# AN EXPLORATORY STUDY OF A ROBOTICS EDUCATIONAL PLATFORM ON STEM CAREER INTERESTS IN MIDDLE SCHOOL STUDENTS

by

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ABSTRACT

With the large expected growth in STEM-related careers in American industries, there are not enough graduates to fill these positions (United States Department of Labor, 2015). Increased efforts are being made to reform STEM education from early childhood to college level studies, mainly through increased efforts to incorporate new technologies and project-based learning activities (Hegedorn & Purnamasari, 2012). At the middle school level, a robotics educational platform can be a worthwhile activity that provides hands-on learning as students learn basic programming and engineering skills (Grubbs, 2013). Based on the popularity of LEGO toys, LEGO Education developed an engaging and effective way to learn about computer programming and basic engineering concepts (Welch & Huffman, 2011). LEGO MINDSTORMS offers a project-based learning environment that engages students in real-life, problem-solving challenges.

The purpose of this qualitative study was to investigate the instructional use of a robotics educational curriculum on middle school students' attitudes toward and interests in STEM and their experiences with LEGO Robotics activities. Participants included 23 seventh grade students who were enrolled in a Career Cluster Technologies I class in a suburban middle school. Data for the study were collected from three focus group interviews, open-ended surveys, classroom observations, and the Career Cruising program. Findings revealed that the robotics activities led to an increased interest and higher self-efficacy in STEM tasks. If students continue to nurture and develop their STEM interests, it is possible that many of them may

develop higher confidence and eventually set personal goals related to STEM classes and careers.

While other studies have been conducted on similar topics, this qualitative research is unique because it contributed to the gap in research that investigates the impact of an in-class robotics curriculum on middle school students' attitudes and interests in STEM. Throughout the robotics unit, students exhibited positive reactions, including much excitement and enjoyment as they solved the robotics challenges. In addition, students demonstrated a greater interest in STEM courses and careers as a result of this hands-on activity. Middle school teachers should incorporate STEM-based activities such as robotics to help students gain hands-on STEM skills.

# DEDICATION

I would like to dedicate this dissertation to Mom and Granny, who have been my biggest supporters and finest examples of Christian ladies that I have ever known. I love you both so much and am forever grateful for your love, support, and encouragement throughout my life.

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# CHAPTER I

## INTRODUCTION

In a society that is reliant on emerging technologies, businesses seek employees that are proficient in advanced technology and communication skills (Karp, Gale, Lowe, Medina, & Beutlich, 2010; Liu, Newsom, Schunn, & Shoop, 2013; Naizer, Hawthorne, & Henley, 2014). Many professional and industry positions require employees who are skilled in the areas of science, technology, engineering, and math (STEM). Increasingly, more people are realizing the importance of STEM degree programs. With the rising advances in technology, employees are needed who possess the critical talent to define productivity in business and industry (Grubbs, 2013; Naizer, Hawthorne, & Henley, 2014). According to Sonnert and Fox (2012), college graduates in STEM fields possess this much-needed knowledge, but America's colleges are not producing enough graduates to meet these needs. In particular, fewer women and minorities are entering STEM-related fields of study, which contributes to a shortage of workers in many technology-based industries (Sonnert & Fox, 2012; STEM Education Coalition, 2016).

With growing attention on the nation's need for graduates of STEM degree programs, educators at all levels are faced with the issue of attracting students to these college majors and ensuring that they are prepared for the coursework. According to Thiry, Laursen, and Hunter (2011), middle and high schools have increased efforts to provide more rigorous courses of study in math and science, so that entering college students are better prepared to pursue STEM-related fields of study.

Experiential education (project-based coursework, labs, co-ops, internships, etc.) in secondary education provides worthwhile benefits, such as helping students to establish career goals and develop social and workplace skills (Thiry et al., 2011). Such specific learning experiences contribute to areas of growth including better understanding of the curriculum, enhanced research skills, greater interest in science careers, and development of critical thinking skills (Thiry et al., 2011). By linking these hands-on experiences with specific STEM career goals, students have a greater opportunity for success as they understand the relevance of the course material (Miller & Lauterbach, 2014; Welch & Huffman, 2011). As students learn and participate in STEM-based learning activities, they can make more informed decisions regarding their high school coursework (Grubbs, 2013). Possibly, these activities will inspire a love for science, technology, engineering, and/or math so that students can continue to take classes that will prepare them for STEM-based college programs and careers (Langdon, 2009; Yuen et al., 2014).

At the middle school level, a robotics educational platform can be a worthwhile activity that provides hands-on learning as students learn basic programming and engineering skills (Grubbs, 2013). Based on the popularity of LEGO toys, LEGO Education has developed an engaging and effective way to learn about computer programming and basic engineering concepts (Welch & Huffman, 2011). LEGO MINDSTORMS offers a project-based learning environment that engages students in real-life, problem-solving challenges. Such realistic learning activities are based on Jean Piaget's constructivist learning and Lev Vygotsky's social views on learning (Welch & Huffman, 2011). Project-based learning, constructivism, and collaboration are considered to be important factors in student attitudes and motivation toward science and mathematics (Welch & Huffman, 2011; Yuen et al., 2014). Robotics offers an engineering-based platform that combines STEM concepts as a way for students to work collaboratively to solve a shared problem or reach a common goal.  In addition, robotics can offer ways for students to increase their technological literacy through direct manipulation and a variety of problem-solving tasks (Slangen, Keulen, & Gravemeijer, 2011).

## Statement of the Problem

In a 2014 study, the Bureau of Labor Statistics (BLS) reported that STEM-related careers have a large expected growth rate, but there are not enough graduates to fill these positions (United States Department of Labor, 2015).  According to Hegedorn and Purnamasari (2012), "American policy makers, educators, and others are concerned that predicted workforce shortages in science, technology, engineering, and mathematics (STEM) fields will have a catastrophic impact on the economy" (p. 145).  Specifically, technology-related positions suffer acute shortages in workers.  In a 2012 study, Soldner, Rowan-Kenyon, Inkelas, Garvey, and Robbins maintain that STEM education needs reforms in order to retain students in these fields of study.

Only 1 in 7 students receives a degree in engineering or math in the United States, in comparison with 2 out of 3 students in Singapore and 1 out of 2 students in China (Hegedorn & Purnamasari, 2012).  With these low graduation rates in STEM areas of study, the effects will threaten America's ability to compete in a global society and provide economic growth (Hegedorn & Purnamasari, 2012).  As the number of STEM college graduates decreases, especially among women and minorities, researchers are seeking ways to retain students in STEM majors so that they are better prepared to enter careers in science and technology. Increased efforts are being made to reform STEM education from early childhood to college level studies, mainly through increased efforts to incorporate new technologies as well as project-based learning activities (Hegedorn & Purnamasari, 2012).

## Statement of Purpose

The purpose of this study was to investigate the instructional use of a robotics educational curriculum on middle school students' attitudes toward and interests in STEM and their experiences with LEGO Robotics activities. Since the impact of a middle school robotics platform has yet to fully be explored, the researcher carefully observed students throughout the activities and provided suggested instructional uses of the robotics curriculum.

## Research Question

The research question explored in this study was: What are middle school students' interests and attitudes toward STEM after participating in a robotics curriculum and what are their experiences with the curriculum?

## Significance of the Study

This study contributes to the gap in the body of literature that addresses specific methods middle school teachers can incorporate into their instruction to stimulate interest in STEM-related college majors and careers, including engineering, math, and computer-related degree programs. Since STEM fields wield much influence in communication, transportation, energy, and other areas, engineers and scientists play important roles in the overall workforce (Sonnert & Fox, 2012). The results of the study can provide information to other STEM teachers on the use of robotics in middle school.

## Theoretical Framework

The theoretical framework that guided this study is Social Cognitive Career Theory (SCCT), which focuses on the development and influences of occupational choice (Brown & Lent, 2013). As a way of understanding occupational and educational behavior, Social Cognitive Career Theory helps to explain how people (a) develop occupational interests, (b) make career choices, (c) reach various levels of career success, and (d) attain career satisfaction (Brown & Lent, 2013). In this theory, three cognitive-person variables affect career development: (a) self-efficacy beliefs, (b) outcome expectations, and (c) personal goals (Brown & Lent, 2013; Olson, 2014; Rogers, Creed, & Glendon, 2008). First, self-efficacy is linked to a person's capabilities in particular areas; in effect, past performance accomplishments have a great impact on self-efficacy (Brown & Lent, 2013). If people think that they cannot accomplish a goal, they will not attempt to make it happen (Bandura, 1997). Next, outcome expectations are defined by a person's beliefs regarding the consequences of performing particular activities and, in turn, shape a person's career decisions (Olson, 2014). Last, personal goals refer to a person's intention to participate in an activity and development of career plans (Brown & Lent, 2013; Olson, 2014).

Social Cognitive Career Theory includes four models that focus on (a) development of interests, (b) making decisions, (c) effects on and results of performance, and (d) the experience of well-being or satisfaction (Brown & Lent, 2013; Leong, 2008). According to SCCT's interest model, outcome expectations and self-efficacy help to develop career interests (Brown & Lent, 2013). As they participate in learning experiences at home, school, and the community, young people increase their knowledge and discover their interests regarding different tasks (Bocanegra, Gubi, & Cappaert, 2016). While parents and teachers encourage and provide feedback, students discover skills that encourage further pursuit regarding particular activities.

When young people have a high self-efficacy and positive outcome expectations, they are more likely to develop interest in an activity. As interests develop, they tend to develop goals that increase one's involvement in particular activities (Brown & Lent, 2013; Leong, 2008).

In the SCCT's choice model, the processes of self-efficacy, outcome expectations, skills, and interests lead to the development of a career decision (Brown & Lent, 2013; Leong, 2008). This is a developing process that can be revised over time (Bocanegra et al., 2016). As barriers or even fresh opportunities arise, new paths may open during the course of career selections (Brown & Lent, 2013). SCCT's performance model focuses on the quality of attainment of educational or work tasks and their devotion to those tasks, even when obstacles are encountered (Brown & Lent, 2013; Leong, 2008). This level of persistence is considered to be indicative of performance success as it reflects the degree to which a person is committed to a particular career path (Leong, 2008). The SCCT's satisfaction model focuses on a person's level of happiness in work or academic settings (Brown & Lent, 2013). One's level of satisfaction can be influenced by a strong self-efficacy, involvement in activities that they value, and pursuit toward achieving their goals (Brown & Lent, 2013).

Adolescence is a time of significant career interest and development, and teachers can play a role in inspiring students to pursue STEM careers (Kaminsky & Behrend, 2015; Rogers & Creed, 2011). A robotics activity can provide students with a hands-on, authentic learning experience that simulates real-world engineering concepts. As students work together to solve problems, they rely on each other to overcome barriers and find solutions. According to Social Cognitive Career Theory, self-efficacy and outcome expectations greatly affect choices and personal goals (Brown & Lent, 2013). If a person has high self-efficacy and positive outcome expectations in a particular area, he or she is more likely to devote time, persist in adversity, and even pursue a career in that field (Bandura, 1977; Brown & Lent, 2013). These authentic learning opportunities might lead to a greater interest and higher self-efficacy in the areas of STEM. As a result, these robotics activities have the potential to play key roles as students make decisions regarding academic and career goals (Leong, 2008).

## Methods

The researcher approached this qualitative research from a Social Cognitive Career Theory perspective. Participants included 23 seventh grade students who were enrolled in a Career Cluster Technologies I class in a suburban middle school. Data for the study were collected from three focus group interviews, open-ended surveys, classroom observations, and the Career Cruising program. The researcher, who was also the teacher, utilized the STEM Interest Inventory Observation Tool (Franker, 2015) found in Appendix D and at www2.uwstout.edu/content/profdev/rubrics/secondaryteamworkrubric.html to document behaviors during the group activity. According to Dr. Franker, the tool was vetted with a small group of secondary teachers but has not undergone formal testing by educational researchers. Throughout these observations, the researcher used the observation tool to document the participants' experiences with the robotics curriculum.

Data collected from the focus group interviews, open-ended surveys, and questionnaires were analyzed to further inform the research regarding participants' attitudes and interest in STEM topics and careers. The data were examined using constant comparative analysis, which entails making comparisons at all stages of the process. In this method, the researcher compared the analysis to prevailing ideas about the topic (Charmaz, 2006). In addition, triangulation and crystallization were utilized throughout the study to enhance the interpretation of the data (Tracy, 2010). Triangulation is vital to provide multiple views, increasing the scope and deepening the understanding of the material, which offers a more complex understanding of the material. By using different data collection techniques, the researcher used triangulation to strengthen the qualitative study as it provides various viewpoints of the same experience (Denzin & Lincoln, 2000; Glesne & Peshkin, 1992; Tracy, 2010). Crystallization involves telling a story from different points of view (Denzin & Lincoln, 2000). Throughout the study, the researcher gathered responses from the participants about themselves and each other, as well as with firsthand observations of the participants performing the activities. By gathering evidence from multiple points of view, the research reflected on different perspectives of the same activity (Denzin & Lincoln, 2000).

## Assumptions of the Study

This research study was based on the following assumptions: (a) the technology and equipment were available and in proper working condition, (b) the participants responded truthfully to all focus group and interview questions, and (c) the participants understood the robotics activities.

## Limitations of the Study

This research study had the following limitations: (a) due to the small sample size, the researcher recognizes that the results of this study might not be generalizable to other middle school classrooms; (b) due to a limited time frame of a 10-day unit, a longer study could yield different results; (c) the teacher had not previously used this curriculum; (d) the observation tool has not been used in a formal study; (e) with only one researcher to observe six groups, additional observers might prove useful to spend more time studying each group; and (f) the participants had not participated in previous LEGO Robotics activity, so there was a possibility of the novelty effect.

