INFLUENCE OF STEM ENRICHMENT ACTIVITIES ON 3RD -5TH GRADE STUDENTS' ENGINEERING IDENTITY

by

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(Under the Direction of Jay W. Rojewski)

ABSTRACT

This study used a pre-test, post-test quasi-experimental design to examine the influence of an integrative STEM enrichment program on 3rd through 5th grade students' identity in engineering. An *Engineering Adventures* unit was used as a model for integrative STEM education and was delivered through after-school programs at two elementary schools in Georgia. The Engineering Identity Development Scale (EIDS) was used to assess students' engineering identity formation in the areas of academic identity and engineering career awareness. Findings showed the engineering career subscale scores were significantly higher among students who participated in the after-school STEM enrichment program than those that did not. When a replication round of treatment was administered to the original control group, however, that difference was eliminated. The replication round also showed a lasting effect with the original treatment group after having not been exposed to STEM instruction for a period of time.

INDEX WORDS: Integrative STEM, elementary STEM, STEM education, engineering education, engineering identity, SCCT, after-school

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STUDENTS' ENGINEERING IDENTITY

by

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Fulfillment of the Requirements for the Degree

DOCTOR OF EDUCATION

ATHENS, GEORGIA

2016

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May 2016

DEDICATION

This dissertation is dedicated to all of those that have supported me through my personal and professional endeavors- my wife, my kids, my family, and students and colleagues throughout my educational career.

To my wife, Christie, your love and support have helped get me through this process. I love you more than words can tell and can honestly say I would not have gotten through this without you. Many thought we were crazy when we decided to work on our doctoral degrees together, but I'm so proud to have shared the experience with you. I leaned on you for support and encouragement through the entire process and you amazed me every step of the way.

To my two boys, Carson and Nathan, thank-you for dealing with the craziness that came with two parents working full time jobs and going to school as well. I hope you have seen, by our example, how important education is. I am so proud of you both and can't wait to see what you'll accomplish in life!

To my parents, Mom and Jule; Dad and Kathy, I've been blessed to have two sets of parents for most of my life. You have all taught me so much about hard work, dedication, and the pursuit of excellence. I would not be the man I am today without your continued love, support, and guidance. Throughout my life, I have always felt loved by all of you and that love has seen me through good times and bad.

To my little sister, Jamie, I'm proud of the woman you have become and the family you have built. I hope you are proud of me, too. One day, maybe we'll discover why you were taught MLA as an English Ed. major while the rest of the world uses APA.

To my in-laws, Doug and Donna, thank you for sharing your daughter with me and providing support to both of us through this journey. I really appreciate all you do for our family.

To all my other family (Grandma, Grandpa, Granny, Aunts, Uncles, Cousins), I love you all! Each of you have played a role in my life and I wouldn't be where I am now without you. There are simply too many of you to list individually, but please know that I think of you often and cherish the time we get to spend together.

To all the students and colleagues I've crossed paths with in my 17-year career in education, please know that I've learned more from you than you did from me. My interest and passion in Workforce Education has been fueled by the work we have done together and I am excited to continue that work alongside of you. So much of who I am, professionally, has been shaped by all of you and I would be missing a huge group if I didn't dedicate a portion of this work to all my former, current, and future students and colleagues.

ACKNOWLEDGEMENTS

I'd like to thank my committee members (past and present) for all of your support through my dissertation, Dr. Jay Rojewski, Dr. Roger Hill, Dr. Robert Wicklein, and Dr. John Mativo. Most of you have known me more than half my life. I can only imagine what you thought of me as an 18 year-old freshman at UGA. I can remember a few interesting stories from those days, although there are several I hope you don't remember! In all seriousness, your advice and support throughout the process have been invaluable. I couldn't have asked for a better team.

Specifically, to Dr. Jay, you are an amazing motor-cycle riding, blue jeans and Harley t-shirt wearing, top-notch crazy professor! I knew it as an undergrad and it was confirmed during our first research class in the doctoral program (statistics are not that exciting, by the way). I can't imagine what a paper would look like if it wasn't marked upside down and sideways with suggestions for improvement. That means, however, that I never have to worry about making it through. If it is good enough for you, it will be good enough for anyone. You have taught me to think and write like a scholar and I am forever grateful. There is no doubt that I was a better graduate student because of you.

I'd be remised if I didn't acknowledge Dr. Paul Camick, a friend and mentor that played a huge role in my career and studies. Our talks over lunch and your guidance as someone that had been through the process were always helpful. I think of you as a big brother, and want you to know that I appreciated all the guidance you provided. Although we don't work together anymore, I know I can always depend on you when needed.

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CHAPTER 1

INTRODUCTION

Background

Technological innovation has driven economic growth in the United States for over 50 years. The need for workers with STEM (Science, Technology, Engineering, and Math)-related skills to lay the foundation for such technological innovation is heightened in today's global economy (U.S. Congress Joint Economic Committee, 2012). The number of STEM-related jobs in the U.S. is expected to grow 18% by 2018 compared to 9.8% for non-STEM jobs (Langdon, McKittrick, Beede, Khan, & Doms, 2011). The field of engineering and technology education has attempted to address this need for skilled workers throughout its existence and has evolved over time to meet new and emerging workforce demands.

While the need for a workforce knowledgeable in STEM fields is increasing, the ability of the United States educational and workforce development entities to prepare workers to fill available positions has been questioned. Low math and science scores among U.S. students compared to their international counterparts have raised concern in both the American political and educational systems. For example, U.S. 15-year-olds ranked 25th in math and 17th in science on standardized Program for International Student Assessments (U.S. Congress Joint Economic Committee, 2012). The United States has been cited as losing its competitive edge with other countries in science, technology, engineering, and math (Augustine, 2005) while U.S. students' inability to compete globally in these areas have called for improved educational efforts in STEM (Ostler, 2012). The future scientists, engineers, technologists, and mathematicians in the United States appear to be falling behind the global marketplace (Wang, Moore, Roehrig, & Park, 2011).

Fear that the U.S. is losing its competitive advantage in the STEM arena, despite attention and funding being allocated in the area, is prompting an increase focus on STEM education (Sanders, 2012). Political discussions and funding efforts have been applied to all levels of education across every state. As a result, we have seen a rise of STEM experts vying for federal dollars and national attention (Oster, 2012). While much attention has been placed on STEM recently, it is not a new phenomenon. Focus on increasing the number of U.S. students entering STEM fields have been in place for over 40 years, with particular focus on women and minorities. These efforts, however, have not seemed to change the landscape of the U.S. STEM workforce as the deficit of U.S. workers is still prevalent and the problems of inequity and underrepresentation are still widespread (Metcalf, 2010).

As the demand continues to rise in STEM fields, the education community continues to look for ways to encourage students to build STEM-related skills. Engineering and technology education is uniquely positioned to provide the framework for integrative STEM education as it focuses on project-based, real-world design problems that require students to pool knowledge from several subject areas (Sanders, 2012). STEM education research shows promise related to supporting learning across K-12 STEM disciplines as well as the development of STEM-related interest and identity, but a limited research base and mixed results warrant additional studies within the field

(Honey, Pearson, & Schweigruber, 2014). The need for additional integrative STEM-related research, especially as it relates to elementary-aged students, is a driving force for this study.

Integrative STEM Education

Historically, K-12 STEM education in the United States focused on individual subject areas contained within the acronym, especially the areas of science and mathematics. Under that model, beginning in the upper-elementary years and continuing through postsecondary education, school subjects are taught during different portions of the instructional day by different teachers with little to no collaboration between those delivering the content (Honey et al., 2014). Despite recent education reform efforts connected to standards development and national assessments, a silo approach to STEM is still prevalent and independent subject areas are kept in isolation as they are delivered in many K-12 classrooms (Honey et al., 2014). Sanders (2012) pointed out that the STEM acronym is growing in familiarity, but still remains ambiguous, even to those that are involved in the work. STEM as separate subject areas and STEM as an integrative approach have different meanings. STEM as separate subjects refers to the disconnected teaching of science, technology, engineering, and math currently seen in most schools. STEM as an integrative approach changes that focus to address the subject areas collaboratively (Sanders, 2012). Integration could occur in a single course where teachers purposefully address the various subject areas related to a unit of study or project; while in other cases, STEM educators in an integrative model could work together in teams with students assigned to cohorts that share those instructors (Sanders, 2012). The use of the term *integrative* rather than *integrated* in this study is intentional.

The original operational definition of integrative STEM Education developed by Sanders and Wells (2010) read, “Integrative STEM Education refers to technological/engineering design-based learning approaches that intentionally integrate content and process of science and/or mathematics education with content and process of technology and/or engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc.” An intentional focus on the application of engineering design through math and science was a very important component of this study, thus the use of the term *integrative*.

Trends within the literature provide a context in which discussions of integrative STEM education can be held (Bybee, 2010; Honey et al., 2014; Mann, Mann, Strutz, Duncan, & Yoon, 2011; Sanders, 2012; Stohlmann, Moore, & Roehrig, 2012). Mann et al. (2011) argued for an integrative approach by referring to STEM as a meta-discipline that goes beyond grafting technology and engineering layers onto science and math curricula. They viewed integrative STEM as a holistic approach to teaching that is larger than its academic parts. Bybee (2010) connected STEM education to STEM literacy and suggested integration connected to acquiring and applying multi-disciplinary knowledge; understanding the processes of inquiry, design, and analysis; recognizing how STEM shapes our world; and engaging in STEM-related issues as concerned and constructive citizens. When looking at integrative STEM through the lens of an engineering and technology educator, Sanders (2012) defined it as technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with those of technology and engineering education. Technological/engineering design-based learning approaches focus on real-world problems where students work through a systematic process to identify the problem, research its origin and context, develop possible solutions, create a prototype of the best solution, test their design, communicate their work, and continue to improve their solutions through iteration (Mehalik, Doppelt, & Schunn, 2008).

Elementary STEM Education

Elementary STEM education has not gotten as much attention as STEM in upper-grades and college, but that trend is beginning to change (Honey et al., 2014). To address the growing concern over a lack of STEM-prepared youths, elementary school educators are beginning to seek more hands-on approaches to teach abstract concepts in STEM subject areas, while outreach projects are looking to integrate engineering into elementary-level after-school curriculum by teaching practical applications of technical and STEM concepts in everyday life (Epstein & Miller, 2011).

Engineering concepts are being included in educational standards across the nation, even in the younger grades. The Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS), for example, include concepts related to STEM and engineering education through standards addressing higher-order thinking skills, necessity for real-world contextual problems, as well as the inclusion of engineering terminology and processes (Carr, Bennett, & Strobel, 2012).

Curriculum efforts such as Engineering is Elementary (EiE), from the Boston Museum of Science, is also gaining momentum among elementary educators. These units are designed to infuse engineering design and technological literacy into K-5 settings by strategically connecting engineering problems to existing science and literacy standards (Lachapelle, Phadnis, Jocz, & Cunningham, 2012). Developers at the Boston

Museum of Science have released an after-school and summer enrichment version of their engineering curriculum titled Engineering Adventures (EA). Like its in-school counterpart, Engineering Adventures infuses Science, Technology, Engineering, and Math concepts through an integrative engineering unit where students work to solve problems within a real-world context (Higgins, Hertel, Cunningham, & Lachapelle, 2013). Both the EiE and EA curriculum units have shown promising results in increasing awareness and knowledge of engineering careers and concepts in hundreds of programs across the country.

After-school programs and summer camps are regarded as popular ways to connect elementary students to engineering and technology education concepts. Foster and Shiel-Rolle (2011) found that participation in short-term camp style programs can have a positive impact on the perceptions of students with reading proficiency, computing, laboratory skills, and hands-on research. Honey et al. (2014) looked at enrichment programs used to help teach students STEM concepts and found the programs to be effective at changing student perceptions about the academic and career areas.

STEM enrichment programs also provide support in the areas of interest and identity development by providing increased self-efficacy, or confidence, in STEM-related tasks; as well as providing increased student engagement and success during STEM-related projects (Capobianco, French, & Diefes-Dux, 2012). The Afterschool Alliance (2010) reported after-school STEM enrichment programs create strong linkages to the regular school day by engaging and inspiring youth, keeping them on a STEM path, and preparing them for further STEM study through post-secondary schooling. Each positive STEM-related experience, like those discussed by the Afterschool Alliance

(2010), is likely to lead to a stronger sense of identity within that area of study (Lent, Brown, & Hackett, 2002).

Engineering Identity

Engineering identity can be defined as how students see, or identify with, the field of engineering and its value as a career choice (Capobianco et al., 2012). Chubin, May, and Babco (2005) indicated that the image of engineers and engineering as a career choice is a critical issue in the formation of this concept. Vocational identity development (in engineering or any other area) occurs differently for every individual and one cannot point to a specific ideal age for career decision-making. Pre-adolescents, however, are primed for career development as they explore careers during elementary school (Porfeli & Lee, 2012). STEM careers are often not considered during the pre-adolescent years because students are simply not exposed to them. The limited focus on STEM-related careers in elementary schools is significant because such careers can span a multitude of areas with varying contributors to identity development. Further, if educational opportunities can impact how students see themselves academically, as well as how they relate to engineering careers, significant progress can be made towards furthering engineering identity development (Capobianco et al., 2012).

Measuring engineering identity was a task undertaken by Capobianco et al. (2012) through the implementation of their Engineering Identity Development Scale (EIDS). The scale was originally made up of four factors or subscales: academic identity (self-image of who children are as students), school identity (children's attachment to their school), occupational identity (children's self-understandings of an occupation), and engineering aspirations (children's self-goals or objectives of becoming an engineer).

The four factors were aligned to items on a survey given to children and each item was scored on a scale from 1 to 3, with 3 meaning the respondent agreed, 1 meant they disagreed, and 2 indicated the child was not sure (Capobianco et al., 2012). As a result of that study, two (rather than four) factors were found to best describe young children's identity: (a) academic identity and (b) engineering career awareness (Capobianco et al., 2012). Additional research using the EIDS (Capobianco, Yu, & French, 2014; Yoon, Lucietto, Capobianco, Dyehouse, & Diefes-Dux, 2014) has continued to use the two-factor model measuring academic identity and engineering career awareness and scores on EIDS have showed evidence toward students constructing their identities with and in the field of engineering (Capobianco et al., 2012; Capobianco et al., 2014, Yoon et al., 2014).

Purpose

The purpose of this pre-test, post-test quasi-experimental study was to examine the influence of an integrative STEM (Science, Technology, Engineering, and Math) enrichment program on 3rd through 5th grade students' identity in engineering. Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with those of technology and engineering education (Sanders, 2012). An Engineering Adventures unit, developed by the Boston Museum of Science (Higgins et al., 2013), was used as a model for integrative STEM education. The unit was delivered during an after-school program at two elementary schools in Georgia for 45 minutes each day over the course of nine days. The Engineering Identity Development Scale (EIDS) developed by Capobianco et al. (2012) was used to assess students' engineering identity formation in the areas of academic identity and engineering career awareness.

Research Questions

1. What is the engineering identity of elementary students?
2. Are there statistically significant differences between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that are involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness?
3. Are there statistically significant differences between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that are involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness when the original control group receives treatment?

Theoretical Framework

This study was grounded in social cognitive career theory (Lent, Brown, & Hackett, 1994) and builds on prior work in the areas of children's occupational identity development and children's identity development in engineering. The sections below highlight those key theoretical areas and provide evidence of the theories' link to this study.

Social Cognitive Career Theory

Social Cognitive Career Theory (SCCT; Lent et al., 1994) is described as one of the most influential theoretical perspectives in career development and provides a rich explanatory construct for researchers (Blustein, 1999). SCCT was developed to merge common aspects of related developmental theories into an inclusive system that could clarify the process of individual career development (Lent et al., 2002). Among the theories that formed SCCT are: social learning (Mitchell & Krumboltz, 1990), personality typology (Holland, 1985), life-span, life-space (Super, 1990), and general social cognitive theory (Bandura, 1986). SCCT (Lent et al., 1994) put these theories into the context of careers by focusing on career choice being influenced by beliefs one develops through four major sources: (a) personal performance and accomplishments, (b) vicarious learning, (c) social persuasion, and (d) physiological states and reactions.

