect, instructors can align projects to learning goals (Barron et al., 1998). Additionally, a greater focus on restructuring or improving STEM standards and curriculum appears to be needed across the nation K-8.

In addition to the aforementioned individual factors, it may also be speculated that certain environmental factors might have played a role in contributing to the discrepancy. For example, students from less affluent school districts might have had more experiences fixing malfunctioning technology than students in more affluent schools. Subsequently, the students from the less affluent schools may have had less frequent exposure to other modes of technology and engineering instruction.

One of the main contributing factors in the decline of graduates interested in and prepared to enter STEM fields is a breakdown of effective STEM integration and instruction within the US K-12 school system which is failing to prepare students for future careers (Rockland et al., 2010). As a result, there is a growing concern that the US may lose its competitive edge in the global economy. This research study contributes information that can be valuable in improving the US K-12 school system through the identification of instructional modes that are highly predictive of increased student achievement in technology and engineering literacy. The results of this study indicating exposure amount and instructional mode type that will be most effective in helping students achieve higher TEL, can assist educators in better preparing students for future STEM careers.
Research thus far regarding technology and engineering literacy has been extremely limited (Carr, Bennett, & Strobel, 2012; Daugherty, 2013; Thomasian, 2011). Further research into factors that affect technology and engineering literacy is needed. Identifying factors related to increased student achievement is paramount to helping policy makers and educators develop and improve high quality STEM programs and curricula.

**Limitations of the Study**

While this study provided significant implications to the literature, limitations need to be considered for future research studies to overcome. In this section, suggestions are provided on how future studies can overcome these limitations.

This study used pre-existing data from the NAEP. While the NAEP has high quality data, limitations to this study due to the use of NAEP data existed. First, the 2014 Technology and Engineering Literacy Assessment was the first and only assessment given by the NAEP, at the time of this research, to assess what students know and are able to do in the areas of technology and engineering. For this reason, the option of analyzing performance based on multiple testing dates did not exist. Likewise, the assessment had only been administered to students at one grade level, grade 8. As such, it was not possible to make comparisons of student achievement to identify whether differences existed between elementary, middle, and secondary education.

Additionally, because the NAEP TEL assessment data used was so current it provides researchers and the public with valuable information no other assessment has been able to provide; however, statistical limitations exist as the data has not yet been released for export into statistical software. Thus, the researcher was limited to the use of
the NAEP Data Explorer tool to conduct statistical analyses. Within the Data Explorer, the researcher was limited to selecting a maximum of 3 independent variables at a time. For this reason, modes of instruction were chosen that represented each of the 3 assessment areas. When several modes were very similar, a representative mode was selected for use in consultation to experts to avoid repetition while working with the Data Explorer. When identifying how modes of instruction influenced achievement, tests for multicollinearity were used to help increase validity. When the data is released for export, more comprehensive statistical analyses may be run using alternative statistical software.

Another limitation was the use of self-reported data in student questionnaires. The student questionnaire measured the students’ perspectives on frequency in which they were exposed to certain technology and engineering instructional modes. While research supports the importance of analyzing student perceptions as opposed to objective data (Fredricks & McColskey, 2012), self-reported measures are subject to the validity with which the respondent completing the survey truthfully answered the questions.

Finally, the terminology of measures in some of the questions related to exposure frequency of instructional modes. The terms ‘never’, ‘rarely’, ‘sometimes’, and ‘often’ were used to describe how frequently a topic was learned or discussed. These terms are subjective and may be interpreted slightly differently across participants. If not administered properly, self-reported surveys may not result in accurate student reported data (Taylor et al., 2006). Other questions that relate to frequency of instruction provide more clear indications of exposure frequency including, ‘never’, ‘once or twice’, ‘three to
five times’, and ‘more than five times’. Using these terms consistently may provide students with a clearer understanding of frequency.

**Future Research**

A national focus on preparing United States students for global competitiveness began decades ago and as the US moves through the 21st century, students are in need of new competencies including critical thinking, problem solving, collaborating, and working with digital tools (US Department of Education, 2016). Science, Technology, Engineering, and Mathematics (STEM) careers involve the need for such skills and are growing exponentially in the US. There is and will continue to be an eminent need for qualified workers in STEM fields. As such, future research is needed to inform leaders and educators on best practices in STEM education and how the US can better prepare and motivate students to enter STEM fields.