## Operational Definitions of Terms

*21st Century Learning Skills:* The knowledge, skills, and expertise that students need to prepare for work and life in the 21st century. A focus on communication, critical thinking, creativity, and technology skills will help to prepare students for life in the future (P21 Partnership for 21st Century Learning, 2015).

*Alabama Math, Science, and Technology Initiative (AMSTI):* AMSTI is a state-supported program that was developed to support mathematics and science problem-solving skills (Newman et al., 2012). Chapter III provides a more in-depth discussion of the AMSTI program.

*Career Cruising:* A web-based career planning program that allows users to learn about themselves so that they can explore career possibilities and set school and life goals (Career Cruising, 2016).

*Career Cluster Technologies I:* Curriculum that provides 7th grade students with the knowledge and skills to increase their technological literacy as they learn about the 16 career clusters and associated careers (Alabama State Department of Education, 2008).

LEGO Robotics: A robotics platform that helps students learn math and science skills as they create and manipulate their own robots. This fun and educational science toy allows children to develop creativity and problem-solving skills as they simulate real-world scenarios (Shih, Chen, Wang, & Chen, 2013).

*Middle School Students:* For this study, middle school students include students in grades 6, 7, and 8.

*Science, Technology, Engineering, Arts, and Math (STEAM):* A framework for teaching that includes science, technology, engineering, arts, and math that is based on exploratory learning (STEAM Education, 2015).

*Science, Technology, Engineering, and Math (STEM):* Learning, teaching, and careers in the fields of science, technology, engineering, and math (Gonzalez & Kuenzi, 2012; Koonce, Zhou, Anderson, Hening, & Conley, 2011).

*Technology:* For the purposes of this study, technology refers to digital technologies that include laptop and desktop computers, iPads, mobile devices, and LEGO Robotics software.

*Technology Skills:* The ability to evaluate and apply information, media, and technology (P21 Partnership for 21st Century Learning, 2015).

## Summary

This dissertation includes five chapters. Chapter I contains an introduction, statement of the problem, statement of purpose, theoretical framework, methods, and research questions. Chapter II reviews the professional literature related to this study. In Chapter III, the research methodology details the setting, participants, instrumentation, data collection, and data analysis. Chapter IV contains the results of the study, and Chapter V includes a discussion of the results, implications of the study, and future recommendations.

CHAPTER II

REVIEW OF RELATED LITERATURE

## Introduction

With an increased need for employees who are college graduates in STEM-related fields, K-12 educators are seeking ways to introduce students to these areas of study. By taking advanced math and science classes in high school, students will more likely become interested in science, math, engineering, and math college majors (Melguizo & Wolniak, 2012). In their longitudinal study, Melguizo and Wolniak (2012) indicate a positive relationship between STEM college majors and careers that are closely related to science, technology, engineering, and math. The authors further suggest that educational institutions and industries should work together to create valuable learning experiences for students, so that they can realize the potential salary benefits of earning STEM-related degrees in college. Furthermore, such motivational efforts should begin in middle school, as students take coursework and participate in learning opportunities to prepare for STEM college majors (Melguizo & Wolniak, 2012).

Thiry et al. (2011) conducted a multi-institutional research study from four liberal arts colleges that consisted of 62 interviews with STEM students to determine if hands-on educational activities contribute to their overall learning experiences. The researchers concluded that such specific learning experiences impact areas of growth including greater understanding of the curriculum, enhanced research skills, increased interest in science careers, and development of critical thinking skills. In yet another study, participants from ages 12 – 19 in multiple schools reported increased attitudes and interests toward STEM as a result of educational robotics activities (Kandlhofer & Steinbauer, 2016). In general, robotics programs are successful, as they provide real-life learning that is measurable, and offer activities that produce higher student engagement and motivation (Gura, 2011).

Although some studies exist that examine related topics, no relevant studies were found that used the Social Cognitive Career Theory to examine middle school students' experiences with a robotics curriculum and its impact on their interests and attitudes toward STEM and STEM careers. While a comparable study determined that an after-school middle school robotics program resulted in a greater interest in engineering careers (Blanchard et al., 2015), another study showed that middle school students demonstrated increased self-efficacy and STEM learning, such as mathematics, computer programming, engineering, and geospacial technologies, as an effect of robotics tasks (Nugent, Barker, Grandgenett, & Adamchuk, 2010). Similar studies supported that middle school robotics activities resulted in increased critical thinking, creativity, innovation, collaboration, and other STEM-related skills (Ardito, Mosley, & Scollins, 2014; Eguchi, 2016; Yuen et al., 2014). In related studies, robotics activities have been shown to foster creativity and increase STEM content knowledge in K-12 students (Williams, Igel, Poveda, Kapila, & Iskander, 2012). Robotics activities have also been shown to enhance creativity and innovation skills in high school minority students (Erdogen, Sencer, Corlu, & Capraro, 2013) and college students (Eguchi, 2014). In additional studies, robotics activities have resulted in an increased interest for high school and college students in STEM careers (Ayar, 2015; Kandlhofer & Steinbauer, 2016; Williams et al., 2012). Using the Social Cognitive Career Theory (SCCT), the researcher contributes to this gap in literature by examining middle school students' interests and attitudes about a robotics curriculum as well as their attitudes toward STEM.  Based on these findings, the researcher suggests hands-on, real-world learning activities that will create a greater interest in STEM courses and careers.

## The Importance of STEM Education

While there is no common definition of STEM, most experts agree that STEM workers often use technology to solve real-world problems in science, technology, engineering, and mathematics (Vilorio, 2014).  Such fields are closely related and rely on each other.  Vilorio defines the fields as follows:

*Science:*  Scientists often use the scientific method to test theories and hypotheses.  They often conduct research and present their results.  Disciplines include physics, chemistry, life sciences, earth sciences, and space sciences.

*Technology:*  STEM technology workers use engineering and science to create and maintain computer networks and develop software.  These technology fields of information and computer sciences include programming, artificial intelligence, mobile computing, and operating systems.

*Engineering:*  Engineers develop materials or systems that use science and mathematics to solve real-world issues.  Engineering disciplines include materials, mechanical, industrial, civil, and chemical engineering.

*Mathematics:*  Mathematicians analyze and solve problems using spatial and numerical relationships.  Math disciplines include algebra, geometry, calculus, and statistics.

While STEM occupations can be rewarding, such jobs can also be tiresome and demanding.  Since STEM fields are rapidly changing, workers must adapt to the variety of challenges they face each day.  They must stay abreast of changes in their fields, but they often feel valued for their expertise and skills. STEM workers also collaborate with other experts as they work together to solve problems (Vilorio, 2014).

According to the STEM Education Coalition (2013), STEM education is a national priority. U.S. companies are having difficulties finding employees to fill their positions, and in STEM fields, there is a great shortage of STEM workers. STEM experts recommend that potential STEM workers possess the education, skills, and background needed for jobs in these fields. According to the U.S. Department of Education (2016), students should learn STEM skills such as gathering information and solving problems in order to better prepare students for careers in STEM fields.

*Education:* Most of the STEM fields require a college degree, such as a technical or bachelor's degree, while more advanced jobs require a master's or doctoral degree. While in high school, students can begin taking advanced math and science classes, as well as register for college technical classes.

*Skills:* Creative and critical thinking skills are needed to develop effective solutions to problems. In addition, communication skills are important to explain challenging concepts or communicate ideas via speaking and writing.

*Background:* Background and experience are often required to obtain STEM positions. Such experience can include volunteer work or internships that help to develop communication and problem-solving skills (Vilorio, 2014).

While there are many choices in STEM programs of study, students should begin taking advanced math and science classes in high school to prepare for the rigorous college coursework in STEM majors. In order to encourage students to enroll in such coursework, high schools are developing hands-on, collaborative approaches such as robotics to build interest and awareness in engineering and science. Studies have demonstrated that educational robotics activities have increased student interest in STEM (Eguchi, 2016). Since robotics is an inherently collaborative activity, such opportunities can provide a greater motivation in further exploring STEM fields of study (Gura, 2011). As a result, the greater interest and positive attitudes may lead to careers in STEM fields (Welch & Huffman, 2011).

## STEM Initiatives

According to the Microsoft STEM survey, while 93 percent of K – 12 parents believe that STEM education *should be* a priority in schools, only 49 percent indicated that it truly *is* a priority (STEM Education Coalition, 2016). National STEM initiatives seek to provide students with a STEM education that prepares and empowers students to enter the STEM workforce. According to the National Math + Science Initiative (2016), only one-third of middle school math and science teachers are certified to teach in these areas. Since there is an inadequate number of math and science teachers, a national priority has been set to prepare students and teachers who are proficient in these fields. The Committee on Stem Education (CoSTEM) was developed to help improve youth instruction and engagement with STEM in order to better prepare tomorrow's workforce (U.S. Department of Education, 2016).

The STEM Initiative, developed by Teach for America and the Amgen Foundation, also seeks to supply qualified elementary and secondary math and science teachers to schools throughout America. Currently, approximately 3,500 of the corps teachers are working to provide students with a high-quality STEM education (Teach for America, 2016). It supports increased funding for higher quality STEM activities during class time, after school hours, and summer school programs, which have been shown to increase student learning in STEM areas (Brown, 2012). In addition, there is a strong emphasis on collaborative, hands-on, inquiry-based instructional activities, including partnerships with STEM professionals and participation in STEM competitions. As middle schools implement STEM activities that include real-world problem solving skills, benefits include an increase in students' academic achievement as well as social skills of students (Lambert, 2014). Inquiry-based STEM activities have also been associated with more positive student attitudes toward science and STEM-based careers (Finnerty, 2013).

Another initiative, the National Math + Science Initiative's (NMSI's) College Readiness Program, helps to increase college preparation. According to NMSI (2016), students that pass AP exams in high school are three times more likely to earn a college degree. This program seeks to help students enroll and pass AP courses in math, science, and English. As a result, the 83 schools that participated in the NMSI's College Readiness Program saw dramatic results as the number of AP exams passed grew from 4,407 to 7,370 (National Math + Science Initiative, 2016).

In Alabama, a new program of study called Career Cluster Technologies has been implemented to replace the traditional Family and Consumer Sciences (FACS) curriculum in middle schools. With an emphasis on career explorations, students participate in hands-on technology projects that help to solve real-world problems. Students gain skills in the application of technologies in different areas including communication, medicine, agriculture, manufacturing, and other technologies. These courses help to develop workplace readiness abilities, improve leadership skills, and provide opportunities for professional and personal growth. As students explore the engineering design process, they gain creativity, resourcefulness, research, and collaborative skills. As an optional program for

Career Technologies classrooms, another state initiative called *Project Lead the Way (PLTW)* provides structured, challenging STEM activities (Lawrence & Mancuso, 2012).

An Alabama program, the Alabama Math, Science, and Technology Initiative (AMSTI) seeks to improve math and science instruction (Newman et al., 2012). AMSTI strives to enhance science and math teaching in Alabama, and it has produced positive results. Teachers report that students who participate in AMSTI enjoy the activities and learn and remember more of the information (Alabama Department of Commerce, 2013). Also, students gain an average of 50 days of math instruction. After two years of AMSTI classes, students on average improved 4 percentile points in comparison with students not in the program. This Alabama STEM education initiative helps students learn math and science with exciting, hands-on activities. AMSTI materials, professional development, and ongoing support are provided to teachers. Former State School Superintendent Tommy Bice stated that his goal was to prepare students for college or the workforce. As a result of this program's success, this model is being considered by other states and over 21 countries, including Mexico, China, and Russia (Alabama Department of Commerce, 2013).

Similar to the STEM initiative, STEAM includes the disciplines of science, technology, engineering, arts, and mathematics. Some experts recognize the value of arts and imagination in the scientific inquiry, and so the arts were included in the STEAM paradigm (STEAM Education, 2015). Since the visual arts and aesthetics reinforce engineering concepts, the need for engineers to have these skills was recognized. Examples of companies that require engineers to have artistic skills include Disney and Apple (Watson & Watson, 2013). Schools throughout the United States have adopted this model as they learn how all things relate to each other in a more natural environment (STEAM Education, 2015). Most of the materials are based on items that are readily available, rather than purchasing expensive equipment and supplies. Educators can use lessons that are readily available or adapt them for their own students based on current events. Lessons are not created by a small group of teachers, but rather can be customized by the teacher or group of teachers according to the needs and interests of the students (STEAM Education, 2015).

## The Importance of STEM Graduates in the Workforce

With increasing technologies, businesses and industries seek employees that are proficient in STEM areas. "There is a recognized shortage of domestic-born scientific and technical expertise in the United States" (Dubetz & Wilson, 2013, p. 41). With stricter immigration laws, foreign-born math, science, and technology majors often are not allowed to stay and join the U.S. workforce. As a recognized world leader in technological and scientific developments, the shortage of technical personnel will greatly impact the global market of the United States (Dubetz & Wilson, 2013). According to the U.S. Bureau of Labor Statistics (BLS), job growth in STEM employment fields is anticipated to result in an increase of more than 1 million jobs from 2012 to 2022, with a total of over 9 million jobs in STEM areas, but many U.S. students will be unprepared to enter these jobs. This 13 percent growth rate in STEM fields is greater than the 11 percent growth rate in all occupations during this time frame (STEM Education Coalition, 2016; Vilorio, 2014).

In addition to the STEM needs in the workplace, our everyday lives are centered around modern technologies, including cell phones and computers. "Lack of understanding in science and mathematics adversely affects society, not only by contributing to deficiencies in technical and scientific personnel, but also by citizens making uninformed decisions" (Dubetz & Wilson, 2013, p. 1). A certain level of mathematical and scientific understanding is necessary to make informed decisions as consumers, as well as voters that make decisions about the environment, economy, industry, and our society.  One of the top priorities for researchers and policy makers is to increase the skills of STEM employees (Christensen et al., 2014).