The key components of SCCT included self-efficacy, outcome expectations, and goals. Self-efficacy refers to the beliefs one has about his/her ability to successfully complete the steps for a given task. Self-efficacy is typically developed from personal performance, learning by example, social interactions, and how one feels in a situation. Outcome expectations are beliefs related to the consequences of performing a specific task. Outcome expectations are formed through past experiences and the perceived results of these experiences. Goals are seen as a driving force for behavior and are defined as decisions to begin a particular activity or pursue a set plan (Lent et al., 1994).

According to SCCT (Lent et al., 1994), as individuals develop, they narrow the scope of career choices based on successes and barriers experienced in connection with activities related to particular careers. Individuals, therefore, form lasting interests in activities when they experience positive outcomes and will avoid activities where experiences or beliefs create negative outcomes. Perceived barriers (e.g. gender, ethnicity, age, socioeconomic status, or family background) may also create negative outcome expectations, even when an individual has had previous success in a particular area (Gibbons, 2004).

Occupational Identity Development

A student's ability to form coherent and realistic occupational identities is essential for successful transition into adulthood (Malanchuk, Messersmith, & Eccles, 2010; Marcia, 1993). Exposure to possible occupational identities is important for students to be able to make a decision about what to explore further, commit to as a part of their identity, or exclude from their career options (Marcia, 2002). Occupational identity development is often cited as occurring during adolescence and early adulthood, but research shows roots of that development beginning in pre-adolescence. During this stage of life, the influence of children's interactions with their environment and the people within those environments help shape who they are (Adragna, 2009). Parents, teachers, and other adults they encounter are included among those that assist in shaping this identity (Malanchuk et al., 2010; Phillips & Pittman, 2003). Occupational identity development of this age group has also been shown to be strongly influenced by interactions at school in areas such as guidance counseling, self-perceived ability, peer influence, and school subjects (Adragna, 2009; Phillips & Pittman, 2003). These factors should be arranged to positively influence student development, but can be experienced in ways that restrict occupational choices and erect barriers to the development of occupational identity. Without support and exposure in place, students may commit to choices their parents have made or follow their peers into areas that are not of particular interest to them, thus limiting the experiences that could provide exposure to occupational areas where they can be successful (Messersmith, Garrett, Davis-Kean, Malanchuk et al., 2010).

Engineering Identity Development

The foundation for engineering identity development was built on Gee's (2000) work outlining identity as a lens for research in education. Gee (2000), defined identity as what is means to be a certain kind of person. He suggested four dimensions of viewing identity and referred to them as interrelated in complex and important ways. Those dimensions explore identity depending on our nature (nature-identity), the positions we occupy in society (institution-identity), the interactions recognized by others (discourse-identity), or by the experiences we have had with certain groups (affinity-identity).

Nature-identity (N-Identity) involves forces outside of the control of individuals or society. Being a red-head or an identical twin are examples of this dimension. Gee (2000) pointed out that these natural occurrences, by themselves, are not enough to form an identity. The identity exists because they are recognized by individuals and given meaning. Because of this, N-Identities always collapse into one of the other dimensions.

Institution-identity (I-Identity) considers the process through which identity is authorized by an outside organization. An individual's profession can be considered an I-Identity in that the employer or governing body of that profession determines what it means to be that type of person. For example, a school teacher is given certain authority and a specific role by the school, board of education, or certifying agency. These institutional authorities form the essence of that identity. According to Gee (2000), I-identities can either be a calling or an imposition. Individuals said to be called towards an occupation, strive to fulfill that identity; while others, like prisoners, see their identity imposed upon them.

Discourse-identity (D-identity) is defined by how others treat, talk about, and interact with an individual. The source of power, in this case is not natural or institutional, but rather given by individuals. Gee (2000) discussed D-identity using the example of a charismatic person. In this example, the label of charismatic is placed on a person by other individuals and does not have meaning without the context of others to interact with it.

Affinity-identity (A-identity) takes into account an individual's association with a certain affinity group. Those groups have allegiance to, access to, and participate in a specific area of interest. An example of *Trekkies* is considered an A-identity group in that those individuals who have a firm interest in Star Trek have a certain identity because of their affiliation with that group. Members in an affinity group have allegiance primarily to a set of common endeavors or practices and, secondarily, to other people (Gee, 2000).

The 4-dimension model presented by Gee (2000) allows researchers to develop the idea that identity can be developed and shaped based on the interaction among and between individuals within the varying identity groups. Identity is not stagnant and is constantly molded by the positions we hold within institutions, how others see us, and which groups we choose to belong to. It is within that context that Capobianco et al. (2012) began to explore engineering identity development among elementary students.

Leaning on Gee's (2000) work, Capobianco et al. (2012) explored engineering identity development as characterized by four dimensions by which children view themselves. Those dimensions included: (a) academic identity, (b) school identity, (c) occupational identity, and (d) engineering aspirations. Academic identity deals with self-beliefs in who children are as students, school identity involves children's affiliation to their school, occupational identity deals with children's self-understandings of an occupation, and engineering aspirations focuses on children's self-goals or aims of becoming an engineer. Data collected in early engineering identity trials showed that school identity did not contribute to the overall engineering identity, so the framework was changed to a two-factor model, including academic identity and a combined version of occupational identity and engineering aspirations, termed *engineering career awareness.* These two-factors of engineering identity were found to not be fixed and able to be developed through various experiences students encounter (Capobianco et al., 2012). Later works (Capobianco et al., 2014; Yoon et al., 2014) also used the two-factor model with success.

Theoretical Links to the Present Study

The theories presented here support the idea that identity among pre-adolescent learners can be developed through interaction with and exposure to different areas of study through unique experiences and involvement within certain groups. Social Cognitive Career Theory (Lent et al., 1994) provides evidence that exposure to and comfort-level with STEM-concepts will strongly influence self-efficacy and willingness to continue pursuing a STEM-focused area of study. Additionally, student success in STEM-related projects also promotes outcome expectations and goal setting outlined as key aspects of SCCT (Lent et al., 1994).

Occupational identity development, specifically within the area of engineering is an area that can be impacted using the knowledge provided by SCCT (Lent et al., 2002). Elementary students' engineering identity has been linked to their academic identity and engineering career awareness (Capobianco et al., 2012). Studies have shown the development of engineering identity can be influenced by introducing integrative STEM instruction during the regular school day by targeting how elementary children see themselves as students, problem solvers, and potential engineers (Capobianco et al., 2012; Capobianco et al. 2014; Yoon et al., 2014). This study further examined the role after-school STEM enrichment programs can have on the engineering identity development of elementary students.

Importance of Study

The emergence of a new economy; characterized by customized manufacturing, competitive global business markets, substantial information handling, outsourcing, and fierce competition; is continually changing the landscape of the U.S. workforce and has sparked ongoing discussion on the role of education in preparing students for the 21st century workplace (Rojewski, 2002). The need for STEM-prepared youth to fill future roles in the STEM arena as well as the struggles current U.S. educational practices are having in meeting that need is well documented (Augustine, 2005; Langdon et al., 2011; Ostler, 2012; U.S. Congress Joint Economic Committee, 2012; Wang et al., 2011).

The role educational systems play in career development and the enhancement of 21st century skills is not limited to preparation students receive in high school. In fact, findings in an ACT (2008) report suggest academic achievement attained by the 8th grade has a larger impact on college and career readiness than anything that happens academically in high school. Magnuson & Starr (2000) argue, “it is never too early” (p.101) to expose children to careers and that the early years are critical for career development where supportive adults should provide interaction-rich experiences; intentionally incorporating concepts of career awareness, exploration, and planning into children’s experiences as they are making decisions about themselves and the world. Despite evidence showing the need for earlier exposure to STEM, limited opportunities are available for elementary students and teachers to engage in the field of study. Few studies have looked at impacts of elementary STEM education on student achievement or attitudes towards STEM-related careers (DeJarnette, 2012). Additionally, literature can be found on STEM outreach programs (Foster & Shiel-Rolle, 2011; Sexton, Watford, & Wade, 2003; Scherer & Well, 2010), but little data on the effectiveness of such programs is available. Data has been primarily focused on high school programs and the ability to recruit students into undergraduate STEM programs (Scherer & Wells, 2010).

This study aims to add to the overall body of knowledge surrounding elementary STEM education, specifically contributing to the areas involved in engineering identity development (Capobianco et al., 2012). Results of this study also adds to the research base discussing effectiveness of after-school programs on the development of students’ identity in engineering and STEM fields.

CHAPTER 2

REVIEW OF LITERATURE

The purpose of this chapter is to provide a critical review and discussion of the literature relevant to the current study. The topics of review include (a) background information regarding engineering and technology education and STEM (Science, Technology, Engineering, and Mathematics) education, specifically at the elementary school level, (b) important conceptual frameworks connected to career and identity development, (c) methods used to measure engineering conceptions and identity, and (d) specific research focused on engineering identity development of young children.

Background

Technological innovation has driven economic growth in the United States for over 50 years and the need for workers with STEM-related skills to lay the foundation for such technological innovation is heightened in today's global economy (U.S. Congress Joint Economic Committee, 2012). This section provides information about the need for a STEM-prepared workforce, historical and current trends of engineering and technology education in elementary schools, the concept of integrative STEM education, a review of STEM programs offered in outside of school time (OST) settings, and information related to the school's role in children's career development.

Need for a STEM-Prepared Workforce

The United States has a long history of concern regarding the need for a STEM-prepared workforce as it has pushed to stay on the forefront of technological advancement and scientific discovery (Brody, 2006). World events, like the Sputnik launch in 1957, have historically added attention to the topic (Brody, 2006). As the world becomes more of a landscape of global competitiveness, strategies aimed at STEM education and STEM career preparation have been thought to be central to the U.S. economy's ability to grow and thrive (Occupational Outlook Handbook, 2013). Employees within the STEM fields are critical; as fifty percent of the nation's sustained economic growth is accounted for in the STEM workforce (Babco, 2004). Currently, however, only five percent of the U.S. workforce is employed within the STEM fields and the number of STEM-related jobs in the U.S. is expected to grow 18% by 2018 compared to 9.8% for non-STEM jobs (Langdon et al., 2011).

While the need for a workforce knowledgeable in STEM fields is increasing, the ability of the United States educational and workforce development entities to prepare workers to fill available positions has been questioned. Low math and science scores among U.S. students compared to their international counterparts have raised concern in both the American political and educational systems. For example, U.S. 15-year-olds rank 25th in math and 17th in science on standardized Program for International Student Assessments (U.S. Congress Joint Economic Committee, 2012). The United States has been cited as losing its competitive edge with other countries in science, technology, engineering, and math (Augustine, 2005) while U.S. students' inability to compete globally in these areas have called for improved educational efforts in STEM (Ostler, 2012). The future scientists, engineers, technologists, and mathematicians in the United States appear to be falling behind the global marketplace (Wang, et al. 2011).

Engineering and Technology Education in Elementary Schools

It is important to examine the historical context, as well as ongoing reform and curriculum changes that have occurred within the discipline of engineering and technology education at the elementary level, when discussing the role that STEM education can play in meeting the demands of a 21st-century STEM workforce, especially when targeting pre-adolescent learners. The information contained in this section provides a historical look at the field of engineering and technology education in elementary school, as well as an overview of the evolution of educational standards in shaping that history.

History. Engineering and technology education at the elementary level has historical roots that can be traced well into the educational foundations of the United States. Bonser and Mossman's (1923) book, *Industrial Arts in Elementary Schools*, is widely cited as the first publication to provide a definition for Industrial Arts (the early term for what is now engineering and technology education). Here, they explained industrial arts education as a subject that studies the changes made by man in the forms of materials to increase their values as well as one that studies the problems of life related to such changes. A large portion of that early work suggested constructive, investigative, or appreciative activities as a way to help young students learn about the subject.

Work expanding from the early efforts of Bonser and Mossman (1923) continued, with increased attention on elementary industrial arts during the time period from the 1950s to 1970s. Miller (1979) cited evidence of increased attention at the elementary level, discussing (a) the establishment of university courses to prepare teachers in the field, (b) publications of books focused on industrial arts teacher preparation, (c) increased employment of industrial arts specialists to work in elementary schools, and (d) establishment of the American Council for Elementary School Industrial Arts (ACESIA).

As industrial arts began to include a focus on technology in the early to mid-1980s, the discipline shifted directions towards technological literacy and changed names to technology education (Lewis & Zuga, 2005). This transition occurred throughout the discipline as the elementary grades also began to include information related to technological literacy (Brusic, 2003). In an effort to stay in line with the discipline transition, ACESIA changed names in 1987, becoming the Technology Education for Children Council (TECC) (Foster, 1999).

The release of the Standards for Technological Literacy in 2000 marked a considerable milestone in the evolution of engineering and technology and had considerable implications for elementary education. Standards were divided by grades; K-2, 3-5, 6-8, and 9-12. One hundred (100) benchmarks were included to outline what all K-5 students should know and be able to do in order to advance their technological literacy (Dugger, 2002). The concept of design was one of the most important content categories within the standards because of its alignment with the field of engineering. Design, in the context of this discussion, refers to a systematic process where solutions to problems are generated, evaluated, and implemented (Dym, Agogino, Eris, Frey, & Leifer, 2005). Four of the 20 standards published, specifically included design (Standard 8 - attributes of design; Standard 9 - engineering design; Standard 10 - troubleshooting, research and design, invention and innovation, and experiment in problem solving; and Standard 11 - the design process) (Lewis & Zuga, 2005).

Leaders from both technology education and engineering education began to find common ground in the years following the release of the Standards for Technological Literacy and shared in their support of the outcomes described in the document (Hill, 2006). The overlap between design within technology education and design as an essential element of engineering helped the field progress toward an engineering focus from 2000 to 2010. Elementary School Technology Education (ESTE) had a history of focusing on design and problem solving throughout its evolution and was well positioned to shift towards an increased focus on engineering (Lewis & Zuga, 2005). This progression of K-12 technology education toward engineering not only strengthened the focus on design within the curriculum, but also helped to elevate the field to higher academic and technological levels while giving a more understandable context of the teaching field for those outside of the profession (Wicklein, 2006).

The American Society for Engineering Education (ASEE) and the International Technology Education Association (ITEA) also showed recognition and support of the inclusion of engineering in the K-12 arena. ASEE did so by forming a K-12 and pre-college engineering division in 2004 and ITEA followed suite in 2010 by adding the word *Engineering* to its title, becoming the International Technology and Engineering Educators Association (ITEEA). These two professional organizations have continued to support the advancement of engineering and technology education through the present day.

Standards. What teachers focus on in K-12 classrooms is closely tied to what material is emphasized in state and national standards. Discussion regarding engineering and technology inclusion at the elementary school must consider this focus to determine what role it can play on meeting standards and improving test scores (Brophy, Klein, Portsmore, & Rogers, 2008). In order to help make these connections, various organizations have produced national standards for science and technology, including those focusing on engineering. Documents produced by the National Academy of Engineering (2005) and the National Research Council (1996) highlighted topics like design and technology, calling for students to learn to classify natural and human-made objects as well as practice and understand the steps of the design process. The National Technology Standards (Kelly & McAnear, 2002) and the Standards for Technological Literacy (STL) (International Technology Educators Association, 2000/2002/2007) also conveyed the importance of the design process and the critical thinking skills connected to the process students use while engaged in it. The National Mathematics Standards from the National Council of Teachers of Mathematics (2000) called for number sense, use of mathematical operations, and quantitative analysis as a way to solve problems. Elementary students use these skills to build competence with graphing, charting, and other visual representation. The science, math, and technology standards discussed here all encourage a progression of standards from basic to more complex as students get older.

More recent connections to engineering and technology education at the elementary level are also evident in emerging standards like the Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS). The CCSS identify cognitive processes and learning strategies students need in order to acquire and retain curriculum content. The key strategies connected to the CCSS include problem formulation, research, interpretation, and precision and accuracy (Conley, 2011). These strategies, along with a focus on higher-order thinking skills, align well with the engineering design process covered within engineering and technology education. Students' ability to read and write technical reports, perform basic and complicated math functions to solve problems, research and prepare presentations, use media tools, and synthesize data are among the outcomes specified in CCSS that are easily correlated with long-standing foci within engineering and technology education (Rust, 2012).