This study identified differences in student achievement based on gender, socioeconomic status, and race/ethnicity. It would be beneficial for future studies to identify whether these trends are the same at the 4th grade level and higher grade level (e.g., 12th) once assessments are administered to those populations. Additionally, identifying whether growth trends can be identified across years would be beneficial once the assessment has been administered for a number of years. It would then be worthwhile to compare the assessment results of underrepresented populations in STEM fields to identify whether increased scores relate to increased representation of populations in STEM fields.

As this study found that females outperformed male students, yet females are an underrepresented population in STEM career fields, a focus on the female population
once the TEL assessment is administered at a higher grade level will be worthwhile. Achievement at the 8th grade level does not appear to correlate with the underrepresentation of females in STEM fields, so their performance on the TEL assessment in a higher grade will be interesting to identify and relate to the small population of females in STEM fields.

Further research on instructional modes that relate to increased student achievement is also needed. When the NAEP TEL data is released for export into statistical software, more comprehensive comparisons are needed among variables. It would be beneficial to compare school-reported responses regarding frequency and modes of instruction to student-reported response data to see if the findings are similar.

**Application of Findings**

School districts, students, and researchers could benefit from the findings in this study on technology and engineering literacy achievement. This study can provide information beneficial to school districts when working to make improvements in their STEM instruction programs. For example, the conclusions in this study can help school districts identify where to best allocate funding, which course requirements may need to be added, or whether curricular changes or enhancements are needed. Likewise, this study can provide positive implications for students because as school districts identify better ways of implementing progressive STEM integration, students will have a greater opportunity to learn skills needed to be successful in college STEM programs and/or the workforce. The findings in this study are also relevant to future researchers as they contribute to the limited body of research that currently exists in the area of technology
and engineering literacy achievement among US K-8 students, thus helping to guide them to other areas in need of study.

Chapter Summary

The purpose of this research was to identify factors related to technology and engineering instruction and student achievement on the National Assessment of Educational Progress (NAEP) Technology and Engineering Literacy (TEL) assessment. Several conclusions were drawn from the results of this study. First, differences do exist between gender groups, socioeconomic status groups, and some race/ethnicity groups. The gender achievement difference, where females performed significantly higher than males, was not expected based on the literature, but serves to inform that achievement at the 8th grade level is not related to whether females will continue their STEM education throughout their high school years, college, or careers. Differences in achievement were also found most significant between SES groups and between some race/ethnicity groups and were consistent with the literature. In addition to differences in the aforementioned groups, achievement differences were found based on exposure frequency of technology and engineering instruction. The majority of instructional modes yielded higher achievement when students were exposed to technology and engineering instructional modes ‘often’ throughout their K-8 education supporting the need for STEM standards and curricula.

Recommendations include the continued research of technology and engineering literacy and factors associated with higher achievement focusing on additional grade levels and years. Additionally, a focus on the female population once the TEL assessment is administered at the higher grade level will be worthwhile as achievement at
the 8th grade level does not appear to correlate with the underrepresentation of females in STEM fields.

It is hoped that the information provided in this study will be used to further examine factors related to technology and engineering literacy and contribute to the literature on developing best practices for STEM in K-8 education. Furthermore, the researcher would like the information for this study to be used in support of creating the most effective learning environment for students, creating greater integration between STEM areas, and facilitating STEM learning opportunities targeting underrepresented population groups.
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doi:10.1016/j.edurev.2015.02.003


doi:10.1108/10748120110424816

doi:10.1145/950566.950596


Appendix A

Research Question 1 Reports

Average scale scores for technology and engineering literacy, grade 8 by gender [GENDER], year and jurisdiction: 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Jurisdiction</th>
<th>Male</th>
<th>Standard Error</th>
<th>Female</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>National public</td>
<td>147</td>
<td>(0.7)</td>
<td>150</td>
<td>(0.6)</td>
</tr>
</tbody>
</table>

NOTE: The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant.

Figure 7. Average scale scores reported by gender (IV 1). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
<table>
<thead>
<tr>
<th>Year</th>
<th>Jurisdiction</th>
<th>Eligible Average scale score</th>
<th>Eligible Standard Error</th>
<th>Not eligible Average scale score</th>
<th>Not eligible Standard Error</th>
<th>Information not available Average scale score</th>
<th>Information not available Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>National public</td>
<td>135</td>
<td>0.7</td>
<td>163</td>
<td>0.5</td>
<td>141</td>
<td>4.0</td>
</tr>
</tbody>
</table>

NOTE: The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant.