While colleges seek to attract and maintain students who will study STEM-related majors, such programs are adjusting their instruction to meet the needs of industries.  For example, "Engineering training must cover both theoretical aspects as well as practical applications that show the students how to relate the abstract knowledge they learn in the lecture sessions with real world problems and their difficulties" (Cruz-Martin et al., 2012, p. 974).  Such practical applications are inherent to developing graduates that can apply their learning to real-world settings in STEM environments.  Middle school career and technical education programs can play a vital role in providing STEM instruction that includes project-based learning and real-world applications, especially when they can establish connections between what they are learning in classes and future careers (Wu-Rorrer, 2015).  Such middle school programs that combine math and science to solve engineering problems can increase students' desire and interest in STEM courses in high school and college, as well as stimulate a desire to pursue some STEM careers (Kutch, 2011).

## Shortage of Women in STEM Majors and Careers

While there exists a major shortage of workers to fill STEM jobs, the number of females interested in STEM careers is much lower.  Even though women represent half of the U.S. workforce, they only fill 25% of STEM jobs (Naizer, Hawthorne, & Henley, 2014).  According to Christensen et al. (2014), this trend begins in middle and high school, as females tend to take fewer advanced science and math classes than males.  "Girls tend to prefer to learn in a more social context and need to see connections between school assignments and the real world" (Christensen et al., 2014, p. 174).

In addition to the shortages to fill STEM positions, there are also gender disparities among women who complete degrees in science, math, technology, and engineering. Even though these areas have been declared "areas of national need," there still exists a shortage among graduates to fill related positions (United States Department of Labor, 2015). According to Shapiro and Sax (2011), women, especially, are underrepresented in STEM college programs, especially in the fields of physical sciences, computer sciences, and engineering. The effects include a lack of women who are prepared for 21st century skills in the engineering and science workforce (Shapiro & Sax, 2011). Sonnert and Fox (2012) explain that the effects of obvious gender disparities in STEM majors result in a loss of potential contributions by women to these fields of study. Shapiro and Sax (2011) suggest creating opportunities for more females to be successful in STEM-related degree programs. Such programs must begin in middle and high schools, as females should take more math, science, and computer science courses with their male classmates (Hyun, 2014; Kier, Blanchard, & Albert, 2014; Naizer, Hawthorne, & Henley, 2014). Most females prefer coursework that helps them connect their learning to real-life situations (Lawrence & Mancuso, 2012; Shapiro & Sax, 2011). In addition, Shapiro and Sax (2011) have noted the competitive nature of most STEM coursework should be changed to a more supportive climate for success.

As a way to promote middle school girls' interest in science and engineering, *Girls Excited about Engineering, Mathematics, and Computer Science (GE2McS)* was developed as an extension of the Project Lead the Way (PLTW) initiative. These hands-on activities promote girls' participation in the study of engineering. GE2McS "is a program designed to nurture girls' enthusiasm for technology and engineering; encourage their continued participation in these fields in high school and college; and increase their awareness of the array of career opportunities within these fields" (Lawrence & Mancuso, 2012, p. 11). Based on the results of this program, there is a correlation with girls that participate in this program and later major in engineering in college. In yet another middle school robotics course, females reported positive experiences with robotics as they participated in real-world learning experiences and indicated a higher confidence regarding their abilities in STEM fields (Hyun, 2014). As young women participate in middle and high school technology courses, they might develop a greater interest in STEM majors if they take part in career explorations and engineering classes (Lawrence & Mancuso, 2012, p. 16).

## 21st Century Learning Skills and Robotics

With the purpose of ensuring 21st century readiness for all students, The Framework for 21st Century Learning was developed (P21 Partnership for 21st Century Learning, 2015). In order to produce a support system for today's students, learning environments, curriculum, instruction, assessments, and 21st century standards should focus on producing 21st century outcomes for today's learners (P21 Partnership for 21st Century Learning, 2015). The critical systems include Core Subjects and 21st Century Themes; Learning and Innovation Skills; Information, Media, and Technology Skills; and Life and Career Skills. Three important elements compose the Learning and Innovation Skills category: Creativity and Innovation, Critical Thinking and Problem Solving, and Communication and Collaboration. With the implementation of a hands-on robotics platform, these three elements of learning can take place in an innovative and exciting way to produce the desired learning results in STEM content areas.

Robotics learning environments enhance creativity and innovation skills as students use previous knowledge to make scientific inferences to construct new products (Erdogan, Sencer Corlu, & Capraro, 2013). In a study by Eguchi (2014), student participation in an undergraduate educational robotics course increased learning for creativity and innovation skills as well as other STEM skills, including collaboration, communication, and problem solving skills. The college institution in Eguchi's study primarily serves underprivileged, first-generation college students, many of whom are African Americans and Hispanics. In the study, data were collected from teacher observations and student reflective essays. This educational robotics course was developed to promote interest in robotics and engineering fields, as well as to increase 21$^{st}$ century learning skills. Such skills are important for our nation's youth to continue to develop technological innovations (Eguchi, 2016).

In another study by Erdogan et al. (2013), high school students engaged in robotics activities using LEGO MINDSTORMS robots during a two-week summer camp. Participants in the study were eleventh graders from an inner city school in Texas that primarily served economically disadvantaged youth. In this quantitative study, students completed a fifteen-question pre- and post-activity questionnaire that assessed their perceived increased innovation literacy skills. There were no Caucasian students in the camp and no gender differences in the results. Whereas African Americans experienced a significant gain in science and mathematics skills, Hispanics demonstrated an increased degree of creativity. While the current study indicates that robotics activities can greatly contribute to learning abstract science concepts, such learning opportunities can also enhance innovation literacy skills in minority students (Erdogan, Sencer Corlu, & Capraro, 2013).

Critical thinking and problem-solving skills are also enhanced through robotics activities. In the RoboCupJunior competitions, students may use any robotics platform, but the focus is on student learning, rather than competition (Eguchi, 2016). This educational robotics initiative stands apart from similar activities, since the committee members improve the rules each year to enhance the learning experience of students, with a scaffolding learning environment. As the students improve their knowledge and skills, they improve their robots and develop more technical solutions, further advancing their problem-solving skills. The leagues, or challenges, are based on topics of interest to students to motivate and attract them to STEM activities – especially robotics (Eguchi, 2016).

Finally, robotics activities promote communication and collaboration skills, which are vital skills to be successful in STEM fields (Eguchi, 2016). In a one-week summer robotics camp at a large university in Texas, Yuen et al. (2014) found that elementary and middle school students demonstrated both cooperation and collaboration while designing and building robots. These experiences were engaging for the students, as the instructors facilitated collaboration that resulted in students' synthesis of ideas. When educators design robotics activities, they must recognize the importance of assisting students in collaborative activities, since some students are not accustomed to group work, and certain activities are more appealing than others. Overall, the robotics activities provided engaging, challenging activities that promoted collaboration as students worked together to design, construct, and troubleshoot their robots (Yuen et al., 2014).

Ardito et al. (2014) examined the roles of cooperation and collaboration in a sixth-grade classroom during semester-long robotics activities. Through teacher observations and student blogs, their study results indicated that collaborative efforts enhanced the students' perceptions of the group work. Increasingly, students used terms such as "our" and "we" and also began referring to their “group” as a “team” (Ardito et al., 2014). These authors suggest that class activities can be reshaped to include such groups so that students can collaborate productively with their peers as they work together to solve real-world problems.

In order to promote such collaborative classroom activities, classroom organization must change from traditional teacher control to student-led projects with teacher assistance (Gura, 2011). In addition, changes in the behaviors of students and teachers are vital, as students engage in project-based learning activities (Gura, 2011). When students are provided with informal instruction on STEM concepts, they can learn problem-solving skills through project-based learning (Barak & Zadok, 2009). In order to promote more meaningful learning in class, the teacher should adjust from strict teaching to a more flexible manner so that students can have more control while working on their projects (Barak & Zadok, 2009). As control shifts from the teacher, students can take control and trust themselves, which gives them more ownership and power in their own learning (Martinez & Stager, 2013).

Among other benefits, a robotics platform can provide students with an increased technological literacy, which is explained in different ways, but all of the definitions of technological literacy emphasize ways that we interact with technology. In particular, a functional technology literacy suggests applicability and hands-on capabilities with science and technology (Slangen et al., 2011). With robotics, other learning contexts involve a deeper understanding of physics, engineering, and programming. In addition, students develop problem-solving skills as applicable to science and technology (Slangen et al., 2011). Robotics can be “an ideal platform for concepts to be introduced to support youth success with building, testing, and refining their robotics/geospatial projects” (Nugent et al., 2010, p. 404).

While challenging STEM concepts are supported by a robotics platform, teamwork, creativity, and problem-solving skills are also greatly enhanced. An inherently collaborative activity, robotics projects closely resemble real work efforts, as students divide efforts, brainstorm ideas, and work together for a group project (Gura, 2011). Such educational opportunities encourage students to further explore math and science topics, which can enhance STEM learning in our technology-rich world (Nugent et al., 2010; Yuen et al., 2014). Robotics is a cross-disciplinary field, which helps students better understand how different subjects interact with each other (Gura, 2011). Since engineering topics often require different types of knowledge and skills, collaboration is an important skill in learning and in the workplace. "Collaboration is important to the learning process because it brings together multiple perspectives, ideas, and abilities" (Yuen et al., 2014, p. 39). "Robotics programs can be as structured or free-form as you like, and kids with different levels of expertise can learn from one another, which makes them great for collaboration" (Fraser & Vernola, 2014, p. 33).

With a robotics platform for learning, students can solve real-life problems, such as realistic engineering scenarios through design challenges. "Working through the engineering design process to solve a robotics problem quickly allows students to connect and apply science concepts of current, voltage, and resistance, while applying math through scaling and graphing, calculating wheel rotation, and predicting how far the robot will travel" (Grubbs, 2013, p. 12). As students participate in robotics programs, they demonstrate an enjoyment in creative and design-based activities (Blanchard et al., 2015). Such hands-on lessons give students a better understanding of the work of engineers. Many students might not understand the role that engineers play in society and need real-world connections for them to learn about the skills and education required for STEM careers (Blanchard et al., 2015).

Students also use math concepts and predictive analysis to determine what their robot will do. In addition, they can use trial and error to make predictions and adjustments, until their calculations are more precise. This learning platform allows students to further explore realistic ways that robots can improve our society. According to Grubbs (2013), students also develop important workplace skills, such as collaboration and teamwork. Most importantly, students are genuinely interested not only in STEM skills, but also in authentic, real-world learning.

As in actual engineering problems, robotics requires a change in the order of learning (Gura, 2011). With the experimental nature of robotics, students first envision and construct a model. Then they attempt an initial "build" and try to create a program that provides instructions for the robot. After program adjustments, with a "back-and-forth" manner, they can later understand the learning concepts in the activity (Gura, 2011). Robotics requires much "trial-and-error testing" as students make modifications to the robot, the program, or both (Gura, 2011). Robotics is informal and discovery-based, even though much learning is involved (Gura, 2011). This constructivist approach to student learning allows students to make discoveries, since they better understand and communicate their successes and failures from a shared learning activity that is largely student self-directed (Gura, 2011).

As a way to help students better understand what engineers do and to promote interest in these fields, schools should provide robotics learning activities. Working with parents and the community, schools can also provide more hands-on, problem-based learning activities such as robotics to help students gain a greater awareness of engineering work. "The goal of these activities is to pave the way for students to embrace engineering, consider engineering careers, and align their educational and occupational ambitions" (Blanchard et al., 2015, p. 11).

In a mixed-methods study by Blanchard et al. (2015), the authors find that students gained a greater interest in engineering after taking part in an after-school robotics program. In addition, middle school participants in this inquiry-based robotics program indicated an increased interest in earning a college degree. Participants in the program came from three different schools in a primarily minority, low-income community. While 80 students were enrolled in the robotics program, 54 students completed the pre- and post-questionnaires that addressed students' school attitudes, as well as engineering knowledge, interests, and career plans. Students who did not participate in the after-school robotics program also completed the questionnaires, with 1,943 students completing the survey in the fall and 1,835 students completing the survey in the spring. In addition, 19 of the students participated in focus groups to gain a better understanding of participants' views of problem solving, school, and engineering. As a result of these activities, students' enthusiasm increased for engineering careers, which extended into the broader school culture. However, only participants in this program demonstrated an increased understanding of the skills and education required for engineering and science careers. As a result, the authors suggest that teachers and industry mentors should provide encouragement and information regarding college STEM degrees as students participate in these robotics activities (Blanchard et al., 2015).

## LEGO Robotics Educational Platform

As educators seek ways to introduce students to STEM topics, an innovative, hands-on learning approach is the use of robotics tools. "Robotics in education is an expansive trend, and at present, more and more educational institutions, ranging from elementary school to college, are including robotics in their curricula" (Cruz-Martin et al., 2012, p. 975). Robotics offers great opportunities for bringing fun and excitement into a classroom, and also encourages interest in technology-related careers (Johnson & Londt, 2010). In addition, "robotics provide[s] the opportunity for students to bring their individual interests, perspectives, and areas of expertise together in order to work collaboratively on real-world science, technology, engineering, and mathematics (STEM) problems" (Yuen et al., 2014, p. 39).

Robotics technology can introduce students to experimental investigations in math and science classrooms, potentially bringing the various STEM disciplines together in a way that helps the learner to solve real-life issues (Williams et al., 2012). In addition, robotics "programs that engage students in authentic scientific problems can significantly improve students' attitudes and views of science," and in turn, "the positive attitudes and interest may also lead to future careers in science-related fields" (Welch & Huffman, 2011, p. 423).