The Next Generation Science Standards (NGSS) include multiple references to engineering and technology as well as their connections to science and society as a whole. This conceptual shift from science as a stand-alone subject to one made up of more interrelationships, strengthens the need for engineering and technology education instruction (Sneider, 2012). The new NGSS represent a departure from traditional science in that they are designed to assess what students can do rather than just what they know (Wysession, 2012). This departure is especially important in the discussion of the delivery of science at the elementary level where, historically, very little hands-on experimentation has been done. Engineering and technology activities can provide teachers an avenue to meet the expectation of applied science through the use of engineering focused project-based learning.

Integrative STEM Education within Engineering and Technology Education

Historically, K-12 STEM education in the United States has focused on the individual subject areas contained within the acronym, especially the areas of science and mathematics. Despite recent educational reform efforts connected to standards development and national assessments, a siloed approach to STEM is still prevalent and independent subject areas are often delivered in isolation in many K-12 classrooms

(Honey et al., 2014). Sanders (2012) pointed out that the STEM acronym is growing in familiarity, but still remains ambiguous, even to those that are involved in the work. STEM as separate subject areas and STEM as an integrative approach have different meanings. This section highlights integrative STEM education and the role that engineering and technology can play in overlaying those subjects rather than isolating them.

Trends within the literature provide a context in which discussions of integrative STEM education can be held (Bybee, 2010; Honey et al., 2014; Mann et al., 2011; Sanders, 2012; Stohlmann et al., 2012). Mann et al. (2011) argued for an integrative approach by referring to STEM as a meta-discipline that goes beyond grafting technology and engineering layers onto science and math curricula by viewing integrative STEM as a holistic approach to teaching that is larger than its academic parts. Bybee (2010) connected STEM education to STEM literacy and suggested integration connected to acquiring and applying multi-disciplinary knowledge; understanding the processes of inquiry, design, and analysis; recognizing how STEM shapes our world; and engaging in STEM-related issues as concerned and constructive citizens. When looking at integrative STEM through the lens of an engineering and technology educator, Sanders (2012) defined it as technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with those of technology and engineering education.

Honey et al. (2014) provided goals aimed at integrative STEM education for both students and educators that can serve as a driving force of educational change. Five goals were outlined for students; (a) STEM literacy, (b) 21st century competencies, (c) STEM workforce readiness, (d) interest and engagement, and (e) ability to make connections among STEM disciplines. Two goals were established for educators; (a) increased STEM content knowledge and (b) increased pedagogical content knowledge.

While it is not common practice in today's elementary schools, engineering and technology education is a natural fit to integrate STEM content as it provides a strong mechanism for incorporating cohesive, level-appropriate engineering experiences for K-12 students. After all, the need for curriculum integration is built from the fact that in the real world, problems are not separated into isolated disciplines (Czerniak, Weber, Sandmann, & Ahern, 1999). This connection to the real world, and student's interest in becoming an active part of it, helps further the argument for engineering and technology as a central component to integrative STEM. Kimmel, Carpinelli, & Rockland (2006) stated that students involved in engineering and technology education programs, in many cases, have already shown interest in the area and may be strong candidates to enter engineering professions in later years. In a report by the National Academy of Engineering (NAE;) Katehi, Pearson, and Feder, (2009) explicitly identified K-12 engineering as a catalyst for integrative STEM education. Koszalka, Wu, and Davidson (2007) highlighted the development of communication skills and teamwork that occurs when students are engaged in engineering design tasks. While a strong case has been made in the literature for including engineering and technology as a central theme of integrative STEM education, more studies related to integrative STEM education are needed (Honey et al., 2014).

Engineering and Technology as an Integrative STEM model in Elementary Schools

While engineering and technology education is not new in the elementary setting, an increased focus on early exposure to engineering has been seen. This can be contributed, in large part, to trends revealing falling student interest in engineering, poor educational preparedness, a lack of diverse representation in the field, and low persistence of engineering students (Dawes & Rasmussen, 2007; Lambert, Diefes-Dux, Beck, Duncan, Oware, & Nemeth, 2007). Trends in research suggest STEM careers are often not considered by pre-adolescent learners because students are simply not exposed to them during their early career exploration experiences. As children experience different career options, they are able to better understand what is available and appropriate for them. STEM careers can span a multitude of areas and engineering provides a wide context for exploration in the field, yet the availability of engineering and technology in elementary schools is not consistent (Capobianco et al., 2012). To address these and other concerns over STEM-prepared youths, educators are beginning to seek more integrative, hands-on approaches in grades K-5 to teach abstract concepts in STEM subject areas, while outreach projects aimed at younger students are looking to integrate engineering into the curriculum. Both efforts attempt to teach practical applications of technical and STEM concepts in everyday life (Epstien & Miller, 2011).

Engineering is considered an effective integrating area of study as it provides hands-on application of math and science concepts and allows typically abstract concepts to be physically demonstrated to students. Design and problem-solving found within the engineering discipline also teaches critical thinking, discovery, and the application of cross-disciplinary tools (Scott, 2009). This connection has given rise to engineering curriculum efforts geared toward younger students within the area of integrative STEM education. Programs like Engineering is Elementary (EiE) from the Boston Museum of Science and LEGO Education are among those with significant implementation at the elementary level. Other efforts, such as Engineering by Design's (EbD) TEEMS and Project Lead the Way's (PLTW) Launch programs have recently emerged. Both EbD and PLTW have been major contributors to the engineering and technology education arena at the middle school and high school level for some time and their emergence at the elementary level will likely become prevalent in upcoming research and review. The following sections discuss efforts from Engineering is Elementary (EiE) and LEGO Education as contributors to integrative STEM education, while introducing the newly implemented PLTW-Launch and EbD TEEMS programs. Additional information is presented on elementary programs delivered in outside-of-school time (OST) settings.

Engineering is Elementary. The Boston Museum of Science has developed 20 Engineering is Elementary (EiE) units designed to infuse engineering design and technological literacy into the K-5 setting by strategically connecting engineering problems to existing science and literacy standards (Lachapelle et al., 2012). Each EiE unit is based on a science topic and revolves around a field of engineering while highlighting a technology from within that field. Students are first introduced to the content through storybooks containing fictitious children from various parts of the world who have encountered problems to be solved. This integrative framework specifically targets the STEM content areas as well as English and Social Studies. The engineering design process is central to the units and students are exposed to each step of the process as the lessons progress (Cunningham, 2009).

The Engineering is Elementary curriculum has undergone extensive design, pilot testing, and revision to ensure its quality and appropriateness within the elementary setting. The EiE team includes a group of researchers and evaluators whose goals are (a) to learn about what students across the country know and believe about engineering, technology, and the engineering design process, (b) to improve the curriculum by observing lessons and gathering feedback from participants, (c) to develop assessment tools to use in evaluating the implementation of EiE, and (d) to evaluate the impact of the curriculum on students' understanding of, attitudes toward, and interest in engineering, technology, and related science topics (Lachapelle, Cunningham, Jocz, Kay, Phadnis, Wertheimer, & Arteaga, 2011).

LEGO Education. LEGO Education offers engineering and technology-related products geared specifically at the K-5 level with Simple Machines (grades K-1), LEGO WeDo (grades 2-3), and LEGO NXT/EV3 (grades 4-5). Additional LEGO materials are available to encourage literacy and writing (LEGO StoryStarter and LEGO BuildToExpress).

The LEGO engineering and robotics materials are frequently used as educational tools to engage students in engineering and technology activities in K-12 classrooms (Chambers, Carbanaro, & Murray, 2007). The easily identifiable bricks and building blocks are especially appealing at the elementary level. Several studies have been conducted focusing on LEGO's inclusion within education and have discussed topics related to math and science concept mastery as well as LEGO's ability to enhance problem solving and critical thinking skills (Castledine & Chalmers, 2011). Chambers et al. (2007) discussed LEGO's ability to increase student understanding of gear mechanics and motion. Portz (2002) demonstrated student understanding of navigation and direction through LEGOs. Norton, McRobbie, and Ginns (2007) connected the use of LEGO robotics to concepts of ratio. Castledine and Chalmers (2011) had students to solve authentic problems using LEGO robotics.

Project Lead the Way – Launch. The Project Lead the Way (PLTW) engineering program began in 1997 with a focus on high school pre-engineering. Since that time, the program has expanded and is now implemented widely in middle schools and high schools across the country (Kelley, Brenner, & Pieper, 2010).

An elementary component of PLTW (Launch) was added to their engineering and technology education offerings in 2013. PLTW Launch is being piloted in 43 schools across the country at the K-5 level. According to a PLTW press release, initial implementation of the program is increasing student knowledge of STEM subject matter and is engaging students who typically are not interested in school (PLTW, 2014).

Engineering by Design TEEMS. The Engineering by Design (EbD) program was developed by the International Technology and Engineering Educators Association (ITEEA), based on the Standards for Technological Literacy, as an integrative K-12 STEM solution for schools (Strimel, 2013). Since its inception, it has evolved to include correlations to the Common Core State Standards (CCSS), Principles and Standards for School Mathematics, the National Science Education Standards, and the Project 2061 Benchmarks for Science Literacy.

Most recently, the EbD TEEMS (Technology, Engineering, Environment, Mathematics, and Science) materials have been developed for use in K-5 classrooms. TEEMS program goals include (a) STEM literacy for all students, (b) personal, social, and global responsibility, and (c) educational transformation (Strimel, 2013). As the TEEMS content begins to gain popularity among elementary schools, more data will be available as to its effectiveness.

STEM Enrichment Activities and Programs

STEM enrichment activities refer to experiences offered to students outside of the regular school day that integrate science, technology, engineering, and math concepts. These activities can be an avenue for encouraging students to develop further interest in STEM fields, as well as a means for strengthening academic and career readiness (Walker, 2012).

STEM enrichment programs provide an atmosphere where students can foster a positive attitude toward academic content by interacting with learning in different ways than are typically employed in regular classroom settings. In an issue brief from the Afterschool Alliance (2010), benefits such as an increased STEM pipeline, fostering of diversity, adding value to after-school programs, increasing expectations of students, and an increase of community involvement through professional mentors and community-based organizations are cited in connection to STEM enrichment programs.

Several studies can be found related to STEM enrichment through camp experiences. A study by Foster and Shiel-Rolle (2011) involved a six day camp at a Bahamian Marine EcoCentre. The goal of the camp was to expose students to science concepts related to the Bahamian environment and economy including the scientific method, geologic and oceanic sciences, biological sciences, and the future of science and technology. Camp participants ranged from age 9-18. Students were given a pre-camp about their motivation for attending the camp and their perceptions of science. 71% of the students agreed that science was an important part of their education in the pre-camp survey as compared to 86% in the post-camp survey. The post-camp survey showed significant increases in student's confidence in science.

Post-secondary institutions are involved in STEM enrichment as well. Virginia Tech, for example, hosts an *Imagination* camp to help promote engineering education. The camp is one week and run two times per year through the College of Engineering. Activities during the camp include (a) chemistry magic show, (b) animated bridge design, (c) egg drop, (d) electric cars, (e) Kodak Take-Apart lab, (f) bubble powered rockets, (g) Lego Mindstorms, and (h) roller coasters. The study focused on how summer camps targeted at middle school students influence their choices in higher education. Twenty-three percent of the camp participants majored in engineering when enrolled in college and more students who had not yet entered college said the camp had an influence on their decisions to pursue engineering or a technical degree. Overall, a correlation was found between camp participation and students decisions for higher education (Sexton et al., 2003). In a program aimed to expose elementary students to hands on experiences in science and engineering, the University of Waterloo runs an extensive summer camp series reaching 2,200 participants in over 115 one-week summer camp sessions. These camps have grown in participation from several hundred to several thousand students, thus emphasizing an interest in STEM education (Scherer & Well, 2010).

While studies such as those listed in this section show that camps and enrichment programs are popular among students in grades K-12, most studies do not identify evidence regarding what can and cannot be considered STEM enrichment. Additionally, quantifiable data is scarce on measuring effectiveness of such programs; especially when targeting young children (Capobianco, Diefes-Dux, & Habashi, 2009). Since limited quantifiable evidence can be found to determine success of enrichment programs, it is important to look to the research to determine what studies have discovered make a quality after-school STEM program. Table 1 provides information shared in several research studies about effective STEM enrichment programs and several commonalities between research findings can be found.

Table 1

Characteristics of Quality STEM Enrichment Programs

Bayer Corporation, (2010)	Freeman, Dorph, & Chi (2009)	Higgins et al. (2013)	Terzian, Anderson-Moore, & Hamilton (2009)
Includes challenging content and curriculum	Staff is knowledge of STEM concepts, pedagogy, and relevance	Use open-ended challenges with multiple solutions	Instructors are experienced and knowledgeable
Occurs in an inquiry learning environment	Includes hands-on, inquiry based learning opportunities	Activities that are fun, exciting, and connected to the real world	Include learning experiences that are fun and grounded in real world context
Includes defined outcomes and assessment	Priority is placed on STEM materials and access to expertise	Opportunities provided to succeed in engineering challenges	Provides hands-on experiences
Includes sustained Commitment/ Community Support	STEM activities are regularly scheduled and encourage consistent attendance	Allow for communication and collaboration	

Among the areas where findings overlap are the importance of hands-on activities situated in the real world (Bayer Corporation, 2010; Freeman, Dorph, & Chi, 2009;

Higgins et al., 2013; and Terzian et al., 2009), the need for knowledgeable instructors (Freeman et al., 2009; Terzian, Moore, & Hamilton, 2009), a focus on challenging content (Bayer Corporation, 2010; Higgins et al., 2013), and a commitment to sustainability and regular delivery (Bayer Corporation, 2010; Freeman et al., 2009). Practitioners should use these common themes to ensure STEM enrichment programs are as effective as possible. Once those characteristics are included in a planned enrichment program, attention should also be given to the areas that were identified, but not necessarily duplicated. Those include a focus on defined outcomes and assessment (Bayer Corporation, 2010), priority on STEM materials (Freeman et al., 2009), opportunity for success in open-ended engineering challenges, and a focus on communication and collaboration (Higgins et al., 2013).

School's Influence on Career Exploration

The role educational systems play in career development and the enhancement of 21st century skills is not limited to the preparation students receive in high school. In fact, findings in an ACT (2008) report suggest that academic achievement attained by the 8th grade has a larger impact on college and career readiness than anything that happens academically in high school. Magnuson and Starr (2000) argued that, "it is never too early" (p.101) to expose children to careers and that the early years are critical for career development. During this development, supportive adults should provide interaction-rich experiences, intentionally incorporating concepts of career awareness, exploration, and planning into children's experiences as they are making decisions about themselves and the world (Magnuson and Starr, 2000). Novakovic and Fouad (2013) suggested that interventions concerning girls' exploration of nontraditional careers be aimed at younger students based on findings that high school females had already developed more gender-traditional career plans and were not as likely to consider other options. In their review of available literature, Wood and Kaszubowski (2008) highlighted a deficit in the research on elementary students' career development, but pointed out that the studies that had been conducted strongly supported the inclusion of career development at that level. They also cited the importance of exposure to a broad range of careers, including those in science and technology, especially in rural communities where direct exposure to such areas are not readily found.

Given the need for a STEM-prepared workforce and evidence of the importance of career preparation, it is necessary to discuss a conceptual framework outlining the extent to which schools should influence student career exploration and areas in which students are exposed. Rojewski (2002) suggested a three-dimensional triangle made up of different philosophical positions (essentialism, pragmatism, and pragmatism with a reconstructivist strand) applicable to career and technical education (CTE). These three positions hold different viewpoints regarding the role of CTE and can be analyzed separately as well as in combination with one another. Work by Sarkees-Wircenski and Scott (1995) served as the basis of the essentialism leg of Rojewski's (2002) triangle. From this philosophical position, the role of CTE is to meet the needs of the labor market by preparing students for specific skills. The pragmatism section of the model was based on the work of Miller (1985, 1996) where CTE was said to meet individual needs for personal fulfillment and life preparation. The third side of the triangle, made up of a reconstructivist strand of pragmatism, was based on the work of Miller and Gregson (1999). This philosophical position viewed the purpose of CTE as one guided to transform work into democratic learning organizations focused on proactive workplace practices. Rojewski's (2002) model could be used as a lens to view STEM education as well in that STEM and CTE are similar in several areas, such as their ability to launch students into a competitive job market through increased student engagement, providing innovative integration of traditional academic courses, and by meeting the needs of employers and the economy as a whole (Drage, 2009).