*Figure 8.* Average scale scores reported by eligibility for the National School Lunch Program (SES) (IV 2). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
**Figure 9.** Average scale scores reported by race/ethnicity (IV 3). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 10. Multiple linear regression analysis for gender, National School Lunch Program eligibility, and race/ethnicity (IV 1 – IV3). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Appendix B

Research Question 2 Reports

Technology & Society

Figure 11. Average scale scores for choices that people make that affect their environment (IV 4). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 12. Average scale scores for inventions changing the way people live (IV 5). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 13. Average scale scores for people working together to solve community or world problems (IV 6). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.

<table>
<thead>
<tr>
<th>Year</th>
<th>Jurisdiction</th>
<th>Average scale score</th>
<th>Standard Error</th>
<th>Average scale score</th>
<th>Standard Error</th>
<th>Average scale score</th>
<th>Standard Error</th>
<th>Average scale score</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>National public</td>
<td>132</td>
<td>(1.1)</td>
<td>147</td>
<td>(1.0)</td>
<td>152</td>
<td>(0.6)</td>
<td>151</td>
<td>(0.7)</td>
</tr>
</tbody>
</table>

NOTE: The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant.

Figure 14. Multiple linear regression analysis for Technology & Society modes of instruction (IV 4 – IV6). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Design & Systems

Average scale scores for technology and engineering literacy, grade 8 by figured out why not working in order to fix it [D809501], year and jurisdiction: 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Jurisdiction</th>
<th>Never</th>
<th>Standard Error</th>
<th>Once or twice</th>
<th>Never</th>
<th>Standard Error</th>
<th>Three to five times</th>
<th>Never</th>
<th>Standard Error</th>
<th>More than five times</th>
<th>Never</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>National public</td>
<td>152</td>
<td>(0.6)</td>
<td>151</td>
<td>(0.8)</td>
<td>144</td>
<td>(1.0)</td>
<td>140</td>
<td>(0.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant.

*Figure 15.* Average scale scores for figuring out why something is not working in order to fix it (IV 7). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Table: Average scale scores for using different tools to see which are best (IV 8).

<table>
<thead>
<tr>
<th>Year</th>
<th>Jurisdiction</th>
<th>Never Average scale score</th>
<th>Standard Error</th>
<th>Once or twice Average scale score</th>
<th>Standard Error</th>
<th>Three to five times Average scale score</th>
<th>Standard Error</th>
<th>More than five times Average scale score</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>National public</td>
<td>141</td>
<td>(1.1)</td>
<td>148</td>
<td>(0.7)</td>
<td>152</td>
<td>(0.7)</td>
<td>154</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>

NOTE: The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant.


Figure 16. Average scale scores for using different tools to see which are best (IV 8). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Average scale scores for technology and engineering literacy, grade 8 by built/tested model to check solution [D809401], year and jurisdiction: 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Jurisdiction</th>
<th>Never Average scale score</th>
<th>Never Standard Error</th>
<th>Once or twice Average scale score</th>
<th>Once or twice Standard Error</th>
<th>Three to five times Average scale score</th>
<th>Three to five times Standard Error</th>
<th>More than five times Average scale score</th>
<th>More than five times Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>National public</td>
<td>143</td>
<td>(0.9)</td>
<td>149</td>
<td>(0.7)</td>
<td>152</td>
<td>(0.8)</td>
<td>155</td>
<td>(1.1)</td>
</tr>
</tbody>
</table>

NOTE: The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant.


Figure 17. Average scales scores for building/testing a model to check a solution (IV 9). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 18. Multiple linear regression analysis for Design & Systems modes of instruction (IV 7 – IV 9). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 19. Average scale scores for learning to credit others for their ideas (IV 10). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Average scale scores for technology and engineering literacy, grade 8 by learn to judge reliability of sources [D812001], year and jurisdiction: 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Jurisdiction</th>
<th>Average scale score</th>
<th>Standard Error</th>
<th>Average scale score</th>
<th>Standard Error</th>
<th>Average scale score</th>
<th>Standard Error</th>
<th>Average scale score</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>National public</td>
<td>131</td>
<td>(0.9)</td>
<td>144</td>
<td>(0.9)</td>
<td>153</td>
<td>(0.7)</td>
<td>161</td>
<td>(0.9)</td>
</tr>
</tbody>
</table>

NOTE: The NAEP Technology and Engineering Literacy scale ranges from 0 to 300. Some apparent differences between estimates may not be statistically significant.


Figure 20. Average scale scores for learning to judge the reliability of sources (IV 11). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.
Figure 21. Multiple linear regression analysis for Information & Communication Technology modes of instruction (IV 10 – IV11). Adapted from “National Assessment of Educational Progress (NAEP), 2014 Technology and Engineering Literacy Assessment,” by U.S. Department of Education, Institute of Educational Sciences, National Center for Education Statistics.