A robotics platform can produce a positive impact on student learning, as demonstrated throughout the literature. In a quantitative study conducted by Nugent et al. (2010), 141 students (average ages 11 – 12) participated in a 40-hour summer intensive robotics camp in an effort to get them excited about technology and improve their attitudes toward STEM topics. "Students participating in the week-long intervention clearly increased their STEM learning, as measured by a content test covering topics in computer programming, mathematics, geospatial technologies, and engineering" (Nugent et al., 2010, p. 402). The pre- and post-assessment contained 37 multiple-choice questions that covered computer programming, geospatial concepts, mathematics, and engineering. In addition, students completed a pre- and post-questionnaire with 33 Likert scale items that included topics on attitude, motivation, self-efficacy, motivation to learn, and learning strategies. As a result of the robotics camp, students also demonstrated a greater self-efficacy to perform robotics tasks. The authors concluded that such an intensive, week-long robotics curriculum can increase students' understanding of challenging STEM concepts. Results showed that the short, three-hour intervention increased students' interest in STEM-related subjects, which has the potential to motivate students to learn more about STEM topics and careers (Nugent et al., 2010).

In yet another study, a robotics summer camp provided first-hand experiences with STEM concepts and developed and maintained student interest in engineering topics and careers (Ayar, 2015). In addition, robotics contests have also led to an increased interest in the robotics, computing, and engineering fields (Qidwai, Riley, & El-Sayed, 2013; Ruiz-del-Solar, 2010).

One of the most innovative, popular choices of robotics platforms is LEGO Robotics. While there are several platforms, varying by complexity as well as cost, LEGO MINDSTORMS kits provide a range of versatility as well as wide array of topics that can be taught, as it excites and educates young students (Cruz-Martin et al., 2012; Karp et al., 2010). LEGO Robotics materials are affordable, durable, readily available, and easy to learn, and so are often the favored choice by teachers, schools, and international robotics competitions (Gura, 2011). While teachers are not required to have advanced programming skills, a reasonable level of comfort with computers is suggested. Coaching is the most ideal skill, in order to guide and motivate students to discover solutions to their own problems (Gura, 2011).

Based on Seymour Papert's constructionism as well as constructivism, the design of LEGO Robotics empowers children to learn math and science concepts as they design, build, and troubleshoot different projects (Shih et al., 2013). This educational toy of science cultivates creativity and problem solving abilities in the learning process. According to Shih et al. (2013), another exciting aspect of the LEGO Robotics platform is its playfulness, which is a major factor to attract children. Even though students find the platform to be sometimes difficult, they report that they would like to use LEGO Robotics more often in the classroom. Overall, this toy with educational meaning provides significant learning effects and has a positive impact on improving students' knowledge and skills (Shih et al., 2013).

The LEGO company first added electric motors to its train sets in 1966. As the market developed, LEGO MINDSTORMS was released in 1998. The most recent versions, LEGO MINDSTORMS NXT and LEGO EV3, are most popular today. As the LEGO company inspires children to become interested in math and science, it has dominated the market with fun and educational robots. Thanks to its versatility, educators at all levels can use robotics to teach hands-on math and science concepts to students, further inspiring an interest in STEM topics (Langdon, 2009).

With the connections to STEM standards, the LEGO Robotics platform has the potential to reach and inspire young people as they often would participate in these opportunities outside of school (Donovan & Sullivan, 2012). LEGOs are often targeted to boys, and so many girls report that they have little to no experience with these fun building blocks (Donovan & Sullivan, 2012). The LEGO Robotics allows students to engage in teamwork as both boys and girls learn to solve problems in a collaborative environment. It is quite likely that engaging robotics activities will spark a greater interest in STEM topics and possibly motivate them to pursue career fields in science, technology, engineering, and math (Donovan & Sullivan, 2012).

LEGO MINDSTORMS kits have been used in classrooms from elementary to college levels, and they are popular for several reasons. Not only are the LEGO Robotics systems fun, but they are also relatively easy to learn for all levels of programmers (Qidwai et al., 2013). Also, they are fairly inexpensive and can be used interchangeably with other systems. As students participate in these enjoyable activities, they learn basic computer programming and mechanical engineering concepts. According to these authors, this "learning by doing" approach is universally popular with students (Qidwai et al., 2013, p. 524). While the LEGO robot might not initially do what the students plan for it to do, it will likely do something so that users are encouraged to make adjustments to the code in order to better manipulate the robot to do as they intend. This problem-solving approach gives the students confidence as they correct errors and debug the program, which are also important skills in engineering disciplines (Qidwai et al., 2013).

In a K-12 teaching environment, the LEGO Robotics platform was used to teach New York State as well as national learning standards for math and science. The lessons were developed to promote inquiry and collaboration. Throughout the hands-on explorations, students were more intrigued with the topics of math and science. As students completed learning goals, the LEGO MINDSTORMS-based lessons fostered their creativity and allowed for more enjoyable learning (Williams et al., 2012). An additional observation was that students were more actively engaged throughout the robotics lessons. When measuring student outcomes, the LEGO MINDSTORMS-based experiments proved effective as students demonstrated an improvement in content questions in K-12 science and math subjects (Williams et al., 2012).

## Motivating Students to Consider STEM Careers

According to Kier et al. (2014), the number of new jobs in STEM fields is expected to rapidly increase, but students often lose interest in STEM topics in early high school. Often careers in STEM are viewed as requiring too much education, and the professionals in these fields are seen as noncreative and boring. If teachers are to motivate students to consider STEM careers, it should begin at the middle school level (Kier et al., 2014). Actually, many teachers and students are unaware of the wide array of careers in STEM fields, especially those individuals who are in underserved populations or live in rural areas. Female role models and mentors can motivate young women to better realize their potential in STEM fields. Classroom projects can help to promote and encourage an interest in STEM fields. In particular, hands-on math and science activities that provide field and laboratory experiences can motivate students to consider potential STEM career opportunities (Dubetz & Wilson, 2013; Kier et al., 2014).

A prevalent attitude for students not to enter STEM careers is that "STEM courses are often viewed as difficult and sometimes unrelated to reality" (Christensen et al., 2014, p. 174). In order to get students excited about science career opportunities, it is important for teachers to make real-life connections with the curricula. "Connecting curricula to authentic experiences helps students appreciate why learning science matters" (Miller & Lauterbach, 2014, p. 17). When students begin to picture themselves in science or math roles, the learning becomes more relevant and exciting. In addition, "interest and motivation play a vital role in the selection of a science career" (Miller & Lauterbach, 2014, p. 21). This cultivation of interest in STEM-related fields should begin in middle school, as interest plays an even greater role than achievement in science and math in determining whether students will pursue STEM degrees (Miller & Lauterbach, 2014). Robotics can play a key role in increasing STEM skills, understanding, and attitudes (Nugent et al., 2010).

## Social Cognitive Career Theory

The Social Cognitive Career Theory (SCCT) is the theoretical framework guiding this qualitative study. Based on Bandura's (1977; 1986; 1997) Social Cognitive Theory (SCT), this theory explains human behavior as a result of behavioral, environmental, and cognitive events. According to the Social Cognitive Theory, there are three aspects of career development: (a) formation of career interests, (b) selection of career and academic options, and (c) performance and persistence in career pursuits (Lent, Brown, & Hackett, 1994). To better understand career development, SCCT focuses on the three variables of self-efficacy, outcome expectations, and goals, as well as their interactions with a person's environment, to determine a person's career interests and goals (Lent et al., 1994; Lent, Brown, & Hackett, 2000). According to SCCT, people are more likely to develop interests in areas in which they feel competent and anticipate positive results (Lent at al., 2000; Leong, 2008). People form beliefs about what they are capable of doing, predict the consequences, set desired goals, and then plan courses of action (Bandura, 1991). When people obtain knowledge and develop interest in activities, they are more likely to find ways to increase their participation and proficiency. As they continue to develop their skills, they are more apt to set goals and develop a greater competence in the activity. Furthermore, this leads to a higher self-efficacy and outcome expectation for an area of study (Lent at al., 2000; Leong, 2008).

Bocanegra et al. (2016) find that learning experiences have a direct influence on a person's choice intentions. In their study, undergraduate psychology students had greater exposure to school psychology programs, which led to an increased interest and intention to enter this area of study. In addition, self-efficacy and outcome expectations were found to be significantly, positively correlated to a student's choice intentions to enter a particular program of study (Bocanegra et al., 2016; Lent & Hackett, 1987). Bocanegra et al. (2016) concluded that exposure to programs can lead to better ways to recruit students, and thus higher enrollment in particular areas of study.

According to Rogers and Creed (2011), adolescence is an important time in the development of career interests. According to recent studies, the SCCT variables of self-efficacy, goals, and outcome expectations positively influenced high school students as they developed academic and career goals (Kaminsky & Behrend, 2015; Olson, 2014; Rogers & Creed, 2011; Rogers et al., 2008). In particular, self-efficacy has an important effect on shaping goals and actions, as they influence career interests (Lapan, 2004). In addition, goals, background, financial support, barriers, personality, and social support are important factors in determining a student's level of college planning (Rogers & Creed, 2011; Rogers et al., 2008). Finally, students who participate in activities are more likely to set and pursue goals (Rogers et al., 2008). The closer students get to high school graduation, the more likely they are to participate in activities related to career interests in order to explore a variety of career options. Rogers et al. (2008) encourage more activities that engage students with potential areas of interest as a way of exploring a variety of careers. People tend to choose careers with which they can identify and that make them feel encouraged (Kaminsky & Behrend, 2015). As students develop greater interest and gain knowledge, they develop more confidence and set career planning goals (Rogers & Creed, 2011).

While the Social Cognitive Career Theory has been used with different groups of people, the model has rarely been applied to middle school students in a STEM-based curriculum. In one such study, minority eighth grade students in a rural, high poverty middle school participated in a STEM career video intervention to determine its effects on STEM career interests (Kier, 2013). As a result of the intervention, students – especially females – reported a higher self-efficacy as they identified their own strengths and learned about the many STEM career options. In addition, students demonstrated a higher interest in STEM careers as a result of positive outcome expectations, such as higher salaries (males) and being able to help others (females). While the researcher indicates that interviews might have provided more in-depth accounts of perceived supports and barriers, Kier (2013) concludes that the students' motivation to explore STEM careers increased as a result of the career video intervention.

Similar studies investigate the variables of self-efficacy and outcome expectations as high school and college students, as well as adults, participate in career-related activities. In one study, Christopher (2015) studied the effects of a career program that included a large-scale career fair and accompanying curriculum on the interest and self-efficacy of high school students and adults. The researcher found that the curriculum and career fair were valuable and had a positive impact on students' interests and self-efficacy in relation to career awareness, as they gained more in-depth knowledge about careers that were either familiar or new to them (Christopher, 2015). In another study, Alhaddab (2015) examined the degree of match in which workers held the appropriate degree or skills for STEM jobs. The researcher found that career self-efficacy and expectancy are not significant determinants of higher degree-job match for STEM graduates. As a result, the researcher suggests that university, the workforce, and college students share responsibility for ensuring that the graduate enters a field that matches his or her degree and expertise (Alhaddab, 2015).

Several SCCT studies have attempted to explain the model's applicability within minority groups. Among different ethnic groups, the SCCT theory continues to help explain the decision-making process and career development. In one study that involved minority high school students, a strong link was found between self-efficacy and interests in promoting interest in a teacher recruitment program (Schaffner & Jepsen, 1999). In another study, ninth grade Latino students reported a higher degree of encountering barriers than did White students, but they indicated the same perceptions of adversity in overcoming these barriers. In short, the Latino youth understand that there will be barriers, but they feel confident in defeating these obstacles. In addition, their self-efficacy beliefs are higher than White students (Ali & Menke, 2014). As a result, career programming should focus on overcoming barriers in order to increase career achievement among Latino youth (Ali & Menke, 2014). In yet another study, Ding (2015) examined the influence of social cognitive variables of African American undergraduate students in choosing STEM-intensive agricultural sciences majors. The researcher found that self-efficacy, but not outcome expectations, had a direct result on career behaviors in these college students (Ding, 2015).

In a study that examined gender differences, Colette (2009) examined the SCCT variables of self-efficacy, goals, and outcome expectations of females in professional STEM positions. As females report a lack of confidence and rejection in professional fields, they often turn to academia so that they can teach in their STEM fields. According to Colette (2009), the differences in self-efficacy were displayed because women were more likely to explain shortcomings with internal attributions, whereas men saw outward causes. Their outcome expectations were also different, as women preferred leading graduate students and helping students learn, whereas men expected to earn more money (Colette, 2009). Jirous-Rapp (2015) examined the SCCT variables of self-efficacy, career expectations, interests, and perceived supports and barriers between male and female high school graduates, and between STEM-degree and non-STEM-degree seeking students. Significant differences existed among all four of the groups. The findings showed that STEM-degree seeking students have a higher interest and outcome expectations than non-STEM-degree seeking students. Also, females reported more social support and goal expectations than males, while males better enjoyed STEM activities and perceived more barriers (Jirous-Rapp, 2015).

According to the SCCT, interest, self-efficacy, and outcome expectations encourage people to establish and pursue academic and career goals (Leong, 2008). In addition, factors such as culture, social supports, barriers, and abilities also influence career planning (see Figure 1). In order for students to enter STEM fields, they must be prepared and motivated (Kaminsky & Behrend, 2015). As a way to address the shortage in STEM fields, some schools are offering hands-on, career-related activities in order to provide students with more opportunities for career exploration. Such schools have yielded positive outcomes as they help to prepare students for STEM careers (Kaminsky & Behrend, 2015). Activities such as robotics can help to provide students with hands-on, real-life learning opportunities that have the potential to stimulate greater interest in STEM areas.