Recent trends across K-12 education seem to be uniting under a pragmatic reconstructivist view (Rojewski, 2002). This viewpoint can be seen as a balanced compromise between essentialism and pragmatism as it holds true to the democratic ideals of pragmatism by promoting a well-balanced education, focused on the individual, while taking into account the future needs of society from a proactive stand point. Emphasis is not placed on specific vocational preparation, but rather the types of skills that will be needed in the 21st century workplace (e.g., problem-solving, critical thinking, collaboration, life-long learning). The idea of 21st century skills connected to pragmatic reconstructivism provides a link to engineering identity development and validity to its importance in the overall development of children entering this era as students and our future workforce. Elementary students participating in engineering activities receive the benefit of being pushed to higher-order thinking skills and a more global way of viewing the world, but are not necessarily being tracked into an engineering occupation. The early exposure could open doors for some students to enter STEM fields, but those that choose an alternate path will be better equipped to tackle problems they encounter because of the skills they were able to obtain during exposure to engineering activities.

Conceptual Frameworks

Career and identity development are complex constructs that have been the focus of scholarly writing for decades. This study was grounded in social cognitive career theory (Lent et al., 1994) and builds on prior work in the areas of children's occupational identity development and children's identity development in engineering. To understand these concepts, this section reviews relevant literature that provides foundational knowledge of career and identity development, as well as recent literature describing the specific frameworks of this study.

Foundations of Social Cognitive Career Theory

Social Cognitive Career Theory (SCCT; Lent et al., 1994) was developed to merge common aspects of related developmental theories into an inclusive system that could clarify the process of individual career development (Lent et al., 2002). Among the major theories that formed SCCT are: social learning (Mitchell & Krumboltz, 1990), personality typology (Holland, 1985), life-span, life-space (Super, 1990), and general social cognitive theory (Bandura, 1986). The sections below discuss each of those theories individually.

Social learning. Krumboltz (1976) proposed that an individual's career development and career decisions are based on learned behaviors shaped by unique learning experiences. Building on that work, Mitchell and Krumboltz (1990) outlined determinants on career choice including; (a) genetic endowment and special abilities, (b) environmental conditions and events, (c) learning experiences, and (d) task approach skills. Genetic endowment refers to inherited or innate aspect of the person including physical appearance and characteristics like race and gender. Environmental conditions refer to factors outside of one's control such as physical events, technological developments, community influences, and natural disasters. Learning experiences refer to the unique events that result in a career path (either individual experiences or observed ones). Task approach skills refer to performance standards, work habits, and cognitive processes developed as a result of the first three determinants - genetics, environment, and learning experiences (Mitchell & Krumboltz, 1990). Social learning theory suggests that in order to maximize career development, individuals should have equal opportunity to be exposed to a wide variety of learning experiences (Mitchell & Krumboltz, 1990).

Personality typology. Holland's (1985) theory of career development is based on the interaction between work environment and a person's personality type. The six types in Holland's (1985) theory are; (a) realistic, (b) investigative, (c) artistic, (d) social, (e) enterprising, and (f) conventional. Realistic personalities are described as conforming, practical, and thrifty and include work environments with connection to skilled and technical labor. Investigative personalities are described as analytical, intellectual, and precise and include work environments related to scientific and engineering careers. Artistic personalities are thought to be imaginative and creative and include work related to the arts. Social personalities include those that are friendly and understanding and include career areas such as education and social work. Enterprising personalities are energetic, confident, and talkative and include work related to sales, marketing, and management. Finally, conventional personalities are efficient, practical, and structured and include work environments in an office or clerical setting (Herr & Cramer, 1996). Holland (1985) believed that the pairing of similar personality types and work environments would result in a stable vocational choice. Holland's (1985) classification system is used in many career and interest inventories and has been adapted as a career guidance tool in educational settings.

Life-span, life-space. Super's (1990) theory outlined four stages of adult career development; (a) exploration, (b) establishment, (c) maintenance, and (d) disengagement. Super (1990) described the exploration stage as a time when career choices are narrowed and individuals begin an educational or training path to prepare for an occupation. The establishment stage includes the period of time where an individual gains employment and establishes themselves in the world of work. The maintenance stage represents the time period where one attempts to preserve the place he/she has made in their working world. Prior to entering this stage, individuals often evaluate their occupation and may decide to make a change. If this occurs, Super (1990) suggested a period of recycling occurs where the stages of exploration and establishment are revisited.

Two important pieces of Super's (1990) work dealt with the timing of career stages and movement between stages. Super argued that the timing of career stages were more of a function of personality and life circumstances than one of age and also that passage through a stage may not be permanent (Smart & Peterson, 1997). These two features provide support for the idea that career interest can change and is influenced by experiences and exposure (Hall, 1992).

Social cognitive theory. Bandura's (1986) social cognitive theory suggested that learning occurs in a social context with interaction between the individual, environment, and behavior. Further, how these interactions are interpreted will inform and alter subsequent behavior. Bandura (1986) framed part of that discussion in the idea of *human agency*, where individuals are agents proactively engaged in their own development and therefore can make things happen by their actions. He believed that what people think, believe, and feel affects how they behave.

Another important aspect of Bandura's work is the idea that environments and social systems; such as economic conditions, socioeconomic status, and educational structures; do not affect behavior directly. Instead, they affect it to the degree they influence people's aspirations, self-efficacy beliefs, personal standards, and other self-regulated ideals (Pajares, 1997).

Self-efficacy is a concept central to social cognitive theory, as well (Bandura, 1986). Self-efficacy refers to an individual's judgment of his/her capabilities to perform. Pajares (1997) described it as the foundation for human motivation, well-being, and personal accomplishment. Self-efficacy influences the choices one makes and the course of action they pursue. It also determines how much effort an individual will put into an activity, how long they will spend in it, and how resilient they will be in the face of adversity (Pajares, 1997).

Social Cognitive Career Theory

Social Cognitive Career Theory (SCCT; Lent et al., 1994) is an influential theoretical perspective in career development and provides a rich explanatory construct for researchers (Blustein, 1999). SCCT compiled the works explained in the previous section (Mitchell & Krumboltz, 1990; Holland, 1985; Super, 1990; Bandura, 1986) to produce a unique theory of career development.

SCCT includes three variables that are fundamental to career development; (a) self-efficacy, (b) outcome expectations, and (c) goals (Lent et al., 1994). Self-efficacy refers to the beliefs one has about his/her ability to successfully complete the steps for a given task. Self-efficacy is typically developed from personal performance, learning by example, social interactions, and how one feels in a situation (Lent et al., 2002). Outcome expectations are beliefs related to the consequences of performing a specific task and are formed through past experiences and the perceived results of these experiences (Lent et al., 1994). Goals are seen as a driving force for behavior and are defined as decisions to begin a particular activity or pursue a set plan (Lent et al., 1994). Lent et al. (1994) argued that those variables interact to lead to self-regulation and maintenance of behavior.

Interest development and choice models, combined with performance, also work as interlocking concepts within the SCCT framework (Lent et al., 2002). Within the interest development component, career interest is said to come when an individual believes he/she is good at an activity and when the pursuit of that activity is thought to lead to a desired outcome (Lent et al., 2002). Lent et al. (2002) further postulated that a positive feedback loop develops in this circumstance and continues as the individual experiences more and more desired outcomes.

In the choice component of the model, individuals begin to move from confirming interests to identifying career choices related to those interests (Lent et al., 2002). As this occurs; career goals are formed, a plan is put into place and implemented to pursue the goals, and certain performance targets are developed. As individuals reach the performance targets outlined in these plans, more positive results enter the feedback loop and career behavior continues to be molded (Lent et al., 2002).

Within the performance component, an individual's work performance and perseverance towards career-related tasks are highlighted (Lent et al., 2002). As with the interest development and choice components, performance and perseverance provide additional information in one's feedback loop and positive results support additional career development within the field (Lent et al., 2002). SCCT (Lent et al., 1994), therefore, supports the idea that individuals form lasting interests in activities when they experience positive outcomes and will avoid activities where experiences or beliefs create negative outcomes. Perceived barriers (e.g. gender, ethnicity, age, socioeconomic status, or family background) may also create negative outcome expectations, even when an individual has had previous success in a particular area (Gibbons, 2004).

Contextual and personal influences are discussed as a component of SCCT as well (Lent et al., 1994). Contextual influences relate to an individual's perception of the resources provided in an environment. Examples include exposure to career role models, support or discouragement received for participation in certain academic and/or extracurricular activities, cultural and gender role beliefs, and experiences within a career - both positive and negative (Lent et al., 1994). Personal influences may include things like gender, race, ethnicity, physical health, genetic endowment, socioeconomic conditions, etc. (Betz & Schifano, 2000). While these influences are often social and cultural; one's personal beliefs in how they are interpreted will support or discourage career choice (Lent et al., 2000).

Lent et al. (1994) argued that childhood exposure to various vocational options can act as a source of ideas about possible outcomes associated with those careers. That thought provides evidence that exposure to and comfort-level with STEM concepts can influence STEM-specific career choice. Further, SCCT helps make the argument that student exposure to STEM-related projects and experiences can provide encouragement and motivation for students to pursue a STEM-focused area of study and eventually a career within STEM. Current practices at the elementary school level often omit STEM activities and STEM-related career discussions, narrowing the scope of career choices they may explore (Capobianco et al., 2012).

Foundations of Identity

Before discussing the specific concept of engineering identity development, it is important to review the relevant identity theories to this study. The information in this section provides an overview of the overall construct of identity.

Identity. Erikson (1968) described identity as involving a subjective feeling of self-sameness and continuity over time that can only be understood from a variety of angles. Marcia (1993, 2002) argued that identity could be viewed as a structure of beliefs, abilities and past experiences regarding the self. Josselson (1996) further described identity as a multifaceted construct, describing a combination of roles, beliefs, and values working together to form the whole. Gee (2000) defined identity as what is means to be a certain kind of person and described four dimensions of identity that are complexly interrelated. Kroger's (2007) work is based on identity being described as who one is and how biology, psychology and society interact to produce a subjective sense of self.

Eriksonian Foundation. Erikson (1968) is commonly cited for providing the foundation for identity development research and scholarly writing. He believed identity helps individuals to make sense of, and to find their place in the world. As a developmental psychologist, Erikson outlined eight stages of psychosocial development through which a healthy developing human should pass from infancy to late adulthood (see Table 2). Of particular importance in the discussion of interest and identity is Erikson's fourth and fifth stages of development.

Table 2

Erikson's 8 Stages of Psychosocial Development

Age *(Approximate)*	Conflict	Resolution or "Virtue"	Culmination in old age
Infancy (0-1 year)	Basic trust vs. mistrust	Hope	Appreciation of interdependence and relatedness
Early childhood (1-3 years)	Autonomy vs. shame	Will	Acceptance of the cycle of life, from integration to disintegration
Play age (3-6 years)	Initiative vs. guilt	Purpose	Humor; empathy; resilience
School age (6-12 years)	Industry vs. inferiority	Competence	Humility; acceptance of the course of one's life and unfulfilled hopes
Adolescence (12-19 years)	Identity vs. confusion	Fidelity	Sense of complexity of life; merging of sensory, logical, and aesthetic perception
Early adulthood (20-25 years)	Intimacy vs. isolation	Love	Sense of the complexity of relationships; value of tenderness and loving freely
Adulthood (26-64 years)	Generativity vs. stagnation	Care	Caritas, caring for others, and agape, empathy and concern
Old age (65-death)	Integrity vs. despair	Wisdom	Existential identity; a sense of integrity strong enough to withstand physical disintegration

Stage four of Erikson's model involves children developing a sense of industry, where they begin to master skills, both physically and socially. During this period in life, children begin to attach themselves to teachers and other adults, wanting to watch and imitate people representing occupations which they can grasp (Erikson, 1968).

Development of self-confidence is critical in stage four, as well. Children whose sense of industry is not developed in a healthy manner will likely feel inferior and feel as though they will never be as good as others. This lack of self-confidence can lead to individuals consolidating their identity to specific technical and occupational capacities stereotyped to certain groups; designated by birth, by choice, or by giftedness (Erikson, 1968).

Stage five of Erikson's model involves identity development and role confusion. In this stage, individuals reconcile the person they have to become and the person society expects them to be. It is in this phase that the role one will play in adulthood become increasingly more important. The concept of identity crisis is prevalent in this stage. Erikson did not consider the term crisis, in this context as a sense of impending disaster, but rather a key turning point in one's identity development where earlier interests, talents, and values align with suitable social outlets such as careers (Kroger, 2007).

Marcia's Identity Status Model. Marcia (1993, 2002) focused largely on Erikson's (1968) fifth stage of identity development, which deals with identity development and role confusion. Marcia developed an identity status model related to occupations that supports and expands on the aspects that drive ego resolutions. His model identified four states of adolescents; (a) foreclosure, (b) moratorium, (c) identity achievement, and (d) identity diffusion (Marcia, 2002). Young people in the foreclosure state follow a path chosen for them by their parents or other authority figures without questioning or exploring other options (Marcia, 2002). Those individuals in moratorium are neither attached to parental aspirations nor sure of whom they will become. These young people are considered to be in a state of exploration, attempting to determine what future most appeals to them. Those in a state of identity achievement have made commitments to viable representations of their future selves and decide which paths to pursue and which ones to avoid. This phase usually follows a period of exploration so that the commitment is based on a solid foundation that has been tested for fit. Finally, Marcia's state of diffusion is noted by individuals unable or unwilling to make commitments. These students are considered to be aimlessly wandering along their path toward identity.

Achieving an identity status is based on the level of exploration an adolescent engaged in before committing or diffusing toward a stated identity. This process is likely to occur around any of the major life areas in which young people struggle to develop an identity, such as; (a) occupational, (b) religious, (c) political, (d) social, (e) interpersonal, and (f) sexual identities (Marcia, 2002).

Gee's Four Dimensions of Identity. In an effort to outline identity as a lens for research in education, Gee (2000), defined identity as what is means to be a certain kind of person. He suggested four dimensions of viewing identity and referred to them as interrelated in complex and important ways. Those dimensions explore identity depending on our nature (nature-identity), the position we occupy in society (institution-identity), the interactions recognized by others (discourse-identity), or by the experiences we have had with certain groups (affinity-identity).

Nature-identity (N-Identity) involves forces outside of the control of individuals or society. Being a red-head or an identical twin are examples of this dimension. Gee (2000) pointed out that these natural occurrences, by themselves, are not enough to form an identity. Identity exists because it is recognized by individuals and given some meaning. Because of this, N-Identities always collapse into one of the other dimensions.

Institution-identity (I-Identity) considers the process through which identity is authorized by an outside organization. An individual's profession can be considered an I-Identity in that the employer or governing body of that profession determines what it means to be that type of person. For example, a school teacher is given certain authority and a specific role by the school, board of education, or certifying agency. These institutional authorities form the essence of that identity. According to Gee (2000), I-identities can either be a "calling" or an "imposition." Some individuals, like those called to an occupation, strive to fulfill that identity; while others, like prisoners, see their identity imposed upon them.

Discourse-identity (D-identity) is defined by how others treat, talk about, and interact with an individual. The source of power, in this case, is not natural or institutional, but rather given by individuals. Gee (2000) discussed D-identity using an example related to a charismatic person. One's identity as "charismatic" is placed on them by other individuals. It does not have meaning without the context of others to interact with it and it is not forced.

Affinity-identity (A-identity) takes into account an individual's association with a certain affinity group. Those groups have allegiance to, access to, and participate in a specific area of interest. Gee (2000) used the example of "Trekkies" as an A-identity group of individuals who have a firm interest in Star Trek. This identity is assigned because of their affiliation with that area of interest. Members in an affinity group have allegiance primarily to a set of common endeavors or practices and secondarily to other people (Gee, 2000).