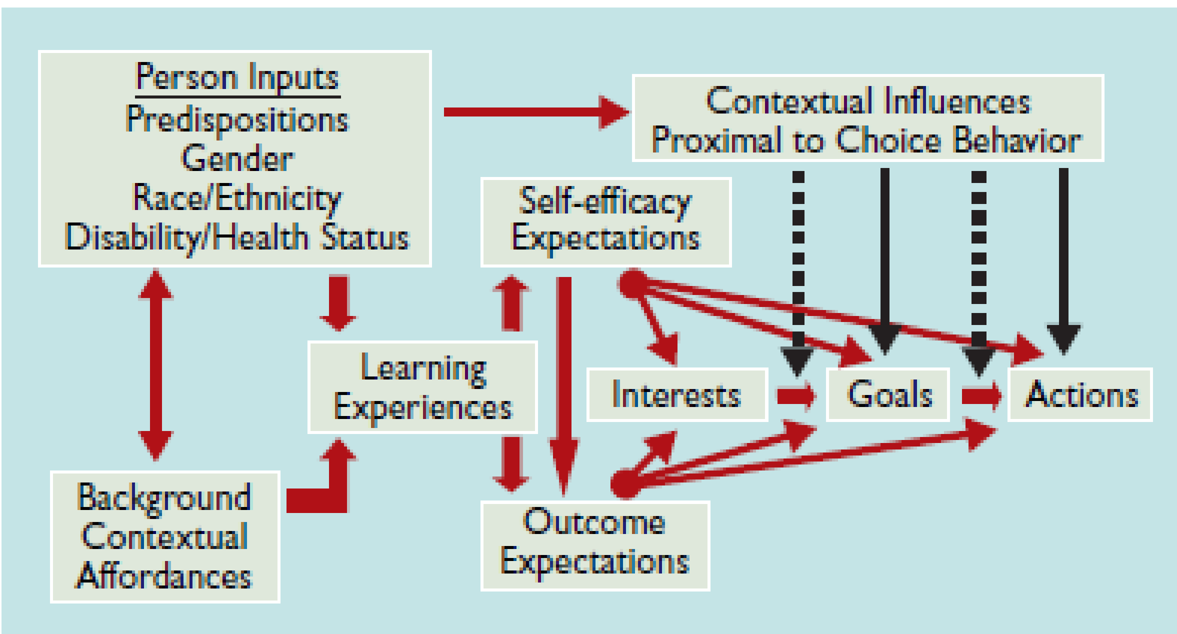


*Figure 1.* Social Cognitive Career Theory (Lopez, Lopez, Lent, & Constantine, 2007).

## Summary

In order to stimulate STEM learning in schools, a robotics platform offers students a way to create and innovate as they solve complicated math and science problems. With predicted workforce shortages in STEM fields, technology lessons such as robotics can offer stimulating, problem-based STEM units that can assist in attracting students to these areas of study (Grubbs, 2013). Students can make real-world connections as they solve authentic problems and learn valuable 21st century skills, including collaboration and teamwork, creativity, and the ability to solve problems. With a robotics educational platform, educators can reach a wide range of learners as they easily adapt projects for their students. Such exciting, hands-on learning activities can hopefully provide a foundation for future STEM studies. As a result, a greater number of students might become interested in STEM college majors and careers.

CHAPTER III

METHODS

## Introduction

The purpose of this study was to investigate the instructional use of a robotics educational curriculum on middle school students' attitudes toward and interests in STEM and their experiences with LEGO Robotics activities. Since the impact of a middle school robotics platform on students' STEM interests has yet to fully be explored, the researcher carefully observed participants and thoroughly recorded actions on the observation tool throughout the activities and provided suggested instructional uses of the robotics curriculum. In addition, the researcher developed specific curriculum suggestions that will enhance students' interests and attitudes toward STEM topics and careers.

## Research Question

The research question for this study was:

What are middle school students' interests and attitudes toward STEM after participating in a robotics curriculum and what are their experiences with the curriculum?

## Setting

This study took place in a metropolitan public middle school comprised of 577 $6^{th}$ – $8^{th}$ grade students from a school district in a West Central Alabama city. According to the United States Census Bureau (2016), the city had a population of 96,122 in July 2014. The median household income in 2013 was $38,762 with 25.2% of the population in poverty. As of 2013, 87.5% of the population (ages 25+) were high school graduates, with 33.8% of the population (ages 25+) having a bachelor's degree or higher.

This middle school is also a participant in the Alabama Math, Science, and Technology Initiative (AMSTI) and the Science, Technology, Engineering, Arts, and Math (STEAM) programs. While AMSTI has been shown to produce math and science achievement in K-12 schools, problem-based instructional strategies and inquiry-based learning methods are important to AMSTI's theory of action (Murphy, 2012; Newman et al., 2012). In addition, the STEAM paradigm reinforces engineering concepts, including creating, inventing, innovating, engineering, and controlling (Watson & Watson, 2013). Since both initiatives encourage active engagement, the school curriculum has shifted to instruction that includes problem-based learning strategies and constructivism. The researcher chose robotics activities to complement the STEAM and AMSTI initiatives, since these collaborative, hands-on activities simulate real-life, problem-based scenarios. Participants were of various racial backgrounds, including Caucasian, African American, Hispanic, and Asian, and diverse socioeconomic backgrounds.

## Curriculum

The name of the class used in the study was Career Cluster Technologies I, with the curriculum based on the Alabama Course of Study standards (Alabama State Department of Education, 2008). Since this curriculum has only been implemented in this school system for three years, middle school teachers are seeking the most effective ways to teach these classes in a way that appeals to students and meets the Alabama Course of Study standards. This curriculum provides 7$^{th}$ grade students with the knowledge and skills to increase their technological literacy as they learn about the 16 career clusters and associated careers (Alabama State Department of Education, 2008). The 16 career clusters are as follows:

- Agriculture, Food, and Natural Resources
- Architecture and Construction
- Arts, A/V Technology, and Communications
- Business, Management, and Administration
- Education and Training
- Finance
- Government and Public Administration
- Health Science
- Hospitality and Tourism
- Human Services
- Information Technology
- Law, Public Safety, Corrections, and Security
- Manufacturing
- Marketing, Sales, and Services
- Science, Technology, Engineering, and Mathematics (STEM)
- Transportation, Distribution, and Logistics

The curriculum for the class consists of instruction in technologies associated with Alabama's sixteen career clusters. In addition, the curriculum includes the development of technologies in society, engineering design principles, and role of innovation and invention in the problem-solving process. In order to increase technological literacy, students learn about innovations in technology and gain skills in technology applications related to various careers. Participants are expected to apply the design process to solve real-world problems as they learn to utilize tools needed to assess technological systems. Finally, the students are expected to understand the relationship of technology to Alabama's sixteen career clusters, as they identify pathways, education required, and employment skills needed for various career opportunities (Alabama State Department of Education, 2008).

The specific unit being taught on robotics was a 10-day unit, with each day consisting of a 60-70 minute session. During this unit, participants constructed a robot to complete various challenges and to maneuver around an obstacle course. Participants worked on LEGO Robotics kits in 6 groups of 4 participants each. Appendices E and F detail the 10-day curriculum used in the unit. The following pages were reproduced (with permission) from the book *Classroom Activities for the Busy Teacher: EV3* (Key, 2013) for student use: 94-95, 106-108, 111, and 113. Pages have not been reproduced in the dissertation due to copyright. Since these activities both introduce participants to the basics of robotics programming and allow for creative exploration, this two-week unit was developed with the potential to change participants' perceptions about STEM as they participated in tasks that were collaborative, authentic, and engaging.

## Participants

Participants in this study consisted of a convenient sample of 23 male and female 7$^{th}$ grade participants who returned their parental permission forms and agreed to participate. These participants were enrolled in a Career Cluster Technologies I class that focused on career explorations and integration of modern technologies, which the researcher taught. Participants worked on LEGO Robotics kits in 6 groups of 4 students each for 10 days, with no role assignments within the groups. These participants were enrolled in the teacher/researcher's first period class. All 24 students participated in the robotics activity, but only the 23 students who returned permission forms participated in the study. The researcher obtained a letter of approval from the school system superintendent as well as IRB prior to conducting the study (see Appendix F).

Focus group interviews were conducted with the 23 participants, who were randomly placed into three focus groups. The questions for the open-ended surveys and focus groups explored the participants' perceptions of their experiences with the robotics curriculum. With questions based on the Social Cognitive Career Theory, the researcher gathered data that explored whether student interests and self-efficacy increase in STEM topics and careers.

## Instrumentation

Instruments used in this qualitative study included teacher observations, focus groups, open-ended surveys, and the Career Cruising Assessments. As the teacher of the Career Explorations classes, the researcher performed the observations herself, and these observations were recorded each day using a STEM Observation Tool (see Appendix D). Since the researcher hoped to draw interpretations from several types of qualitative (open-ended) data, a better understanding of the usefulness of a robotics educational platform was determined. The researcher used a timeline that consisted of 3 – 4 weeks (see Table 1).

Table 1

*Timeline for Study*

| Time | Activity | Tool |
|---|---|---|
| Before robotics unit | Career Cruising Assessments | Career Cruising Assessments: Career Matchmaker, My Skills, and Learning Style Inventory |
| Before robotics unit | Pre-Survey | Open-Ended Survey 1 |
| Week 1, Day 1 | Robotics Activity | STEM Observation Tool |
| Week 1, Day 2 | Robotics Activity | STEM Observation Tool |
| Week 1, Day 3 | Robotics Activity | STEM Observation Tool |
| Week 1, Day 4 | Robotics Activity | STEM Observation Tool |
| Week 1, Day 5 | Robotics Activity | STEM Observation Tool |
| Week 2, Day 1 | Robotics Activity | STEM Observation Tool |
| Week 2, Day 2 | Robotics Activity | STEM Observation Tool |
| Week 2, Day 3 | Robotics Activity | STEM Observation Tool |
| Week 2, Day 4 | Robotics Activity | STEM Observation Tool |
| Week 2, Day 5 | Robotics Activity | STEM Observation Tool |
| Week 3, Day 1 | Post-Survey | Open-Ended Survey 2 |
| Week 3, Day 2 | Focus Group A | Focus Group Questions |
| Week 3, Day 3 | Focus Group B | Focus Group Questions |
| Week 3, Day 4 | Focus Group C | Focus Group Questions |
| Week 3, Day 5 | Career Matchmaker | Career Cruising – Career Matchmaker |

The open-ended survey and focus group protocol were developed from examining the research literature regarding STEM activities and the SCCT. The survey and focus group protocol were sent to five experts involved with STEM activities. These experts included one published author, one middle school teacher, and three high school teachers. They were asked to provide content validity based on the research question and to determine if the survey and focus group questions were appropriate for middle school participants. They provided suggestions for revisions for the survey and protocol and those revisions were incorporated.

In addition, information was analyzed from the Career Cruising program, which is an online career assessment program that provides skills and interest assessments and helps students to keep track of their career assessment and planning (Career Cruising, 2016). Prior to the robotics activity, participants took the Career Matchmaker, My Skills, and Learning Style Inventory assessments. Participants completed the following sections:

- Assessments – This section contains tools to help users to identify their skills, interests, abilities, and learning preferences. The Career Matchmaker provides a list of career suggestions listed in order of suitability. The My Skills component helps users to determine if they have necessary skills for chosen occupations. The Learning Style Inventory helps to determine how participants learn and remember information.
- Explore Careers – This section allows users to search for careers using different criteria. Each job profile contains information such as description, earnings, working conditions, job outlook, education and training, etc.
- Explore Education – This section offers detailed information regarding vocational or college programs that offer specific areas of study.

- Financial Aid – This area provides information regarding scholarships, grants, and other financial aid programs.
- My Plan – This tool allows users to keep track of their assessment results, education plans, programs of interest, and advisement sessions.

Prior to the study as part of school system requirements, participants answered a series of questionnaires in the Career Cruising program. The Assessments section contains tools to help users identify their skills, learning preferences, work interests, and abilities. Career Matchmaker, the first assessment in this section, includes 116 questions for suggested career results, which are ranked in order of suitability. Users can tailor their list according to their favorite career cluster or level of education they plan to obtain. My Skills, the next assessment, allows users to determine if they have the skills needed for the occupations that they have chosen. The Learning Styles Inventory, the third assessment, helps users discover how they best learn and retain information. Based on user responses from the Career Matchmaker, My Skills, and Learning Styles Inventory, careers were suggested for the participants, and then they saved their favorite careers to their portfolios. After the robotics activity, the participants again took the online questionnaires and had opportunities to add or change their choices of careers. Using information from the saved careers, the researcher determined that some participants had developed a higher confidence and/or interest in STEM areas.

All participants completed the open-ended surveys (see Appendices B and C) before and after the robotics activity. The surveys took approximately 30 – 45 minutes. Participants were randomly placed in three focus groups, with one group consisting of 7 students, and two groups consisting of 8 students. The questions for the focus group are in Appendix A. Since the questions are semi-structured, the questions varied slightly based on user responses. The focus groups took approximately 45 – 60 minutes. Tables 2, 3 and 4 demonstrate the development of the questions for the open-ended surveys and focus groups.

Table 2

*Pre Open-Ended Survey Questions Development*

| Question | Source | Rationale/Importance/ Link to Topic |
|---|---|---|
| 1. What do you think STEM means? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 2. What do you think you would learn in STEM classes? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 3. Do you enjoy activities like inventing, exploring, discovering, helping, and problem-solving activities? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-Efficacy |
| 4. If someone were working in a STEM-like job, what sorts of things would they be doing? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 5. What LEGO Robotics activities have you done at school? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 6. What LEGO Robotics activities have you done at home or anywhere else? If somewhere else, where did you do them? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 7. In what career or careers are you most interested? | Brown & Lent, 2013; Olson, 2014 | Personal goals |
| 8. Which advanced or AP classes would you like to take in high school? (AP classes are Advanced Placement classes that are offered in high school. At the end of each course, students can take an exam to try to receive college credit.) | Brown & Lent, 2013; Olson, 2014 | Personal goals |
| 9. How do you feel about college? | Brown & Lent, 2013; Olson, 2014 | Personal goals |
| 10. How well do you feel that you can complete STEM tasks? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |
| 11. Do you think that you would be successful in a STEM career? Why or why not? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |

Table 3

*Post Open-Ended Survey Questions Development*

| Question | Source | Rationale/Importance /Link to Topic |
|---|---|---|
| 1. What do you think STEM means? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 2. What do you think you would learn in STEM classes? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 3. Do you enjoy STEM activities? Why or why not? (STEM stands for Science, Technology, Engineering, and Math. STEM activities include things like inventing, exploring, discovering, helping, and problem-solving activities.) | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-Efficacy |
| 4. If someone were working in a STEM-like job, what sorts of things would they be doing? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 5. Thinking back to when you and your team members were building a robot, who took the lead in designing and building? Why do you feel this person took the lead? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 6. What kinds of problem(s) did you have? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 7. How did you solve your problem(s)? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 8. What is your overall impression of LEGO Robotics activities? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 9. What did you learn from the LEGO Robotics activity? | Bandura, 1986; Brown & Lent, 2013;Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |
| 10. What are some changes you might suggest for this LEGO Robotics activity? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |
| 11. How well do you feel that you can complete STEM tasks? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |
| 12. Do you think that you would be successful in a STEM career? Why or why not? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |
| 13. In what career or careers are you most interested? | Brown & Lent, 2013;Olson, 2014 | Personal goals |
| 14. Which advanced or AP classes would you like to take in high school? (AP classes are Advanced Placement classes that are offered in high school. At the end of each course, students can take an exam to try to receive college credit.) | Brown & Lent, 2013;Olson, 2014 | Personal goals |
| 15. How do you feel about college? | Brown & Lent, 2013;Olson, 2014 | Personal goals |
| 16. As a result of the LEGO Robotics activity, are you more or less interested in activities such as inventing, exploring, discovering, helping, and problem-solving activities? Please explain. | Brown & Lent, 2013;Olson, 2014 | Personal goals |
| 17. As a result of the LEGO Robotics activity, are you more or less interested in STEM activities? Please explain. | Brown & Lent, 2013;Olson, 2014 | Personal goals |
| 18. Has your participation in the LEGO Robotics activities encouraged an interest in any careers related to STEM? If so, in what careers are you interested? | Brown & Lent, 2013;Olson, 2014 | Personal goals |

Table 4

*Focus Group Interviews: Semi-Structured Questions*

| Question | Source | Rationale/Importance/ Link to Topic |
|---|---|---|
| 1. Do you feel that your group was successful in completing the robotics activities? Why or why not? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 2. Did all of your group members equally contribute to the project? If not, describe what happened. | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 3. Do you feel that you were a leader in the group activity? If not, why not? If so, describe how you led the group. | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 4. Did you enjoy the robotics activity? Why or why not? | Bandura, 1986; Brown & Lent, 2013;Leong, 2008 | Self-efficacy |
| 5. Thinking back to when you and your team members were building a robot, who took the lead in designing and building? Why do you feel this person took the lead? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 6. What did you learn from the LEGO Robotics activity? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 7. What are some suggestions for improvement in this LEGO Robotics activity? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Self-efficacy |
| 8. How well do you feel that you can complete STEM tasks? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |
| 9. Do you think that you would be successful in a STEM career? Why or why not? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008; Olson, 2014 | Self-efficacy and Outcome expectations |
| 10. How do you feel about STEM activities? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Personal goals |
| 11. Have your feelings toward STEM changed as a result of this robotics activity? | Bandura, 1986; Brown & Lent, 2013; Leong, 2008 | Personal goals |
| 12. In what career or careers are you most interested? | Brown & Lent, 2013; Olson, 2014 | Personal goals |
| 13. Which advanced or AP classes would you like to take in high school? (AP classes are Advanced Placement classes offered in high school. At the end of each course, students can take an exam to try to receive college credit.) | Brown & Lent, 2013; Olson, 2014 | Personal goals |
| 14. How do you feel about college? | Brown & Lent, 2013; Olson, 2014 | Personal goals |
| 15. Has your participation in the LEGO Robotics activities encouraged an interest in any careers related to STEM? If so, in what careers are you interested? | Brown & Lent, 2013; Olson, 2014 | Personal goals |

## Data Collection

Qualitative data are used to identify a central phenomenon, or key topic, in order to explore it with open-ended questions to participants (Creswell, 2015). Data were collected from teacher observations, focus groups, pen and paper open-ended surveys, and the Career Cruising Assessments during regularly scheduled classes. Prior to the robotics unit, participants completed the Career Matchmaker, My Skills, and Learning Styles Inventory in the Career Cruising program. Prior to beginning the robotics unit, the participants took the Pre Open-Ended Survey. Then they spent 10 days completing the challenges in the robotics unit. On Day 11, participants completed the Post Open-Ended Survey. On Days 12 - 14, participants participated in focus group interviews. On Day 15, participants completed the second Career Matchmaker survey in Career Cruising. During the focus group interviews, a substitute teacher was hired to facilitate lessons while the teacher conducted interviews, which took place in the adjacent Career Technologies classroom. The three focus group interviews lasted 45 – 60 minutes each.

Classroom observations were conducted throughout the robotics activities. The researcher continuously circulated around the classrooms daily to observe the participants and collect data. Using the STEM Interest Inventory Observation Tool (Appendix D), the researcher carefully recorded information and took additional notes about each participant. While the observation tool was originally a rubric developed to assess collaboration skills, the researcher adapted the tool to include additional behaviors, such as teamwork and leadership skills, positive attitude toward the task, and enjoyment of the activity. The researcher spent an average of 10-15 minutes with each group on a daily basis.

## Data Analysis

Data analysis included qualitative data from the teacher observations, open-ended surveys, focus group responses, and the Career Cruising Assessments. The data were analyzed using constant comparative analysis, which entails making comparisons at all stages of the process (Charmaz, 2006). In the first stage, the researcher compared the different types of data for similarities and differences. For instance, the researcher made sequential observations of the same person throughout the robotics activities, to determine if the participant's actions or behaviors changed at different times. In addition, the researcher compared statements made by different participants during the focus group interviews as well as the open-ended surveys and observations, to determine the participants' perceptions about the activity. For instance, participants were asked if they were a leader in the activity, so the researcher analyzed whether all of the group participants and observation data produced similar results. Also, participants were asked what they learned from this activity, and the researcher compared these responses to the observation data. Initially, the researcher utilized line-by-line coding and memo-writing as a way to make early comparisons and explore emerging themes. As the categories developed, the purpose was to create themes that effectively described the experiences that were explored (Kvale & Brinkmann, 2015). To determine if the categories have been saturated, the researcher reflected whether or not data had been compared within and between categories, what this data meant, if they took the researcher in new directions, and if new relationships had been developed. Finally, the researcher compared the analysis to prevailing ideas about the topic (Charmaz, 2006).

In order to reveal the main themes from the data, the researcher used initial and focused coding to reveal the most prevalent themes from the focus group interviews, surveys, observations, and Career Cruising assessments. According to Saldana (2015), coding allows the researcher to extend past the concrete and visible to the abstract meaning of data. Codes were initially organized into categories before themes began to emerge.

In the first coding cycle, initial coding was utilized. This open-ended coding approach allows the researcher to develop tentative codes that can range from the specific to the abstract, depending on the researcher's observations and interpretations of the data (Saldana, 2015). During the initial coding and analytic memo writing, the researcher noted many categories based on the collected data. In this overview of the data, several themes began to emerge as shown in Table 5.

For the second coding cycle, focused coding was selected. This coding method allows comparison of data with different participants and further organization of data (Saldana, 2015). The researcher further coded the data to determine common categories and identify four major themes: (a) increased confidence and self-efficacy toward STEM tasks; (b) self-efficacy and enjoyment in relation to STEM tasks and STEM careers; (c) impact on personal goals; and (d) suggestions for changes for robotics activities. The coding process continued until the researcher felt that the categories were saturated.

Throughout the coding process, the researcher recorded notes in the margins that included codes, patterns, and possible themes. After each round of coding, the researcher wrote analytic memos that further explored the potential themes. This process of analytic memoing allows the researcher to document and reflect on emerging themes and subcategories (Saldana, 2015). An ongoing process, memo writing allowed the researcher to evaluate the codes and understand the relationship between the data and research question. The stages of coding can be seen in Table 5.

Table 5

*Stages of Coding Process*

| Stage 1: Initial Coding | Stage 2: Focused Coding | Emerging Themes |
|---|---|---|
| • Demonstrated problem-solving skills<br>• Collaboration and teamwork<br>• Interest in robotics activity<br>• Enjoyment of robotics activity<br>• Enjoyment of problem-solving skills<br>• Positive attitude<br>• Team player<br>• Leadership – positive or negative<br>• Suggests solutions to problems<br>• Encourages others<br>• Programming robot<br>• Building robot<br>• Communication<br>• Attitude toward challenges<br>• Shares responsibilities<br>• Apprehension toward robotics activity<br>• Attitude toward STEM<br>• Interest in STEM career<br>• Plans to take Advanced or AP STEM classes<br>• Suggestions for changes or improvements | • Increased confidence toward STEM tasks<br>• Increased self-efficacy toward STEM tasks<br>• Problem-solving skills<br>• Leadership and teamwork<br>• Self-efficacy and enjoyment in relation to STEM tasks<br>• Self-efficacy and enjoyment in relation to STEM careers<br>• Impact on personal goals<br>• Effect of robotics activity on feelings toward STEM<br>• Plans to take STEM classes or pursue STEM careers<br>• Suggestions for changes for robotics activities | • Increased confidence and self-efficacy toward STEM tasks<br>Subthemes:<br>(a) Problem-solving skills; and<br>(b) Leadership and teamwork<br>• Self-efficacy and enjoyment in relation to STEM tasks and STEM careers<br>• Impact on personal goals<br>Subthemes:<br>(a) Effect of robotics activity on feelings toward STEM; and<br>(b) Plans to take STEM classes or pursue STEM careers<br>• Suggestions for changes for robotics activities |

Qualitative research allowed the researcher to better interpret the participants' learning and reactions to the robotics activity, as it provides a human element that helps the researcher to understand other viewpoints. Since such studies involve interpretation, validity attempts to increase the objectivity of the results. As the researcher searched for common trends and patterns, the researcher explored the responses of the participants and attempted to provide an accurate reflection of their views, which provides validity to the study. Equally important, ethics provides a foundation to ensure that researchers display respect and sensitivity to the subjects. The credibility of this study was enhanced as the teacher blended into the learning environment to learn more about the participants' perceptions of robotics and attitudes toward STEM classes and careers.

Throughout the study, triangulation and crystallization were utilized to enhance the interpretation of the data. Triangulation is vital to provide multiple views, increasing the scope and deepening the understanding of the material (Tracy, 2010). In the current study, triangulation was achieved by gathering data from open-ended surveys, interviews, observations, and Career Cruising results to obtain more comprehensive data. The researcher analyzed the different types of data to determine common themes and drew conclusions based on these data. Since the different methods yielded similar results, the conclusions are more valid.

Similarly, crystallization "encourages researchers to gather multiple types of data and employ various methods, multiple researchers, and numerous theoretical frameworks" (Tracy, 2010, p. 844). This offers a more complex understanding of the material. Closely aligned to crystallization is the importance of multivocality, which stresses the importance of demonstrating rather than telling. The use of multiple and varied voices allows the researcher to include each participant's point of view, which, in turn, produces a variety of opinions. The researcher allows for differences in cultural backgrounds, race, and gender as she accepts viewpoints that are different than her own (Tracy, 2010). In the current study, crystallization was achieved by gathering information from observations, surveys, interviews, and

Career Cruising results to analyze data from different viewpoints and angles. Although the researcher collected data from observations, the participants' viewpoints might have been somewhat different than what was observed by the researcher. The researcher carefully compared and determined if the data obtained from various methods yielded the same results and determined that the data were frequently consistent.

## Researcher Positionality

### Researcher Background

Throughout my twenty years of teaching at both the elementary and secondary levels, I have strived to incorporate technology and student-centered learning practices into my instruction. While most participants enjoy these activities, I have observed that sometimes they feel that the STEM and technology-based activities are too challenging. Having this inside perspective helped me to realize that students need more fun, hands-on, collaborative activities in order to build confidence in their own skills and to encourage them to become interested in STEM topics. As a way to introduce students to engineering concepts, I decided to implement a robotics curriculum that would rely on teamwork and problem-solving skills in order to solve authentic STEM-based issues. This is the first time that the researcher has implemented the 10-day LEGO Robotics curriculum as outlined in Appendix E.

### Researcher Bias

As a middle school teacher, my motivation was to obtain current research on teaching practices that inspire STEM-related interests. Over the years, my perspective has been shaped by interactions with middle school students, as they enjoy discussing potential careers of interest. With this qualitative study, my main interest was the story behind the research. As the teacher and researcher, I was aware of my biases in the study. I protected against this personal bias with critical self-reflection during each step of the research process, especially during the data collection and analysis.  In order to strengthen the credibility of the research, triangulation of methods and data sources were used to enhance the study.

# CHAPTER IV

# FINDINGS

## Introduction

The purpose of this study was to explore middle school students' interests and attitudes toward STEM after participating in a robotics curriculum and their experiences with the curriculum. The findings for this study are the observations and views of seventh grade students in a Career Cluster Explorations I class in a public middle school in Alabama. These participants represent various races, socioeconomic status, and personal traits. This chapter includes a portrayal of each participant and group that participated in the study. In addition, the qualitative themes that emerged in this study are explained.

## Context

The participants for this qualitative study consisted of a convenient sample of 23 male and female seventh grade participants who returned their parental permission forms. These 12- and 13-year-old participants were enrolled in a Career Cluster Technologies I class that focused on career explorations and integration of modern technologies, which the researcher taught. During class time, the researcher described the purpose of the study and explained that participation was voluntary and would not affect the participant's grade in the course. All participants who were given consent forms and assent forms returned them, providing permission from the parent and agreement from the student to participate in the study. All participants returned their forms in a timely manner, so there was no need for parental contact or follow-up calls or emails.  After IRB approval had been granted and the study started, a new student was transferred to this class.  She was not given permission forms to participate in the study, since she missed the pre Career Cruising survey and IRB approval had already been sought, but she did participate in the LEGO Robotics group activities.