The 4-dimension model presented by Gee (2000) allows researchers to develop the idea that identity can be developed and shaped based on the interaction among and between individuals within the varying identity groups. Identity is not stagnant and is constantly molded by the positions we hold within institutions, how others see us, and the groups to which we choose to belong. Gee (2000) stressed that identity is best understood as a compilation of all four identity dimensions.

Occupational Identity Development

From a developmental standpoint, a students' ability to form coherent and realistic occupational identities is essential for successful transition into adulthood (Malanchuk et al., 2010; Marcia, 1993). Exposure to possible occupational identities is important for students to be able to make a decision about what to explore further, commit to as a part of their identity, or exclude from their career options (Marcia, 2002).

Occupational identity development often occurs during adolescence and early adulthood, but research shows roots of that development begin in pre-adolescence. During pre-adolescence, the influence of children's interactions with their environment and the people within those environments help shape who they are (Adragna, 2009). Parents, teachers, and other adults they encounter are included among those that assist in shaping this identity (Malanchuk et al., 2010; Phillips & Pittman, 2003). Occupational identity development of pre-adolescent children has also been shown to be strongly influenced by interactions at school in areas such as guidance counseling, self-perceived ability, peer influence, and school subjects (Adragna, 2009; Phillips & Pittman, 2003). These factors should be arranged to positively influence student development, but can be experienced in ways that restrict occupational choices and erect barriers to the development of occupational identity. Without support and exposure in place, students may commit to choices their parents have made or follow their peers into areas that are not of particular interest to them, thus limiting the experiences that could provide exposure to occupational areas where they can be successful (Messersmith et al., 2008).

Engineering Identity Development

Concerns regarding equity and access to engineering experiences and a lack of diversity within the STEM pipeline have prompted work connected to engineering identity development focused on under-represented groups within STEM fields. Calabrese-Barton, Kang, Tan, O'Neill, and Brecklin (2012) documented the disengagement from STEM activities in African American girls because they felt as though they had to choose friendship over extracurricular science opportunities. Brown (2006) also found signs of cultural conflicts causing students to not identify with science and related activities. Gender has also been cited in the research as an influencing factor that can cause students to steer clear of STEM subjects (Capobianco, 2006; Carlone, Haun-Frank, & Webb, 2011).

Identity development intervention has shown positive results in reversing cultural disconnect within STEM fields, as well as problems generated by racial and gender stereotyping. Rahm (2008) suggested that students show more success in STEM-related activities when they are able to choose projects that integrate their own histories and cultural backgrounds and that programs aimed at their local community with flexibility to define and develop personalized projects will aid in STEM-related identity development. Similar findings were made in Calabrese-Barton and Tan's (2010) study involving youth researching the urban heat island effect. Students engaged the community as "community science experts" and were acknowledged by adults as legitimate contributors to the project. The study reported this culturally connected, community-based project effectively supported engineering identity development and student learning by increasing student self-efficacy in STEM and provide a context where the content was meaningful and personal.

Honey et al. (2014) suggested that most of the work surrounding engineering identity research has been qualitative and measures of engineering interest and identity need further attention. In an attempt to quantify engineering identity development, Capobianco et al. (2012) developed their Engineering Identity Development Scale, specifically for pre-adolescent learners. They originally framed engineering identity into four areas; (a) academic identity, (b) school identity, (c) occupational identity, and (d) engineering aspirations. Academic identity deals with self-beliefs in who children are as students, school identity involves children's affiliation to their school, occupational identity deals with children's self-understandings of an occupation, and engineering aspirations focuses on children's self-goals or aims of becoming an engineer. Data collected in their early engineering identity trials showed that school identity did not contribute to overall engineering identity, so the framework was changed to include academic identity and a combined version of occupational identity and engineering aspirations, termed *engineering career awareness*. Capobianco et al. (2012) refined their Engineering Identity Development Scale (EIDS) using this framework and have suggested further study using the instrument.

Measurement

Research focused specifically on measuring engineering identity among young learners is primarily a result of Capobianco's (2006) work related to gender, engineering, and identity formation; and the work connected to the Engineering Identity Development Scale (EIDS; Capobianco et al., 2009; Capobianco et al., 2012). This section overviews the foundational construct and formation of the instrumentation used in the present study.

Foundations of EIDS – Capobianco (2006)

In a study involving an intervention designed to increase retention of underrepresented students in engineering, Capobianco (2006) explored personal and professional identity constructs of college women throughout their undergraduate engineering programs. A qualitative case study approach was used and data was collected through interviews, WebCT interactions, and student work on modeling (Capobianco, 2006).

As a result of the study, Capobianco (2006) characterized four ways to view young women's identities in becoming engineers. Those were; (a) their self-beliefs in who they are as students (academic identities), (b) their affiliation or attachment to their engineering programs, courses, and/or university (institutional/school identities), (c) their beliefs in who they are as women and how their gender is mediated in an academic program (gendered identities), and (d) someone they aspire to be and/or how others encourage and support them (role models). The study showed a strong link between academic and institutional/school identities, and a lesser, but still significant link between gender identity and role models (Capobianco, 2006). Capobianco (2006) proposed that the findings from this study be used to help science and engineering educators develop academic programs, curriculum, and best practices to encourage underrepresented groups to continue study in their prospective fields.

EIDS Development and Initial Pilot

Building on the information gained as a result of Capobianco's (2006) study, Capobianco et al. (2009) set out to develop an instrument that would measure elementary (grades 1-5) students' conceptions of self and engineering and how those conceptions are shaped by their participation in learning and engineering activities. The research was linked to Purdue University's Institute for P-12 Engineering Research and Learning (INSPIRE). INSPIRE is focused on creating an engineering literate society through focused engineering education research and study in the pre-k through 12^{th}-grade environment (Capobianco et al., 2009).

Teacher participants in this study were trained at an INSPIRE workshop and then developed a six-week unit made up of various engineering learning modules. Student participants took a series of assessments; including the Engineering Identity Development Scale (EIDS) developed by the researchers; to gather students' knowledge, perceptions, and self-images pertaining to engineering (Capobianco et al., 2009). The data generated from the EIDS provided instrument reliability information for a four-factor scale and also showed a correlation between time, gender, and identity development (Capobianco, 2009).

As a result of the study, Capobianco et al. (2009) suggested using the EIDS to; (a) assess students' perceptions, interests, and attitudes about engineering; (b) monitor the effectiveness of instructional attempts at introducing engineering activities in elementary school settings; (c) correlate with other data related to student performance in math and science; (d) develop newt assessments and programs in K-5 engineering; and (e) generate new lines of research related to learning and identity formation in engineering education. These suggestions provided unique direction for STEM educators and researchers interested in engineering education in early grades (Capobianco et al., 2012).

This original version of the instrument used a four factor model with subscales measuring engineering aspirations, occupational identity, academic identity, and school identity (Capobianco et al., 2009). That study found the following internal consistency reliability coefficients: engineering aspirations $\alpha=.71$; occupational identity $\alpha=.64$; academic identity $\alpha=.48$; and school identity $\alpha=.63$. Capobianco et al. (2009) also calculated the test-retest reliability of each scale, which showed the following correlations: engineering aspirations $r=.05$ ($p=.49$); occupational identity $r=.22$ ($p<.01$); academic identity $r=.62$ ($p<.001$); and school identity $r=.36$ ($p<.001$).

EIDS Modifications and Phase II Pilot

Continuing the work of previous research connected to engineering identity, Capobianco et al. (2012) intended to further validate the EIDS. This second iteration of EIDS research included administration of the instrument to 213 elementary students before and after participation in engineering learning units, in a similar fashion to the initial study group discussed in Capobianco et al.'s (2009) work (Capobianco et al., 2012).

After analyzing the data of the second pilot group, the initial 20-item instrument was reduced to 16 items and the original four-factor model was reduced to two factors, which the researchers called *academic* and *engineering career* (Capobianco et al., 2012).

The academic factor items related to how well students like their school and their confidence in academic subjects, while the engineering career items related to questions about engineering, design, and problem-solving (Capobianco et al., 2012). Reliability of the new version of the EIDS was documented by Capobianco et al. (2012). An internal consistency reliability coefficient of α=.76 was reported for the total score. Additionally, the two factors had internal consistency reliability coefficients of α=.70 (engineering career awareness) and α=.58 (academic awareness).

As a result of this study, Capobianco et al. (2012) suggested additional layers of identity (e.g., personal and social layers – those focused on relationships, purpose, racial identity, gender identity) may need to be measured to help inform discussion around engineering identity; and that researchers and educators must recognize that engineering identity is developmental. Further, the EIDS was suggested as a tool to monitor effectiveness of science and engineering instruction as it provides data that could be used to transform practice, curricula, and program development in science and engineering (Capobianco et al., 2012).

Current Research on Engineering Identity

Two studies, utilizing the current version of EIDS (Capobianco et al., 2014; Yoon et al., 2014), have focused on engineering identity among young learners. This section will summarize those studies and their findings.

Effects of Engineering Design-Based Science – Capobianco et al. (2014)

Capobianco et al. (2014) examined the extent to which engineering identity differed among preadolescents across gender and grade, when students were exposed to engineering design-based science learning activities. Researchers utilized multi-week educational units adapted from the Boston Museum of Science's Engineering is Elementary curriculum to deliver instruction to 550 elementary students (Capobianco et al., 2014). Each unit included tasks built around five key attributes: (a) problems were ill-defined to allow students to frame their own problems, (b) students experienced a sufficient level of uncertainty in finding solutions, (c) learning was driven by students' current state of knowledge about the topic or science concept, (d) students worked in collaboration with other students, and (e) students drew on expertise of more knowledgeable individuals (Capobianco et al., 2014).

The EIDS was administered to measure engineering identity within two subscales, academic and engineering career. The results showed that the treatment group demonstrated greater improvements in the EIDS subscales than the comparison groups, especially in the engineering careers subscale (Capobianco et al., 2014). Further, grade-level data showed a significant difference in mean scores on the engineering careers subscale, with a decline from grade 1 to grade 5. The researchers cited this trend as supporting evidence that students' interest in pursuing the study of science and engineering must be fostered early and often to counter this decline (Capobianco et al., 2014). The study also provided evidence that female students who participated in the engineering activities had higher levels of confidence in their work as students, problem solvers, and members of their schools (as measured by the academic subscale).

As a result of this study, Capobianco et al. (2014) suggested that the EIDS is a viable tool for identifying and characterizing preadolescent learners' conceptions of engineering and their earliest formation of engineering identity. The researchers proposed additional studies need to be conducted to validate these findings over time and specified additional work needed around topics related to the diverse work of engineers and the ongoing development of engineering identity of students as they continue through school (Capobianco et al., 2014).

Effects of Integrated STE Education on Knowledge and Identity – Yoon et al. (2014)

Yoon et al. (2014) examined the effects of integrated science, technology, and engineering (STE) education on elementary students' content knowledge and aspirations concerning engineering. The researchers used Engineering is Elementary engineering design curriculum materials developed by the Boston Museum of Science as well as units developed locally at Perdue University to deliver teacher professional development to educators that would be integrating STE in their classrooms (Yoon et al., 2014). 831 students in grades two through four participated in the study as their teachers implemented the engineering integrated lessons covered in the provided teacher professional development. The two-factor EIDS (Capobianco et al., 2012) was used to measure students' engineering identity, while Student Knowledge Tests (SKTs) were developed to measure students' knowledge in science, technology, and engineering (Yoon et al., 2014).

No significant differences were found on the EIDS academic subscale of treatment and control group students, but significant differences were found on the engineering career subscale for students in all three grade levels, with treatment students showing higher engineering career identity than control students. Additionally, post-EIDS scores showed no significant difference in engineering career identity between genders (Yoon et al., 2014). This was seen as a positive result in that misconceptions of who engineers are or what they do were corrected among all students and not just among one gender group (Yoon et al., 2014). The study found significant differences in SKT scores between treatment and control groups at each grade level, as well (Yoon et al., 2014). These findings indicated that content knowledge may be positively affected by integrated STE instruction in addition to student engineering identity (Yoon et al., 2014).

As a result of this research, Yoon et al. (2014) recommended further research be conducted on instrumentation measuring student content knowledge and acquisition (like the SKT). Additionally, the researchers recommend that practitioners use instruments like the SKT and EIDS to develop initial and follow-up professional development opportunities for teachers who will be integrating STE. Yoon et al. (2014) pointed out the success of a short unit of instruction may translate to even more gains in student knowledge and engineering identity if schools were to institute integrated instruction through the entire school year.

CHAPTER 3

METHOD

Purpose of Study

The purpose of this pre-test, post-test quasi-experimental study was to examine the influence of an integrative STEM (Science, Technology, Engineering, and Math) enrichment program on 3rd through 5th grade students' identity in engineering. Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with those of technology and engineering education (Sanders, 2012). An Engineering Adventures unit, developed by the Boston Museum of Science (Higgins et al., 2013), was used as a model for integrative STEM education. The unit was delivered during an after-school program at two elementary schools in Georgia for 45 minutes each day over the course of nine days. The Engineering Identity Development Scale (EIDS) developed by Capobianco et al. (2012) was used to assess students' engineering identity formation in the areas of academic identity and engineering career awareness.

Research Questions

1. What is the engineering identity of elementary students?
2. Are there statistically significant differences between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that are

involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness?

3. Are there statistically significant differences between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that are involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness when the original control group receives treatment?

Research Design

A pre-test, post-test quasi-experimental design (Creswell, 2011) was used to determine the possible influence of an integrative after-school STEM program on 3rd - 5th grade students' identity development in engineering. Students enrolled in after-school programs at two different elementary schools were utilized. During the first phase of implementation, one school group served as the control group and participated in the school's regularly scheduled, non-STEM activities, while the other group participated in a nine-day (45 minutes per day) integrative STEM program. Pre-tests and post-tests were administered to each group of students using the Engineering Identity Development Scale (EIDS) developed by Capobianco et al. (2012) to assess students' engineering identity formation. The EIDS score is made up of two subscales; academic identity and engineering career awareness. Once the first phase was complete, the control group of students participated in the integrative STEM program in a second phase to provide a replication of the treatment and to ensure all students in the study were provided equal access to the integrative STEM program. During the second phase, the original experimental group participated in the school's regularly scheduled activities, and were given the post-test a second time to check for sustainability of treatment over time, when not engaged in engineering-related activities.

Treatment

An Engineering Adventures (EA) unit developed by the Boston Museum of Science served as the treatment for this quasi-experimental study. Engineering Adventures (EA) is a program, developed by Engineering is Elementary (EiE), through the Boston Museum of Science, designed for after-school and summer camp settings. The materials were built on previous work from EiE that has seen significant implementation and positive results in regards to engineering conceptions and technological literacy development among elementary learners (Higgins et al., 2013). EA is designed to infuse STEM concepts through an integrative engineering unit in which students work to solve problems within a real-world context. Several units were made available for full implementation in 2013 and additional materials continue to be developed and rolled out nationwide after pilot testing and revisions (Higgins et al., 2013). The goal of EA is to positively impact children's attitudes about their abilities to engineer by providing materials uniquely appropriate for the varied landscapes of outside of school time (OST) settings. The main ideas that guided the development of EA units is that children will best learn engineering when they (a) engage in activities that are fun, exciting, and connect to the world in which they live, (b) choose their path through open-ended challenges that have multiple solutions, (c) have the opportunity to succeed in engineering challenges, and (d) communicate and collaborate in innovative, active, problem solving.

As students work through the engineering design challenges presented in each unit, opportunities are provided to build problem-solving, teamwork, communication, and creative thinking skills. The process is designed to ensure students learn to use the engineering design process to solve problems and that engineers design technologies to help people and solve problems. Students' self-belief that they have the talent and potential for designing and improving technologies is also a core concept targeted by the curriculum. Each Engineering Adventures unit follows the same structure; including prep adventures to introduce students to engineering and technology, a literature-based introduction using a storybook to set the context for the main unit challenge, several activities that build knowledge for the final challenge, and a concluding showcase where students present their work. Each of those individual activities is broken down into four sections including, (a) *Messages from the Duo* where a world-traveling brother and sister duo (India and Jacob) provide a quick and exciting real-world context for the material, (b) *Set the Stage (or Ask)* where important information and questions are discussed to prepare students for the main activity, (c) *Activities* where students experiment and work to solve the unit's engineering design challenge, and (d) *Reflect* where students communicate by sharing their work with peers and record information in engineering journals (Higgins et al., 2013).

During this study; the Engineering Adventures unit, *To the Rescue: Engineering Aid Drop Packages*, was used as the integrative STEM treatment. This unit was chosen for two reasons: (a) it was one of the early units developed and therefore has been one of the most widely used, and (b) the design challenge presented within the unit is one that appeals to a wide range of student, regardless of age or gender. The following sections explain the individual adventures that make up the unit.

Prep Adventure 1: What is Engineering? In this adventure, students engineer a tower and are introduced to the Engineering Design Process as a problem solving tool.

Prep Adventure 2: What is Technology? In this adventure, students explore the idea that they, as engineers, can design and improve technology.

Adventure 1: Aid Drops. In this adventure, students are introduced to aid drop packages and test hard casings and soft paddings as potential design components.

Adventure 2: Incoming! In this adventure, students test ways to slow down packages as they fall, using parachutes, wings, and canopies.

Adventure 3: Making it Clear. In this adventure, students figure out how they can make sure their package is easy to spot after it is dropped and how they can communicate what is inside their package.

Adventure 4: Creating an Aid Drop Package. In this adventure, students use the knowledge gained in the previous adventures and the engineering design process to engineer their own aid drop packages.

Adventure 5: Improving an Aid Drop Package. In this adventure, students work through the improve step of the design process to enhance their design and make it better.

Adventure 6: Engineering Showcase. In this adventure, students present their aid drop designs and explain how they used the engineering design process.

Each adventure within an EA unit requires 45-60 minutes of teaching time. In this study, each adventure occurred on a different day, so the entire unit took nine days to complete. A tenth day was available in case of unexpected interruptions, but the facilitators did not need to utilize the extra day during the course of the study.

Treatment fidelity deals with how well a treatment condition is implemented as planned by the researcher (Gall, Gall, & Borg, 2007). Treatment fidelity was ensured in this study through the use of a professional development model issued by the Museum of Science (2014), adherence to the prescribed teacher guide that accompanies the Engineering Adventures unit, checklists for facilitators to ensure proper delivery procedures (see appendix A), as well as supporting evidence gathered from post-treatment interviews with the facilitators (see appendix B). Professional development was provided to each participating after-school facilitator at a half-day training session utilizing the Engineering in OST Educator Workshop Professional Development Guide (Museum of Science, 2014). The OST Educator Professional Development guide is a 60 page document that provides background information on Engineering is Elementary, a workshop agenda, materials lists, master copies of handouts, links to the OST training PowerPoint presentation, and links to video resources to be used. Topics included in the training include: goals and overview of EA, engineering defined, the engineering design process, technology defined, EA unit breakdown and exploration, measuring success in EA programs, questioning strategies, adaptation scenarios, and a tour through online resources. Once trained, each facilitator was issued a teacher guide for the *To the Rescue* unit. The teacher guide is 122 pages and includes information about Engineering is Elementary, Engineering Adventures, the engineering design process, material lists, background information about the content to be taught, detailed lesson plans for each adventure within the unit, and master copies of all materials needed (Museum of Science, 2014). The daily facilitator logs used in this study indicated the treatment was delivered as intended throughout all phases of the study. Student attendance was also well documented by facilitators. The post interview sessions provided additional evidence to ensure the treatment was delivered appropriately. During the interviews, facilitators indicated that they were very confident in delivering the content, had all materials needed, and were able to follow the guide as planned. Additional discussion during the post-treatment interviews provided some insight on possible areas of future research including the importance of training and the need for funding and policy support connected to elementary STEM education.

Participants

A nonrandom convenience sample of intact groups of students involved in after-school programs was used. The target population was 3rd-5th grade students enrolled in elementary after-school programs in a school district near metro-Atlanta. All of the 3rd-5th grade after-school students from two neighboring elementary schools were included. The schools were selected based on similarities of student demographics concerning free/reduced lunch status, race/ethnicity, and gender. Information regarding the school's current involvement with STEM education was also examined to ensure student groups have had similar experiences in the area of STEM. The nature of the convenience sample poses inherent risks to external validity because the sample will not be randomly selected. While the ability to generalize results to the whole population of students in grades 3-5 will be hindered with this approach, some inference can be made about other 3rd-5th grade students enrolled in after-school programs (Creswell, 2011; Trochim, 2000).

Additionally, descriptive statistics were collected and the researcher attempted to make connections, to the extent possible, regarding how the results apply outside the sample.

Two schools served as host sites for the proposed study. One school was randomly assigned to receive treatment, while the other served as the control group. The decision to house treatment and control groups in two different school locations minimized diffusion of treatment threats (Creswell, 2011). Threats of this nature are related to concerns where treatment and control participants interact, providing control students with information about the engineering concepts covered in the treatment group. Housing the two groups in different schools helped guard against this threat.

Since schools were randomly assigned rather than individual students, threats related to participant selection could have been an issue. To counter this threat, two strategies were employed. First, a pretest was given to students in both the treatment and control groups. Pretest results, in this context, were used to establish initial equivalency of groups by comparing the mean, range, and standard deviation of scores from each group (Campbell & Stanley, 1963; Creswell, 2011). Second, the control group received the integrative STEM treatment after posttests had been administered to both groups following initial implementation. During this second iteration, the initial treatment group served as a control group, participating in the regular after-school instructional program. Posttests were administered to both groups at the end of the second round and were analyzed using the same method used on the first posttest scores. This additional data set was used to help validate findings and argue against issues of selection. The second set of posttest scores from the first treatment group were also analyzed to determine if the treatment had sustainability over time.

Instrumentation

This study used the Engineering Identity Development Scale (EIDS) developed by Capobianco et al. (2012) to assess students' engineering identity in the areas of academic identity and engineering career awareness. The dependent variable was engineering identity, while the independent variable was the participation/nonparticipation in the Engineering Adventures after-school treatment. The engineering identity variable is comprised of two subscales, academic identity and engineering career awareness (Capobianco et al., 2012).

Use of the EIDS is supported by findings from research connected to the development of the instrument as well as subsequent studies related to its use (Capobianco et al., 2012; Capobianco et al., 2009; Capobianco et al., 2014; Yoon et al., 2014). Capobianco et al. (2009) suggested using EIDS (and data generated from its use) to: (a) assess students' perceptions, interests, and attitudes about engineering and engineers, (b) monitor the effectiveness of instructional attempts at integrating engineering learning activities in the K-5 setting, (c) correlate with other data related to student performance on science and math assessments, (d) develop new and innovative assessments and programs in K-5 engineering education, and (e) generate new lines of research related to learning, cognition, and identity formation in engineering education. In the initial development of the instrument, Capobianco et al. (2009) used 20 items measuring four subscales (academic identity, school identity, occupational identity, and engineering aspirations) of engineering identity. Work from Capobianco et al. (2012) resulted in a modified instrument using 16 items and two subscales (academic identity and engineering career awareness). Additional research conducted by Capobianco et al.

(2014) and Yoon et al. (2014) also used the 16 item, two subscale version, providing additional support of its use in further studies on engineering identity.

This study utilized the EIDS in its existing state, which includes 6 academic subscale items and 10 engineering career subscale items (see Table 3). The version of EIDS recommended for children in grades 3-5 have students rate items on a scale of 1-3, with 1 = “no”, 2 = “not sure”, and 3 = “yes” (Capobianco et. al, 2012). Students can score a maximum of 48 points on the EIDS, with 18 points being generated from academic subscale items and 30 points generated from engineering career subscale items.

Table 3.

Two-Factor Structure of the Engineering Identity Development Scale

Subscale	Item
Academic	1. I do my school work as well as my classmates.
	2. I am good at solving problems in mathematics.
	3. I use computers as well as my classmates.
	4. I am good at working with others in small groups.
	5. I like being a student at my school.
	6. I make friends easily at my school.
Engineering Career Awareness	7. Engineers solve problems that help people.
	8. Engineers work in teams.
	9. Engineers design everything around us.
	10. There is more than one type of engineer.
	11. Engineers use mathematics.
	12. Engineers use science.
	13. Engineers are creative.
	14. When I grow up, I want to be an engineer.
	15. When I grow up, I want to solve problems that help people.
	16. When I grow up, I want to work on a team with engineers.

High scores within the academic subscale indicate students’ strong belief on how they perform academically, while high scores within the engineering career subscale indicate a greater understanding of the work of engineers and strong aspirations to pursue a career in engineering (Yoon et al., 2014).

Procedure

A meeting was scheduled in August, 2015 with the after-school program manager in a metro-Atlanta school district to discuss implementation of the integrative STEM program at two elementary schools. A proposal was submitted to the school district to request permission to conduct research and approval documentation was obtained. That information was submitted, along with a complete application, to the University of Georgia's Institutional Review Board (IRB) in September, 2015. Participant information was kept confidential and was not reported or released.

Once IRB approval was granted (see appendix C), all instructional and consumable materials needed for teacher training and program implementation was secured and distributed to the participating schools. The after-school teachers at each school participated in the Engineering Adventures professional development workshop developed by Engineering is Elementary (Higgins et al., 2013) one week prior to the treatment start date.

All of the 3rd through 5th grade students enrolled in the after-school program at the two schools were entered into a database and assigned a randomly generated, six-digit identification number (see appendix D). The randomly generated numbers were created using the RANDBETWEEN function in Microsoft Excel. Before beginning the program, parent consent forms (see appendix E) were collected.

At the beginning of the program, the EIDS (see appendix F) was administered to all participants. After the pre-assessment had been administered, instruction of the Engineering Adventures STEM program began with the treatment group. The unit took nine days to complete (45 minutes each day) and culminated with a second administration of the EIDS as a posttest. Students from the control group were also given the posttest at this time. After posttests were administered, the control group participated in the same unit of instruction, while the original treatment group continued with their regularly scheduled, non-STEM after-school activities. Both groups took the posttest, again, at the conclusion of this second iteration. The entire process was concluded by November 20, 2015.

Data Analysis

Previous research has consistently reported validity for the EIDS (Capobianco et al., 2009; Capobianco et al., 2012; Capobianco et al., 2014; Yoon et al., 2014). Validity refers to items' ability to measure the intended constructs within an instrument (Creswell, 2011). A panel of experts made up of STEM educators was used in this study to confirm previous research findings of EIDS validity on the constructs of academic identity and engineering career awareness. This was accomplished by having the experts analyze each question and categorize it as *academic* or *engineering career*. The committee's findings were compared to the item categorization reported by the authors of the instrument.

Research question 1 sought to identify the engineering identity of elementary students as measured by two subscales; academic identity and engineering career awareness. Descriptive statistics; including the mean, standard deviation, variance, and range, from the pretest were used with each subscale. This information provided initial information on the engineering identities of the elementary students involved in this study.

Research question 2 examined the effects of an Engineering Adventures unit on after-school students' engineering identity during a first round of the study where the treatment was provided to one group of students, but not the other. A one-way analysis of variance (ANOVA) was used to analyze subscale scores of students who participate in the treatment and those who did not.

An ANOVA compares the amount of variance in scores between groups with the amount of within-group variance (Allen, Titsworth, & Hunt, 2009). Three assumptions are required in an ANOVA to allow credible conclusions to be drawn. Those assumptions are; (a) the dependent variable is normally distributed in each group, (b) there is homogeneity of variances, meaning the population variances in each group are similar, and (c) independence of observations, meaning the dependent variable is only influenced by the independent variable. An F value is produced from the ANOVA and indicates whether differences among the groups are statistically significant (Allen et al., 2009). A one-way ANOVA is appropriate, in this case, because the instrument produces continuous subscale scores as the dependent variable and only one independent variable exists (participation in an after-school engineering enrichment activity).

Research question 3 examined the effects of the treatment on after-school students' engineering identity during a second round of the study where the treatment was administered to the control group from round one, while the other group of students participated in regularly scheduled, non-STEM, after-school activities. An ANOVA was once again used to analyze the second set of posttest scores gathered after the second round of the study to determine variability between groups. Mean scores from each subscale after this round of treatment were also analyzed to determine sustainability.

Table 4 identifies the research questions, variables, and statistical procedure utilized for the analysis strategy in this study.

Table 4.

Analysis Strategy

Research Question	Independent variables	Dependent variables	Statistical procedure
1. What are the EIDS scores of elementary students?		Pretest score academic engr Career	Descriptive statistics Mean, SD, Variance, Range
2. Are there statistically significant effects between 3rd - 5th grade students who participate in an afterschool STEM enrichment program and those that are involved in regular after-school programs and those that do not on the engineering identity?	Treatment no treatment treatment	Posttest score I academic engr career	ANOVA $p < .05$ $d \geq 0.5$
3. Are there statistically significant effects between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that do not on the engineering identity when the original control group receives treatment?	Treatment no treatment treatment	Posttest score II academic engr career	ANOVA $p < .05$ $d \geq 0.5$

A significance level of .05 was used in this study, meaning that results were considered significant if dissimilar results would be found less than 5% of the time (Creswell, 2011). Significance at this level is supported in previous work related to engineering identity and student perceptions of engineering (Capobianco et al., 2012; Capobianco et al., 2014; Lachapelle et al., 2012; Yoon et al., 2014) and is commonly acceptable in educational research (Creswell, 2011).

Effect size measures how much practical significance results have in the population (Moore, 2004). Cohen's *d* was used to measure effect size in this study. This statistical method estimates the difference in sample means relative to the standard deviation of the population. Cohen's suggestions provide a framework for initial interpretation of effect size, defining a small effect size as 0.2, a medium effect size as 0.5, and a large effect size as 0.8 (Sullivan & Feinn, 2012). Practical significance, in this study, considered the calculated effect size, the impact treatment had on students and the learning environment, the potential impact the treatment had on future academic decisions of student participants, feedback from the facilitators of the after-school enrichment activity, and previous results obtained using the EIDS.

CHAPTER 4

RESULTS

The purpose of this pre-test, post-test quasi-experimental study was to examine the influence of an integrative STEM (Science, Technology, Engineering, and Math) enrichment program on 3rd through 5th grade students' identity in engineering. Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with those of technology and engineering education (Sanders, 2012). An Engineering Adventures unit, developed by the Boston Museum of Science (Higgins et al., 2013), was used as a model for integrative STEM education. The unit was delivered during an after-school program at two elementary schools in Georgia for 45 minutes each day over the course of nine days. The Engineering Identity Development Scale (EIDS) developed by Capobianco et al. (2012) was used to assess students' engineering identity formation in the areas of academic identity and engineering career awareness. Findings related to the following research questions are presented in this chapter.

Research Questions

1. What is the engineering identity of 3rd - 5th grade students?
2. Are there statistically significant differences between 3rd-5th grade students who participate in an after-school STEM enrichment program and those that are

involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness?

3. Are there statistically significant differences between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that are involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness when the original control group receives treatment?

Engineering Identity Development Scale Validity

Instrument validity of the EIDS has been documented in previous research (Capobianco et. al., 2009; 2012). As a safeguard in this study, the EIDS was reviewed by a panel of experts within STEM education to validate the categorization of items into the subscales originally developed by the instrument authors. Three STEM educators participated in this review process and confirmed the categories as outlined by Capobianco et al. (2012).

Research Question 1

The engineering identity of 3rd-5th grade students was the focus of research question one. Engineering identity was assessed using the Engineering Identity Development Scale (Capobianco et al., 2012) through the pretest given to both groups of students prior to implementation of the after-school STEM unit. The treatment group during this phase consisted of 33 students and the control group was made up of 25 students. One student from the treatment group was removed from the study because they withdrew from school after the third day of the unit. A one-way ANOVA was used to assess initial academic and engineering career subscale scores prior to treatment. The overall mean score for the academic subscale was 16.44 (*SD* = 1.61) and the overall mean score for the engineering careers subscale was 24.46 (*SD* = 2.23). Descriptive statistics appear in Table 5. There were no statistically significant differences between the treatment group and control group on either subscale prior to beginning the after-school STEM unit of instruction. This initial equivalence provided likely assurances that the treatment and control groups were relatively similar, despite a lack of random selection. Results of the ANOVA are displayed in Table 6.