All participants took part in the pre-survey, Career Cruising assessments, robotics activities, and focus group interviews.  Identity of the participants was known only by the researcher.  Within this study, participants were only identified by assigned numbers in order to preserve anonymity.

## Participants

Twenty-three participants were asked to take part in this qualitative study.  All of the students and parents provided consent for participation, with no need for follow-up emails or phone calls.  The participants' gender was fourteen females and nine males.  The racial composition was one Asian, four Black/African Americans, and fourteen Whites.  The participants ranged in age from twelve to thirteen years.  Table 6 provides a summary of the demographics of the participants in the study.  Since Career Cluster Explorations I is an elective class, all of the participants chose to enroll in this course, even though their reasons varied, such as friends in the class, teacher preference, parental persuasion, usage of technology, etc.

Table 6

*Demographic Information of Participants*

| Participant | Race | Gender |
|---|---|---|
| Group A | | |
| 1 | Asian | Female |
| 2 | White | Female |
| 8 | White | Male |
| 21 | Black/African American | Male |
| Group B | | |
| 5 | White | Male |
| 14 | Black/African American | Female |
| 18 | White | Male |
| 22 | Black/African American | Female |
| Group C | | |
| 3 | White | Female |
| 4 | White | Female |
| 10 | White | Male |
| 20 | White | Male |
| Group D | | |
| 6 | White | Female |
| 7 | White | Male |
| 9 | White | Female |
| Group E | | |
| 11 | White | Female |
| 13 | White | Female |
| 15 | Black/African American | Female |
| 17 | White | Female |
| Group F | | |
| 12 | White | Female |
| 16 | White | Male |
| 19 | White | Female |
| 23 | White | Male |

## Results

### Surveys

Prior to the robotics unit, participants took a Pre Open-Ended Survey that assessed participants' understanding and feelings about STEM activities. In addition, they assessed their own abilities to complete STEM tasks as well as their interest in STEM classes and careers.

Since the class curriculum had already included the STEM career cluster, most participants demonstrated a good understanding of STEM activities and careers. After the 10-day robotics unit, participants took a Post Open-Ended Survey that assessed the same areas to determine if there were changes as a result of the robotics activities. Those results are further addressed later in this chapter, along with other data collection results.

**Career Cruising**

Prior to the study, participants completed a series of questionnaires in the Career Cruising program. The Assessments section contains tools to help users identify their skills, learning preferences, work interests, and abilities. Based on user responses from the Career Matchmaker, My Skills, and Learning Styles Inventory, careers were suggested for participants, and then they saved their favorite careers to their portfolios. After the robotics activity, participants took the online questionnaires again and had the opportunity to add or change their choices of careers. While several participants indicated no change in career choices, five participants indicated a greater interest in STEM careers after participating in the robotics activity. Of the thirteen participants who were interested in STEM careers before the activity, eight of them indicated more STEM careers in which they were interested.

**Observations**

Each of the participants were observed throughout the robotics activities using the STEM Interest Inventory Observation Tool (Franker, 2015), which was adapted with Dr. Franker's permission. The objective of the observations was to study each participant's behavior throughout the robotics activities, including attention to the task, contributions made, enjoyment of the activity, demonstration of leadership qualities, and teamwork skills. Approximately 10-15 minutes of observation time was spent with each group each day, over a 10-day period. Since the participants were not given role assignments, the researcher examined the emergence of leaders in each group. Table 7 demonstrates the percentage of days that the female participants displayed the qualities shown on the chart, while Table 8 exhibits the percentage of days that the male participants displayed the qualities indicated on the chart.

Table 7

*Observation Results from Female Participants*

| Behavior | S1 | S2 | S3 | S4 | S6 | S9 | S11 | S12 | S13 | S14 | S15 | S17 | S19 | S22 | Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stays focused on the task | 30% | 70% | 30% | 80% | 50% | 50% | 80% | 20% | 10% | 30% | 70% | 70% | 70% | 20% | 49% |
| Makes valuable contributions to the task | 20% | 70% | 30% | 90% | 60% | 50% | 80% | 20% | 0% | 30% | 50% | 60% | 90% | 20% | 48% |
| Encourages others | 0% | 20% | 20% | 60% | 50% | 40% | 60% | 0% | 0% | 10% | 60% | 50% | 60% | 0% | 31% |
| Shares responsibility with others | 0% | 20% | 30% | 60% | 50% | 50% | 70% | 10% | 0% | 20% | 70% | 50% | 100% | 20% | 40% |
| Discusses and listens to others with respect | 10% | 70% | 30% | 70% | 60% | 60% | 70% | 10% | 0% | 30% | 70% | 70% | 90% | 10% | 46% |
| Shares useful ideas | 10% | 70% | 30% | 70% | 50% | 40% | 80% | 10% | 0% | 20% | 70% | 80% | 90% | 20% | 46% |
| Enjoys the activity | 20% | 60% | 40% | 70% | 60% | 60% | 80% | 20% | 10% | 50% | 70% | 50% | 100% | 30% | 51% |
| Suggests solutions to problems | 20% | 70% | 10% | 70% | 30% | 20% | 80% | 20% | 0% | 20% | 60% | 80% | 80% | 20% | 41% |
| Makes compromises with others to meet desired outcome | 0% | 20% | 0% | 10% | 10% | 10% | 20% | 0% | 0% | 0% | 20% | 20% | 20% | 0% | 9% |
| Displays positive attitude toward others & the task | 20% | 70% | 10% | 90% | 70% | 80% | 90% | 30% | 0% | 40% | 80% | 70% | 90% | 30% | 55% |
| Is a "team player" throughout the activities | 20% | 50% | 30% | 90% | 60% | 50% | 90% | 20% | 0% | 30% | 80% | 70% | 100% | 10% | 50% |
| Is a "leader" throughout the activities | 0% | 50% | 0% | 30% | 20% | 10% | 90% | 0% | 0% | 0% | 80% | 40% | 70% | 0% | 28% |

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Table 8

*Observation Results from Male Participants*

| Behavior | S5 | S7 | S8 | S10 | S16 | S18 | S20 | S21 | S23 | Average Percentage of Male Responses |
|---|---|---|---|---|---|---|---|---|---|---|
| Stays focused on the task | 70% | 90% | 90% | 80% | 70% | 80% | 70% | 70% | 70% | 49% |
| Makes valuable contributions to the task | 70% | 90% | 90% | 80% | 80% | 70% | 70% | 60% | 90% | 50% |
| Encourages others | 50% | 50% | 30% | 70% | 80% | 60% | 70% | 10% | 80% | 36% |
| Shares responsibility with others | 60% | 60% | 30% | 70% | 80% | 60% | 70% | 30% | 90% | 39% |
| Discusses and listens to others with respect | 70% | 50% | 50% | 70% | 90% | 70% | 80% | 70% | 100% | 46% |
| Shares useful ideas | 60% | 80% | 80% | 70% | 80% | 80% | 70% | 60% | 90% | 48% |
| Enjoys the activity | 80% | 90% | 80% | 60% | 80% | 80% | 70% | 70% | 90% | 50% |
| Suggests solutions to problems | 60% | 40% | 60% | 70% | 50% | 70% | 60% | 40% | 60% | 36% |
| Makes compromises with others to meet desired outcome | 20% | 10% | 10% | 30% | 20% | 20% | 30% | 10% | 20% | 12% |
| Displays positive attitude toward others & the task | 80% | 100% | 70% | 80% | 70% | 80% | 70% | 70% | 80% | 50% |
| Is a "team player" throughout the activities | 80% | 70% | 60% | 80% | 90% | 80% | 80% | 50% | 100% | 49% |
| Is a "leader" throughout the activities | 60% | 90% | 90% | 90% | 60% | 90% | 50% | 20% | 90% | 46% |

**Adapted with permission from: Dr. Karen Franker (2015)*
www2.uwstout.edu/content/profdev/rubrics/secondaryteamworkrubric.html

The observer noted many similarities between the male and female behaviors, including paying attention and making valuable contributions to the task. Likewise, they seemed to enjoy the activity and displayed positive attitudes. In addition, males and females almost equally displayed effective teamwork skills as they shared ideas and responsibilities in a respectful manner. Overall, there were similarities with the males and females, with the one exception of leadership skills. In this area, the males displayed leadership qualities 46% of the time during the activity, while the females only took the lead 28% of the time. While the observation tool and charts reflect the occurrence of behaviors from participants on each day, this does not necessarily reflect that the participants had more of these behaviors overall. In order to better understand the behaviors, Table 9 shows the specific actions that were displayed for each behavior shown in the tables.

Table 9

*Examples of Actions Displayed for Each Behavior in Observation Tool*

| Behavior | Actions Shown |
|---|---|
| Stays focused on the task | • Watches others' actions during activity<br>• Does not easily get distracted (playing on phone, walking around room, asking to leave room, etc.) |
| Makes valuable contributions to the task | • Offers suggestions to solve challenge<br>• Actively builds, programs, or troubleshoots the robot |
| Encourages others | • Provides positive words of encouragement<br>• Asks others for their input or expertise |
| Shares responsibility with others | • Allows others to help with the task<br>• Works well together |
| Discusses and listens to others with respect | • Demonstrated positive listening skills<br>• Does not interrupt others |
| Shares useful ideas | • Offers ideas and suggestions to group members |
| Enjoys the activity | • Smiles<br>• Demonstrates excitement<br>• Shows a positive attitude |
| Suggests solutions to problems | • Offers ways to solve the challenges<br>• Troubleshoots problems with robot |
| Makes compromises with others to meet desired outcome | • Works with others to figure out solution<br>• Changes idea to support others' suggestions |
| Displays positive attitude toward others & the task | • Speaks words of affirmation and encouragement<br>• Avoids negative words toward others and the task |
| Is a "team player" throughout the activities | • Works well with others to share ideas and responsibility<br>• If leader, he/she encourages others to participate. |
| Is a "leader" throughout the activities | • Takes the lead by offering suggestions for solutions<br>• Other members look to the leader for guidance and expertise. |

The researcher noticed that different groups displayed unique dynamics. In Group A, Participant 8 emerged as an early leader, and while he was quite knowledgeable, he did not share responsibility well. Participants 2 and 21 also enjoyed the robotics activity, but overall, the group experienced much frustration because they did not work well together. On the other hand, Group B increasingly learned to work as a team. Participant 18 was an early leader, but he continued to encourage the others, and finally they became more involved. Overall, they seemed to enjoy working together and solve the challenges as a team. On the whole, Group C worked the best together. While Participant 10 was the leader (and was even recruited by other teams for his expertise), he offered much support and encouragement to other team members. While they were at first reluctant, they became more involved and excited as they solved the challenges together.

While Group D usually solved the challenges faster than the other groups, Participant 7 worked quickly and quietly, often without the help of other teammates. Although he was considered the leader, he usually did not enlist others' help, and so other group members were not very interested in the activities. Overall, Group E had the most difficulty, both with cooperation and solving the challenges. They did not work well together, even though Participant 11 was considered the leader. The negative attitudes (especially from Participant 17) and lack of participation (from Participant 13) contributed to a not-so-enjoyable experience by most of the group members. Last, Group F displayed positive attitudes and shared responsibilities more than most other teams. According to observations and student feedback, Participants 16, 19, and 23 displayed leadership skills at different times, while Participant 12 lacked interest and involvement. This group seemed to enjoy working together and stayed well focused on the tasks each day.

## Focus Group Interviews

After the robotics activity, participants took part in focus group interviews. There were three focus groups with 7 participants in one focus group, and 8 participants in two focus groups. Each focus group lasted approximately one hour. Semi-structured questions allowed the interviewer to further probe into areas of interest. The focus group questions and discussions allowed participants to share their reflections on the robotics activity, including leadership roles, teamwork, and suggestions for improvement. The interviews were audio recorded and then transcribed for the purpose of coding the responses. Using an open coding method, the interviewer found common themes that related to the theoretical framework used in this study.

# Themes

After the data collection process, the researcher explored the data to determine the impact of the LEGO robotics activity on middle school participants' interests and attitudes toward STEM and their experiences with the curriculum. During the initial coding and focused coding process, the following themes emerged from the data: (a) Theme 1: increased confidence and self-efficacy toward STEM tasks, with the subthemes of (1A) problem-solving skills and (1B) leadership and teamwork; (b) Theme 2: self-efficacy and enjoyment in relation to STEM tasks and STEM careers; (c) Theme 3: impact on personal goals, with the subthemes of (3A) effect of robotics activities on feelings toward STEM and (3B) plans to take STEM classes or pursue STEM careers; and (d) Theme 4: suggestions for changes for robotics activities.

## Theme 1: Increased Confidence and Self-Efficacy Toward STEM Tasks

While many participants were nervous before starting the robotics activity, they demonstrated increasing amounts of knowledge and enjoyment as their team solved the daily challenges. Tables 10 and 11 summarize the observed activities of the participants, such as attention to the task, enjoyment of the activity, and leadership skills, throughout the 10-day robotics unit. The groups are as follows: Group A – Participants 1, 2, 8, 21; Group B – Participants 5, 14, 18, 22; Group C – Participants 3, 4, 10, 20; Group D – Participants 6, 7, 9; Group E – Participants 11, 13, 15, 17; and Group F – Participants 12, 16, 19, 23.