Table 5.

Descriptive Statistics of Initial EIDS Administration (Prior to Treatment)

	n	*M*	*SD*	*Min*	*Max*
Academic subscale					
Control group	25	16.64	1.66	12	18
Treatment group	32	16.28	1.59	12	18
Total	57	16.44	1.61	12	18
Engineering career subscale					
Control group	25	24.16	2.08	19	28
Treatment group	32	24.69	2.35	20	29
Total	57	24.46	2.23	19	29

Table 6.

ANOVA of Initial EIDS Administration (Prior to Treatment)

	SS	*df*	*MS*	*F*	*p*
Academic subscale					
Between groups	1.81	1	1.81	.689	.410
Within groups	144.23	55	2.62		
Total	146.04	56			
Engineering career subscale					
Between groups	3.91	1	3.91	.783	.380
Within groups	274.24	55	4.99		
Total	278.14	56			

Research Question 2

Research question two called for the examination of EIDS results after the implementation of an after-school STEM enrichment unit of instruction. The treatment group of after-school students participated in an *Engineering Adventures* unit of study over the course of nine days, while the control group continued with regular, non-STEM, after-school activities. Upon completion of the nine day unit of instruction with the treatment group, the EIDS was administered again to all participating students from both treatment and control groups. A one-way ANOVA was used to assess statistically significant differences between groups. The overall mean score after the first round of treatment on the academic subscale was 16.58 (*SD* = 1.68), while the overall mean score for both groups on the engineering careers subscale was 25.05 (*SD* = 2.98). Descriptive statistics appear in Table 7. Results of the ANOVA are displayed in Table 8.

Table 7.

Descriptive Statistics of Second Round of EIDS (After Treatment)

	n	*M*	*SD*	*Min*	*Max*
Academic subscale					
Control group	25	16.36	1.87	12	18
Treatment group	32	16.75	1.52	13	18
Total	57	16.58	1.68	12	18
Engineering career subscale					
Control group	25	23.32	2.67	17	27
Treatment group	32	26.41	2.50	19	30
Total	57	25.05	2.98	17	30

Table 8.

ANOVA of Second Round of EIDS (After Treatment)

	SS	*df*	*MS*	*F*	*p*
Academic subscale					
Between groups	2.14	1	2.135	.754	.389
Within groups	155.76	55	2.832		
Total	157.90	56			
Engineering career subscale					
Between groups	133.68	1	133.68	20.14	.000
Within groups	365.16	55	6.64		
Total	498.84	56			

There were no statistically significant differences in the academic identity subscale after the initial treatment phase. There was a statistically significant effect, however, on the engineering careers subscale F (1, 55) = 20.14, p = .000. Further, Cohen’s effect size value (d=1.19) suggested a high level of practical significance. Cohen’s *d* provides a means to measure differences between groups in standard deviations (Sullivan & Feinn, 2012).

Research Question 3

Research question three aimed to determine if the after-school STEM enrichment unit would produce similar results with the original control group. Data gathered during a second iteration can provide evidence on the sustainability of the treatment results over time and can provide evidence on the ability to replicate results. To answer research question three, the original control group participated in the *Engineering Adventures* unit while the original treatment group went back to their regularly scheduled, non-STEM activities. At the completion of this phase, the EIDS was administered to both groups again, this time with the original control group identified as the new treatment group and the original treatment group identified as the new control group. A one-way ANOVA was used to assess posttest scores between the groups. The overall mean score after this final administration on the academic subscale was 16.46 (*SD* = 1.79), while the overall mean on the engineering careers subscale was 25.21 (*SD* = 3.28). Descriptive statistics appear in Table 9. Results of the ANOVA are displayed in Table 10.

Table 9.

Descriptive Statistics of Final Round of EIDS (Groups Reversed)

	n	*M*	*SD*	*Min*	*Max*
Academic subscale					
New control group	32	16.66	1.54	13	18
New treatment group	25	16.20	2.08	12	18
Total	57	16.46	1.79	12	18
Engineering career subscale					
New control group	32	25.91	3.06	19	30
New treatment group	25	24.32	3.39	17	30
Total	57	25.21	3.28	17	30

Table 10.

ANOVA of Final Round of EIDS (Groups Reversed)

	SS	*df*	*MS*	*F*	*p*
Academic subscale					
Between groups	2.92	1	2.92	.907	.345
Within groups	177.22	55	3.22		
Total	180.14	56			
Engineering career subscale					
Between groups	35.32	1	35.32	3.43	.069
Within groups	566.16	55	10.29		
Total	601.47	56			

There were no statistically significant differences in either the academic subscale or the engineering careers subscale following this final EIDS administration. This finding provided evidence that the treatment had a powerful effect on both groups of students and that the results from the first control group held up over the two week period in which they were not engaged in STEM-related study.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Summary

STEM integration in K-12 education is gaining attention, and its place within the United States educational system is a current topic of conversation. Fueling that conversation is the continually changing needs of the U.S. workforce looking for workers with skills needed to succeed in the 21st century workplace (Rojewski, 2002). The availability of a quality STEM workforce has been well documented as being vital to economic growth and national security, but the U.S. educational system is not producing quality STEM graduates (Augustine, 2005; Langdon et al., 2011; Ostler, 2012; U.S. Congress Joint Economic Committee, 2012; Wang et al., 2011).

The role that educational systems play in career development and the enhancement of students' 21st century skills is not limited to high school preparation. In fact, findings in an ACT (2008) report has suggested that academic achievement attained by the 8th grade has a larger impact on college and career readiness than anything academically-related in high school. Magnuson and Starr (2000) argued that "it is never too early" (p. 101) to expose children to careers. In fact, the early years are critical for career development where supportive adults provide interaction-rich experiences; intentionally incorporating concepts of career awareness, exploration, and planning into children's experiences as they make decisions about themselves and the world (Magnuson & Starr, 2000).

This section discusses key components of the study, including an overview of elementary STEM education, engineering identity, the theoretical link to social cognitive career theory (Lent et al., 1994), and the research design used. Subsequent sections in this chapter cover key findings of the study, limitations, and implications for practice and future research.

Elementary STEM Education

STEM in elementary education has not received as much attention as in secondary education and college, but that trend is beginning to change (Honey et al., 2014). To address the growing concern over the deficit of STEM-prepared students, elementary school educators are beginning to seek more hands-on approaches to teach abstract concepts in STEM subject areas, while outreach projects are looking to integrate engineering into elementary-level after-school curriculum by teaching practical applications of STEM concepts in everyday life (Epstein & Miller, 2011).

Engineering is a critical component in STEM education. Concepts related to engineering are being included in national policy and educational documents that highlight the importance of improving STEM education (Moore, Glancy, Kersten, Smith, & Tank, 2014). The President's Council of Advisors on Science and Technology (2010), for example, published a document highlighting engineering and STEM education as a means to build professionals that can be internationally competitive in STEM-related workplaces. A report by the National Research Council (2007), *Rising Above the Gathering Storm,* also highlighted the importance of engineering and STEM education as it relates to economic growth and national security. Another NRC (2012) report highlighted the role of engineering as a mechanism to teach meaningful scientific concepts. The Next Generation Science Standards (NGSS) were developed as a result of those reports, and others like them. These standards are the result of a multi-state effort developed to provide rich content and scientific practice in K-12 education. The NGSS includes engineering practices as a part of their framework. Among those practices are defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information (Carr et al., 2012).

Curriculum efforts such as *Engineering is Elementary* (EiE) and *Engineering Adventures* (EA), from the Boston Museum of Science, are also gaining momentum among elementary educators. EiE and EA units are designed to infuse engineering design and technological literacy into K-5 settings by strategically connecting engineering problems to existing science and literacy standards. Research involving hundreds of programs across the country have been conducted with EiE and EA and have demonstrated increased student awareness and knowledge of engineering careers (Lachapelle et al., 2012).

After-school programs and summer camps are popular ways to connect elementary students to engineering and technology education concepts. Foster and Shiel-Rolle (2011) found that participation in short-term camp-style programs can have a positive impact on students' reading proficiency, computing, laboratory skills, and hands-on research. Honey et al. (2014) looked at enrichment programs that taught STEM concepts and found the programs to be effective at changing student perceptions about academic and career areas.

STEM enrichment programs also support interest and identity development by nurturing self-efficacy, or confidence, in STEM-related tasks; as well as providing increased student engagement and success during STEM-related projects (Capobianco et al., 2012). The Afterschool Alliance (2010) found that after-school STEM enrichment programs create strong linkages to the regular school curriculum by engaging and inspiring youth, keeping them on a STEM-related academic path, and preparing them for further STEM study through postsecondary schooling. Each positive STEM-related experience, like those discussed by the Afterschool Alliance (2010), is likely to lead to a stronger sense of identity within that area of study (Lent et al., 2002).

Engineering Identity

Engineering identity development of elementary students was a focus of study of Capobianco et al. (2009). Engineering identity refers to the way students see, or identify with, the field of engineering and its value as a career choice (Capobianco et al., 2012). This work is especially important among elementary-aged students because STEM careers exposure is not typical in the K-5 setting. This limited focus on STEM-related careers in elementary schools is significant because such careers can span a multitude of areas with varying contributors to identity development. Further, if educational opportunities can impact how students see themselves academically, as well as how they relate to engineering careers, significant progress can be made toward furthering engineering identity development (Capobianco et al., 2012).

Building on the work of Capobianco et al. (2009; 2012) my study used the Engineering Identity Development Scale (EIDS) to measure engineering identity. The instrument is made up of 16 items, reflecting two subscales (Capobianco et al., 2012).

The subscales break items into areas of academic identity and engineering career awareness (Capobianco et al., 2012). The EIDS has been used in several research studies since its initial development (e.g., Capobianco et al., 2014; Yoon et al., 2014). Researchers, in those studies, have used the two-subscale model to measure identity.

Theoretical Framework

The idea that identity among pre-adolescent learners can be developed through interaction with and exposure to different areas of study through unique experiences and involvement within certain groups was a critical component of this study. Social Cognitive Career Theory (SCCT; Lent et al., 1994) provided support that exposure to and comfort with STEM-concepts strongly influences self-efficacy and willingness to continue pursuing a STEM-focused area of study. Outcome expectations and goal setting are key aspects of SCCT. Outcome expectations are beliefs related to the consequences of performing a specific task and are formed through past experiences and the perceived results of those experiences. Goals are seen as a driving force for behavior and are defined as decisions to begin a particular activity or pursue a set plan (Lent et al., 1994).

Occupational identity development, specifically within the area of engineering can be impacted using knowledge provided by SCCT (Lent et al., 1994). Interest development and choice models, combined with performance, work as interlocking concepts with the SCCT framework (Lent et al., 2002). Within the interest development component of the model, career interest develops when an individual believes he/she is good at an activity and when the pursuit of that activity is thought to lead to a desired outcome. Further, in the choice component, individuals begin to move from confirming interests to identifying career choices related to those interests while forming career goals and implementing a plan to achieve those goals (Lent et al., 2002).

Elementary students' engineering identity has been linked to academic identity and engineering career awareness (Capobianco et al., 2012). Studies have shown the development of engineering identity can be influenced by introducing integrative STEM instruction during the regular school day. This is done by targeting how elementary children see themselves as students, problem solvers, and potential engineers (Capobianco et al., 2012, 2014; Yoon et al., 2014). The present study examined the role after-school STEM enrichment programs might play on the engineering identity development of elementary students.

Research Design

A pre-test, post-test quasi-experimental replication design (Creswell, 2011) was used to examine the influence of an after-school STEM program on 3rd-5th grade students' identity development in engineering. Students already enrolled in after-school programs at two different elementary schools were used. During the first research phase, one school served as the control group and participated in regularly scheduled, non-STEM activities, while the other school participated in a nine-day (45 minutes per day) integrative STEM program. Pre-tests and post-tests were administered to each group of students using the Engineering Identity Development Scale (EIDS; Capobianco et al. ,2012) to assess students' engineering identity formation. EIDS scores are made up of two subscales, academic identity and engineering career awareness. Once the first phase was complete, the original control group participated in the integrative STEM program in a second phase to replicate the treatment and ensure all students in the study were provided equal access to the integrative STEM program. During the second phase, the students in the original experimental group participated in regularly scheduled after-school activities, and were given a second post-test to check for sustainability of treatment over time when not engaged in engineering-related activities.

Key Findings

Research Question 1

Research question one examined the engineering identity of 3rd through 5th grade students. The Engineering Identity Development Scale (Capobianco et al., 2012) provided two subscales to determine engineering identity, academic identity and engineering career awareness. The academic identity mean score for all participants during the initial administration of the EIDS was 16.44 (SD=1.61) and the overall engineering career awareness mean score was 24.46 (SD=2.23). In the academic identity subscale, the lowest possible score was 6, while the highest possible score was 18. In the engineering career awareness subscale, scores ranged from 10 to 30. Given those ranges, the academic identity mean score of 16.44 placed in the top 91% of possible responses, while the engineering career awareness subscale falls at approximately the 82% range. It is not surprising that students answered more affirmatively in the area of academic identity, as that has been the case in previous studies (Capobianco et al., 2012, 2014; Yoon et al., 2014).

Research Question 2

Research question two examined EIDS results after implementing the after-school STEM enrichment unit of instruction to determine if significant differences existed between treatment and control groups. The analysis of variance (ANOVA) showed no statistically significant differences on academic identity subscale scores, F (1, 55)=0.75, p=.389. There was a statistically significant effect, however, on the engineering career awareness subscale, F (1, 55)=20.14, p=.000. Further, Cohen's d effect size value (d=1.19) indicated a high level of practical significance in the area of engineering career awareness. Cohen's d=1.19 indicated mean scores of the treatment group were 1.19 standard deviations higher than those in the control group. That value means there was about an 80% chance that a person picked at random from the treatment group would score higher than one picked at random from the control group.

Findings associated with research question 2 are similar to those reported in other studies using the two-subscale EIDS model. Capobianco et al. (2014) and Yoon et al. (2014) found no significant group differences on the academic identity subscale, but showed the treatment group scoring significantly higher than the control group in the engineering career awareness area. Although Capobianco et al. (2014) and Yoon et al. (2014) reported no significant differences in the academic identity subscale, they did not offer explanation as to why this occurred. In my analysis, I would pose that the lack of significance may be due to the fact that students were more familiar with and confident in the areas addressed within the academic identity subscale (doing school work, solving math problems, using computers, working with others, liking school, and making friends).

Research Question 3

Research question three aimed to determine if the after-school STEM enrichment unit would produce positive results with the original control group as was found with the original treatment group. I was also interested in determining if the treatment had a lasting effect during periods of time when students were not exposed to STEM-related material. After switching treatment and control groups and conducting the *Engineering*

Adventures unit with the original control group, no statistically significant differences were found in either the academic identity, F (1, 55)=.907, p=.345, or engineering career awareness, F (1, 55)=3.43, p=.069 subscales. This finding provided evidence that the treatment had a measurable effect on both groups of students, i.e., results from the first group remained over the two-week period of time when they were not engaged in STEM instruction. This finding is encouraging as it provides evidence that even a relatively short (two-week) unit of instruction can influence students' engineering identity development that will not fade immediately after exposure is withdrawn.

Limitations of the Study

Limitations to this study are recognized. First, a convenience sample was used. Use of a convenience sample hinders the ability to generalize results to a larger population of grade 3-5 students. In this study, however, pre-test scores were not significantly different between the original treatment and control groups, providing some level of confidence of initial group equivalency (Creswell, 2011). The random assignment of treatment and control groups helped guard against sampling risks by ensuring that both groups had an equal chance of being assigned to the treatment group. Finally, a second iteration of the study, in which the two groups swapped roles, i.e., treatment became control and vice versa, helped to offset concerns related to sampling through replication. A goal of replication studies is often to verify the existence and direction of an effect (Anderson & Maxwell, 2015).

A second limitation is the length of the study. Kroger (2007) discussed identity as something that is formed over a long period of time, meaning that research on identity requires longitudinal study. Identity, in this study, was examined during a two-week period of time as students participated in a concentrated after-school activity. A replication phase of the treatment was administered to the original control group while the initial treatment group received no STEM instruction. After the replication phase, the initial treatment effect was still evident after the group had time away from the treatment. While this finding does not guarantee long-term effect, it does provide promise that the treatment could have lasting effects.

A third limitation involves sample size. Meeus, Iedema, Helsen, and Vollebergh (1999) argued that research involving identity development requires large sample sizes. Other researchers (Capobianco et al., 2012, 2014; Yoon et al., 2014) have found similar results utilizing the EIDS to measure engineering identity development, although not specifically connected to after-school enrichment programs. These findings provide some confidence that results might be similar across larger sample sizes.

Implications for Practice

STEM education is becoming more popular in U.S. schools. This section provides information connected to two key applications for practioners within the elementary STEM education arena: (a) enhancing after-school programs, and (b) incorporation of STEM into the regular school day.

Enhancing After-School Programs

As schools look to enhance after-school program offerings, it is important to consider the role STEM instruction can play. After-school decision-makers often look towards evidence of previous success and quantifiable data to support implementation of programs before spending time and money on new initiatives. This study, and others like it, provide guidance and data to after-school decision-makers as they explore STEM programming as an enhancement to their instruction.

The literature suggests a number of positive effects of STEM enrichment programs such as an increased STEM pipeline, fostering diversity, adding value to after-school programs, increasing students expectations, increasing community involvement, and influencing student decisions for higher education (Afterschool Alliance, 2010; Foster & Shiel-Rolle, 2011; Scherer & Well, 2010; Sexton et al., 2003). Barton and Tan (2010) discussed further that exposure and engagement in STEM study helps to expand students' social networks to include peers interested in science, technology, engineering, and mathematics; while also expanding their identities as achievers in STEM subjects. Higgins et al. (2013) discussed the *Engineering Adventures* program's ability to increase awareness and knowledge of engineering careers and concepts in their studies across hundreds of schools. Studies like those highlight student interest and excitement in STEM, but quantitative data about the effectiveness of such programs is scarce in the literature (Capobianco et al., (2009).

The current study provides quantifiable data that the K-5 community and researchers can use to support the inclusion of STEM programs within after-school and enrichment settings. Student participants in this study showed higher scores on the engineering identity development subscale of the EIDS after participating in an after-school STEM unit of instruction. Additionally, the relatively short (two-week) *Engineering Adventures* unit proved to have a lasting effect with students even when they were not engaged in STEM-related activities for a period of time after implementation.

Incorporation of STEM into the Regular School Day

Children make connections among learning activities across various settings through practical experiences (Ito et al., 2013). Elementary teachers and leaders are looking for ways to bring practical application to academic content during the regular school day (Brophy et al., 2008). Elementary engineering content can be an effective integrating area of study by providing students a hands-on math and science approach while incorporating other important skills like critical thinking, discovery, and applying cross-disciplinary tools (Scott, 2009).

While researchers (Bybee, 2010; Honey et al., 2014; Mann et al., 2011; Sanders, 2012; Stohlmann et al., 2012) have pushed for an integrative approach to education by focusing on STEM as a cross-curricular area of study, practitioners have been slow to make the shift. Several factors are likely to influence resistance to an integrative STEM model, including; teacher experience with STEM subjects, instructional time constraints, and comfort-level with change (Diefes-Dux, 2014). In order to overcome these influencing factors, it is important for schools to establish stakeholder buy-in and develop a roll out plan that allows implementation to occur organically with limited risk of adverse effect.

Schools and administrators looking to include STEM education during the regular school day should consider beginning with STEM exposure in the after-school setting before rolling it out during the regular school day. Implementation that starts after-school will familiarize faculty and students with engineering and STEM education, while building excitement for the program. Teachers and students that participated in this research had very positive feedback regarding the activities and instructional resources used and were eager to try more activities after the study concluded. Incremental implementation of STEM in schools helps develop teacher confidence with the content and methodology needed for making it a success (Diefes-Dux, 2014). A successful after-school STEM program can serve as first steps in incorporation during the regular school day.

Implications for Future Research

This research extended the study of engineering identity development among elementary students, using an after-school enrichment program. This section presents suggestions for future research related to engineering identity development, after-school STEM programs, and implications for elementary STEM education in general.

Engineering Identity Development

Previous work by Capobianco et al. (2014) and Yoon et al. (2014) used the EIDS, in its current format, to identify and characterize elementary students' conceptions of engineering and their earliest formation of engineering identity. Building on those studies, my research validates use of the EIDS as an engineering identity development tool by introducing the instrument within an after-school elementary setting.

Because the EIDS is a relatively new instrument, more research using the EIDS to measure engineering identity development of elementary students should be conducted. Efforts should explore engineering identity development of students involved in STEM education both during after-school programming and during the regular school day. These studies could analyze existing curricular models or provide evidence on the impact of newly-developed STEM curriculum. Further examination should also be done to determine if differences exist in historically underrepresented groups within STEM industries such as female students and from racial/ethnic minority groups.

After-School STEM Programs

Schools offer a variety of after-school activities including academic tutoring, fine arts, play time, science exposure, as well as STEM instruction. While schools vary widely in their after-school offerings, most share the common goal of promoting educational success in an environment less structured than the regular school day (Afterschool Alliance, 2010).

During the course of this study, three key areas of future research came to light regarding after-school STEM programs. First, additional studies should be conducted to determine the long-term effects of elementary after-school STEM programs on students' decisions later in life. High school or college course selection could be examined, as well as longer-term decisions such as career obtainment. Such a study would take years to examine longitudinally, but would fill a gap currently in the research. Second, future research could explore the effect after-school STEM programs have on student performance or interest in subject matter encountered during the regular school day. Many after-school programs operate under the assumption that participation will change the way students interact with content during the regular school day, but few studies have actually examined that topic (Sahin, Adiguzel, & Ayer, 2014). Third, research could analyze students' performance on standardized tests in STEM-related subject areas as they relate to participation in after-school STEM programs.

Elementary STEM Education

Children are natural scientists and engineers. From a very early age, they explore the world around them to understand how things work, much the way scientists do and they adapt their findings to meet their wants and needs as budding engineers. Unfortunately, as children get older, they begin losing interest in STEM subjects and that natural curiosity begins to be overshadowed by other influences (Moore, Stohlmann, Wang, Tank, Glancy, & Roehrig, 2014). A common theme throughout this dissertation has been the need to push STEM education and exposure to students at an earlier age. If that push continues, research will be needed in the broad area of elementary STEM education.

While the current study focused on after-school elementary STEM programs, post-treatment interviews with after-school teachers that delivered treatment revealed two specific areas of research related to elementary STEM education that would be helpful to practioners. First, research should be conducted on elementary teacher preparation and professional development related to integrative STEM education. Second, researchers should examine how educational policy, curriculum, and funding are evolving as more and more research reveals positive outcomes of integrative STEM instruction. These two areas may have the most impact on the future of STEM education in earlier grades and special attention should be given in order to equip decision makers with evidence to support their efforts.

Conclusion

I examined the influence of STEM enrichment activities on 3rd-5th grade students' engineering identity. The study adds quantifiable data to support integrative

STEM education efforts implemented in after-school elementary programs. Further, I propose that after-school STEM programs may lead to further expansion throughout the regular school day.

Students' engineering identity was positively influenced by participation in the STEM activities in the study and proved to have lasting effects over the time allocated for this research. Both teacher and student participants had positive experiences and the schools involved in the study indicated interest in incorporating STEM education in their after-school programs in the future.

Significant differences were present among students who participated in after-school STEM programming in the area of engineering career identity, but that difference dissipated after all students in the study received treatment. This finding indicates that after-school STEM programs can have an effect on the engineering identity of students and shows promise for those trying to impact the level of STEM interest and involvement of elementary students.

As 21st century skills like problem-solving, creativity, and innovation become more and more central to the world of work, it is essential that students are placed in environments where they can practice and develop those skills. Integrative STEM education models provide an ideal environment to foster these types of experiences and will ultimately lead to a workforce that can tackle problems that do not yet exist. The earlier we can immerse students in such an environment, the more prepared they will be for the world in which they will find themselves in after their schooling is complete.

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Appendix A

Daily Facilitator Log

Daily Facilitator Log

Directions: The following form should be completed each day by the facilitator delivering the after-school Engineering Adventures Unit. At the end of the unit, these will be submitted to the principal researcher.

1. **Day of Unit -** Please circle the number below indicating the day of the unit that this form is representing.

Day #: 1 2 3 4 5 6 7 8 9

2. **Preparation Checklist -** Please go through the list below and check each item as it is completed. The items in this section should be completed the day before the activities covered on this sheet (i.e., day 2 preparation should be completed at end of day 1).

____ - Read through the entire Adventure scheduled for tomorrow.

____ - Prepare the physical classroom space for the Adventure scheduled for tomorrow.

____ - Post the agenda for the Adventure scheduled for tomorrow.

____ - Gather and prepare materials needed for the Adventure scheduled for tomorrow.

3. **Delivery of Adventure –** Please complete the items below after delivering this day's instructional activities. The first item should include a check mark and explanation of any variation in planned activities. The second and third items should be given a ranking from 1-4 based on the included rubric.

____ - Today's lesson plan was followed exactly as listed in the teacher guide. If not, explain changes:

____

____

____ - Using the scale below, rate the level of engagement children had in today's lesson.

1	2	3	4
Very few students participated in the activities as expected	50% of the students participated in the activities as expected	Almost all students participated in the activities as expected	All students participated in the activities as expected

____ - Using the scale below, rate the level of cooperation from children during today's task.

1	2	3	4
Only a few students followed directions as presented	50% of students followed directions as presented	Almost all students followed directions as presented	All followed directions as presented

____ - Complete the *Preparation Checklist* section of tomorrow's Daily Facilitator Log

4. **Attendance** – Complete the attendance information below, making note of the number of children absent. List the participant ID's for absent children (to be completed for each day of the unit)

Number of children absent: _______

If any children were absent, list their participant ID(s) here:

___________ ___________ ___________ ___________ ___________

5. **Facilitator Thoughts/Observations –** Use the space below to record any additional thoughts or observations you have from today's activities (i.e. student actions/comments that surprised you, thoughts about changes you might make if you did this again, thoughts about the physical setting of the classroom, etc)

Appendix B

Post-Treatment Interview Questions

Directions: The following questions should be answered by the facilitator delivering the after-school Engineering Adventures Unit during a summary interview with the principal researcher after the completion of the EA unit.

1. How confident were you in your ability to deliver the Engineering Adventures unit as outlined in the instructor resource guide and training?

2. Did you have all the materials needed to conduct each activity? If not, explain.

3. Were you able to complete each activity as outlined in the teacher guide? If not, explain.

4. Did you follow the teacher guide as it is written? If not, explain any changes made.

5. Do you think students enjoyed this unit of instruction? What activities did they seem to like most?

6. Did the children have difficulty with any of the activities? If so, what do you feel was the cause?

Appendix C

IRB Approval

The University of Georgia

Phone 706-542-3199

Office of the Vice President for Research
Institutional Review Board

APPROVAL OF PROTOCOL

September 28, 2015

Dear Jay Rojewski:

On 9/28/2015, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Influence of STEM Enrichment Activities on 3rd-5th Grade Students' Engineering Identity
Investigator:	Jay Rojewski
IRB ID:	STUDY00002538
Funding:	None
Grant ID:	None

The IRB approved the protocol from 9/28/2015 to 9/27/2016 inclusive. Before 9/27/2016 or within 30 days of study closure, whichever is earlier, you are to submit a continuing review with required explanations. You can submit a continuing review by navigating to the active study and clicking Create Modification / CR.

If continuing review approval is not granted before the expiration date of 9/27/2016, approval of this study expires on that date.

To document consent, use the consent documents that were approved and stamped by the IRB. Go to the Documents tab to download them.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,

Adam Goodie, Ph.D.
University of Georgia
Institutional Review Board Chairperson

310 East Campus Rd, Tucker Hall Room 212 • Athens, Georgia 30602
An Equal Opportunity/Affirmative Action Institution

Appendix D

Participant Data Chart

Participant Data Chart

Last Name	First Name	Participant ID
		699199
		206680
		341502
		696102
		582792
		613726
		548223
		319754
		389334
		390864
		299775
		695883
		253625
		200882
		553775
		398173
		918930
		302887
		352650
		835842
		693913
		658972
		507868
		546130
		577660
		825532
		651902
		153750
		159162
		119101
		460712
		907725
		867105
		337908
		385640
		132533
		387986
		254301
		385390

Appendix E

Permission Letter

Dear Parent/Guardian,

A research study is being conducted as part of a dissertation for a University of Georgia doctoral student during a portion of your child's after-school program. This letter is intended to give you information about the study and seek permission for your child to participate.

Purpose of the Study
The purpose of this study is to determine if participation in a Science, Technology, Engineering, and Mathematics (STEM) enrichment program has an influence on how students identify with engineering as a field of study and potential career choice.

Study Procedures
If you agree to participate, your child will be asked to participate in a STEM unit of instruction within their after-school enrichment program. The STEM unit will be delivered during the first hour of their after-school time and will last for nine days. Some students in the study will not receive the STEM unit during the first round of the study, but will be able to participate during round two. A 16 question pretest and posttest will be given to all students who participate.

Risk and Discomfort
No risk or discomfort is anticipated as a result of participation in this study. The activities that your child will be participating in have been done with thousands of elementary-aged children all over the country.

Benefits
Because of the educational nature of this study, your child will likely benefit by learning new content and skills associated with STEM concepts. Additionally, this research will add to our understanding of identity development of elementary students and provide additional information for other researchers to build on.

Privacy/Confidentiality
The data collected about your child will be connected to a random participant ID and will not be shared externally. Identifiable data will only be accessed by the researcher during the course of the study. The project's research may also be reviewed by a committee of professors at the University of Georgia (UGA). Identifiable results of this study will not be released to anyone other than the researcher and the UGA review committee without your written consent unless required by law.

Taking Part is Voluntary
Your child's involvement in this study is voluntary and you may choose to not allow him/her to participate or have your child stop at any time without penalty or loss of benefits to which they are otherwise entitled. If you decide to withdraw your child from the study, the information that can be identified as your child's will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return, or destroy the information.

If you have Questions
The main researcher conducting this study is Tim Schmitt, a doctoral student at the University of Georgia. If you have questions about the study, you may contact him at tschmitt@uga.edu or at 404-372-4816. If you have any questions or concerns regarding your child's rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706-542-3199 or at irb@uga.edu.

Research Subject's Consent to Participate in Research:
To voluntarily allow your child to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire Parental Permission Form, and have had all of your questions answered.

Your Child's Name: ____

Your Signature: ____ Date _____________

Your Printed Name: ____

Signature of Researcher: ____________________________________ Date _____________

Printed Name of Researcher: _________________________________

Please sign both copies, keep one and return one to the researcher.

Appendix F

Engineering Identity Development Scale (EIDS)

<u>Directions:</u> Read each statement carefully. Select **one** of the three answers that best describes how you feel about the statement. For example, if you **agree** with the statement, "I like recess time," you would rate the statement **Yes** by circling the number 3.

		No	**Not Sure**	**Yes**
1.	I do my school work as well as my classmates.	1	2	3
2.	I am good at solving problems in mathematics.	1	2	3
3.	I use computers as well as my classmates.	1	2	3
4.	I am good at working with others in small groups.	1	2	3
5.	I like being a student at my school.	1	2	3
6.	I make friends easily at my school.	1	2	3
7.	Engineers solve problems that help people.	1	2	3
8.	Engineers work in teams.	1	2	3
9.	Engineers design everything around us.	1	2	3
10.	There is more than one type of engineer.	1	2	3
11.	Engineers use mathematics.	1	2	3
12.	Engineers use science.	1	2	3
13.	Engineers are creative.	1	2	3
14.	When I grow up, I want to be an engineer.	1	2	3
15.	When I grow up, I want to solve problems that help people.	1	2	3
16.	When I grow up, I want to work on a team with engineers.	1	2	3