Table 10

*Observations of Behaviors During Robotics Activities – Groups A, B, and C*

| Behavior | Group A | | | | Group B | | | | Group C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 8 | 21 | 5 | 14 | 18 | 22 | 3 | 4 | 10 | 20 |
| Stays focused on the task | 30% | 70% | 90% | 80% | 70% | 30% | 80% | 20% | 30% | 80% | 80% | 80% |
| Makes valuable contributions to the task | 20% | 70% | 90% | 60% | 70% | 30% | 70% | 20% | 30% | 90% | 80% | 70% |
| Encourages others | 0% | 10% | 30% | 10% | 50% | 10% | 60% | 0% | 20% | 60% | 70% | 70% |
| Shares responsibility with others | 0% | 30% | 30% | 30% | 60% | 20% | 60% | 20% | 30% | 70% | 70% | 70% |
| Discusses and listens to others with respect | 10% | 70% | 50% | 70% | 70% | 30% | 70% | 10% | 30% | 70% | 70% | 80% |
| Shares useful ideas | 10% | 70% | 80% | 50% | 60% | 20% | 80% | 10% | 30% | 70% | 70% | 70% |
| Enjoys the activity | 30% | 80% | 90% | 70% | 80% | 40% | 80% | 30% | 40% | 70% | 60% | 70% |
| Suggests solutions to problems | 20% | 70% | 60% | 40% | 60% | 20% | 70% | 10% | 10% | 70% | 70% | 60% |
| Makes compromises with others to meet desired outcome | 0% | 20% | 10% | 10% | 20% | 0% | 20% | 0% | 0% | 10% | 30% | 30% |
| Displays positive attitude toward others & the task | 20% | 70% | 70% | 70% | 80% | 40% | 80% | 30% | 20% | 90% | 80% | 70% |
| Is a “team player” throughout the activities | 20% | 50% | 60% | 50% | 80% | 30% | 80% | 10% | 30% | 90% | 80% | 80% |
| Is a “leader” throughout the activities | 0% | 50% | 90% | 20% | 60% | 0% | 90% | 0% | 0% | 30% | 90% | 50% |

* *Adapted with permission from: Dr. Karen Franker (2015)*
www2.uwstout.edu/content/profdev/rubrics/secondaryteamworkrubric.html

Table 11

*Observations of Behaviors During Robotics Activities – Groups D, E, and F*

| Behavior | Group D | | | Group E | | | | Group F | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 9 | 11 | 13 | 15 | 17 | 12 | 16 | 19 | 23 |
| Stays focused on the task | 50% | 90% | 60% | 80% | 10% | 70% | 70% | 20% | 70% | 70% | 70% |
| Makes valuable contributions to the task | 60% | 90% | 50% | 70% | 0% | 60% | 70% | 20% | 80% | 90% | 90% |
| Encourages others | 50% | 50% | 50% | 40% | 0% | 60% | 50% | 0% | 80% | 60% | 80% |
| Shares responsibility with others | 50% | 60% | 50% | 80% | 0% | 60% | 50% | 10% | 80% | 90% | 90% |
| Discusses and listens to others with respect | 60% | 50% | 60% | 70% | 0% | 70% | 70% | 10% | 90% | 90% | 100% |
| Shares useful ideas | 50% | 80% | 40% | 80% | 0% | 70% | 80% | 10% | 80% | 90% | 90% |
| Enjoys the activity | 60% | 90% | 60% | 70% | 10% | 70% | 50% | 20% | 80% | 100% | 90% |
| Suggests solutions to problems | 30% | 50% | 10% | 80% | 0% | 60% | 80% | 20% | 50% | 80% | 60% |
| Makes compromises with others to meet desired outcome | 10% | 10% | 10% | 20% | 0% | 20% | 20% | 0% | 20% | 20% | 30% |
| Displays positive attitude toward others & the task | 70% | 100% | 80% | 90% | 0% | 80% | 70% | 30% | 70% | 90% | 80% |
| Is a "team player" throughout the activities | 60% | 70% | 50% | 90% | 0% | 80% | 70% | 20% | 90% | 100% | 100% |
| Is a "leader" throughout the activities | 20% | 90% | 10% | 90% | 0% | 80% | 40% | 0% | 60% | 70% | 90% |

* *Adapted with permission from: Dr. Karen Franker (2015)*
www2.uwstout.edu/content/profdev/rubrics/secondaryteamworkrubric.html

As several participants emerged as leaders in their groups, they found ways to encourage and involve other teammates – even those who were hesitant about the activities. In order to determine the participants' level of confidence and self-efficacy toward STEM tasks, the researcher examined data from the surveys and interviews.

**Group A.** According to the data, all participants indicated that they felt confidence in completing STEM tasks. While Participant 1 was reluctant at times, in the survey she shared that she can complete STEM tasks "pretty well if I'm in a group. That way I could get help if I was stuck or confused about anything." Participants 2, 8, and 21 indicated a greater confidence in completing STEM tasks. Participant 2 shared in her survey, "I feel that I could complete [STEM tasks] well if I had enough time to understand and do the tasks." In the interview, Participant 8 stated, "I'm pretty good at completing STEM tasks, but maybe not on time, but I'll eventually get it." In addition, Participant 21 shared in the interview, "I think I could do good with STEM tasks."

**Group B.** All participants in Group B indicated an increased confidence and self-efficacy toward STEM tasks. In the interview, Participant 5 stated, "I think I'd be good on certain tasks with STEM. Participant 18 shared in the survey that he feels confident in STEM tasks "because I always want to be an engineer and work on cars." While Participants 14 and 22 were at first reluctant to participate, they still indicated increased self-efficacy in STEM tasks. Participant 14 stated in the survey, "I feel a little more confident about completing STEM tasks." Participant 22 also shared in the interview that she can complete STEM tasks easily "because I'm a fast learner."

**Group C.** All of the members in Group C indicated an increased confidence in completing STEM tasks. In the survey, Participant 3 stated, "I felt like STEM tasks weren't as hard as I thought they were gonna be. It actually started to become easy at the end, once we figured out how to do everything." Participant 4 also shared in the survey, "I feel good" about completing STEM tasks. Participant 10 also shared in the survey, "I feel like I can complete STEM tasks pretty well. This activity has further reinforced that." In the interview, Participant 20 stated, “I might be able to complete STEM tasks better, because I might be better at engineering than I used to be.”

**Group D.** Participants in Group 4 had mixed reactions, but they mostly indicated a greater self-efficacy in STEM tasks. Participant 6 indicated in the survey that she cannot complete STEM tasks very well, because “I’m not that smart or anything.” On the other hand, she shared in the interview that “I think I’d be okay [at completing STEM tasks]. I’m good at working in groups.” Participant 7 shared in the survey that she feels “great because I’m good at STEM tasks.” Participant 9 indicated in the survey, “I feel that I have become more confident” in STEM tasks.

**Group E.** Only one of the participants in Group E indicated that she felt confident in completing STEM tasks. Participant 15 shared in the survey, “I feel pretty good that I can complete them.” On the other hand, Participant 11 stated in the interview that she felt “more knowledgeable about STEM tasks, but I don’t think this activity has made STEM tasks any easier for me.” Also, Participant 13 shared in the interview, “I don’t think I would do very well in a STEM activity, because I’ve never really been good in [them], and I didn’t do very well on this one, either.” In addition, Participant 17 responded, “I don’t know” in the interview and “Iffy” in the interview, when asked if she felt confident in completing STEM tasks.

**Group F.** All of the participants in Group F felt confident in completing STEM tasks. In the survey, Participant 12 stated that she could complete STEM tasks “pretty good.” Participant 16 also stated in the survey that he was “good, but I don’t like STEM tasks.” Participant 19 shared in the survey, “I feel that I could do it and I could do it alone.” In the interview, Participant 23 stated, “I think I could do the coding and all that other stuff. If I didn’t like the group I had, then I would have a little bit of trouble with the solving stuff.”

During the focused stage of coding, subthemes emerged. The researcher noted that successful problem-solving skills greatly contributed to the participants' increased confidence and self-efficacy in the robotics activity. In addition, the participants' leadership and teamwork skills, including their degree of participation, also affected their attitudes toward the daily challenges. As a result, the researcher included the following subthemes: (1A) Problem-solving skills; and (1B) Leadership and teamwork.

**Subtheme 1A: Problem-solving skills.** Throughout the robotics activities, participants worked in groups to complete daily challenges. Critical thinking and problem-solving skills refer to the ability to develop solutions to a variety of problems in both traditional and inventive methods (P21 Partnership for 21st Century Learning, 2015). Almost all of the participants were observed contributing to the teams' tasks as they demonstrated problem-solving skills (see Table 12). The researcher used data from observations, surveys, and interviews to determine each participant's contribution to the task through problem-solving skills.

Interestingly, many participants included group cooperation as part of problem-solving skills on both the surveys and interviews. Indeed, several groups encountered challenges such as a member's unwillingness to help or work together for a solution, or even a leader that did not enjoy sharing responsibility. As the members worked through these challenges, they usually discovered ways to overcome these personality conflicts and work together as a team.

The majority (seventeen) of the twenty-three participants took part in solving problems, as supported by observations, surveys, and interviews. According to surveys and interviews, the remaining five participants did not report in the survey and/or interview that they contributed to solving their group's problems, while the observations show that they demonstrated problem-solving skills on different days.

Table 12

*Demonstration and Enjoyment of Problem-Solving Skills Based on Surveys, Interviews, and Observations*

| Participant | Demonstrated Problem-Solving Skills | | | Enjoyment of Problem-Solving Skills | |
|---|---|---|---|---|---|
| | Survey | Interview | Observation | Survey | Interview |
| <u>Group A</u> | | | | | |
| 1 | X | X | 20% | X | X |
| 2 | X | X | 70% | X | X |
| 8 | X | X | 60% | X | X |
| 21 | X | X | 40% | X | X |
| <u>Group B</u> | | | | | |
| 5 | X | X | 60% | X | X |
| 14 | X | | 20% | X | X |
| 18 | X | X | 70% | X | X |
| 22 | X | | 20% | X | |
| <u>Group C</u> | | | | | |
| 3 | X | X | 10% | X | X |
| 4 | X | X | 70% | X | X |
| 10 | X | X | 70% | X | X |
| 20 | X | X | 60% | X | X |
| <u>Group D</u> | | | | | |
| 6 | X | X | 30% | X | X |
| 7 | X | X | 40% | X | X |
| 9 | | | 20% | | |
| <u>Group E</u> | | | | | |
| 11 | X | X | 80% | X | |
| 13 | X | | 0% | | |
| 15 | X | X | 60% | | X |
| 17 | | X | 80% | | |
| <u>Group F</u> | | | | | |
| 12 | | | 20% | | |
| 16 | X | X | 50% | X | X |
| 19 | X | X | 80% | X | X |
| 23 | X | X | 60% | X | X |

While most (nineteen) participants indicated that they enjoyed problem-solving tasks as indicated from the surveys and/or interviews, only four participants did not enjoy these challenges.  Usually the level of involvement corresponded with the degree of satisfaction from these problem-solving activities, as noted by participant comments on the open-ended survey and focus groups. While most participants stated that there were problems with building, coding, or teamwork, all of them acknowledged that they were able to overcome their difficulties. Most of them shared that this provided a sense of satisfaction, as they faced such obstacles and solved the problems as a team.

**Group A.** All participants in Group A reported in the surveys and interviews that they contributed to their group's challenges by using problem-solving skills, which was also supported by the observations. Interestingly, Participants 1 and 2 both reported in the surveys and interviews that they had difficulty with working as a team. "Participant 1 stated in the interview, "I learned that it's a bit harder to control cooperation than I thought it would be." Participant 2 also stated in the survey, "Group cooperation was a big problem." On the other hand, Participants 8 and 21 did not refer to cooperation, but rather completion of tasks, when discussing problem-solving skills. Participant 21 indicated that their group had problems with "when to stop and when to move the block." They solved their problem "by using our minds and working as a team." Participant 8 stated, "I enjoyed because…when we struggled and we finally completed it, I felt happy. Probably more happy than I would have if I just completed it the first time." Participant 8 also remarked, "Everyone was bored because I was doing all the work but when I gave them something to do, they asked me for help."

**Group B.** Only two participants (5 and 18) in Group B reported in interviews and surveys that they used problem-solving skills, also shown in the observations. Participant 5 stated in the interview, "I learned how to cooperate with team members." He also felt that his group completed the challenges well, but "this you had to ask each other." Participant 14 shared in the survey, "Most of the problems we had was programming the robot," but "I still had fun." She also said that Participant 18 figured out most of the problems, which was supported in the data. Participant 22 stated in the survey, "We didn't know what type of formula to put on the computer. Well, when we took time and worked together, it started to make a little bit more sense." She also acknowledged in the interview, "I learned that if you join in together, participate, you get stuff done more quicker if you just put your minds to it."

**Group C.** All of the participants in Group C reported in surveys and interviews that they used problem-solving skills, as was supported in the observations. When describing their problems, they usually discussed issues with the building, coding, or troubleshooting. As Participant 10 stated in the survey:

> We mostly had problems with figuring out the right code. We experimented and worked through them. Even if it took time, we still did the same theory. Doing this led us to completing the challenges we had problems with. [Also,] I think we did a good job at completing them successfully. As a group, we learned a lot, because…we've never done this before and it was a new experience for everyone in our group. And yeah, it was a lot of fun.

**Group D.** While observing Group D, Participants 6 and 9 were initially hesitant, especially since Participant 7 worked quickly and quietly to solve each daily challenge. Although the leader was not observed to encourage them to participate, these two participants became more interested and gradually contributed more ideas to the daily tasks. Both participants were observed to get excited when their group members worked together to solve a challenge. Even though Participant 9 did not report that she used problem-solving skills, she shared in the survey, "We had problems working together and problems coding. We worked together and we tried our best to do the coding." As supported by the observations, Participant 6 reported in the interview, “I learned problem-solving skills.” Participant 7 also shared in the interview, “I learned how to code better.”

**Group E.** As noted by the observations, only one participant did not exhibit problem-solving skills throughout the 10-day activity, even though she reported on the survey that she did. Participant 13 was observed to be quiet and withdrawn, and even though other group members tried to encourage her to participate, she often sat back and watched the others complete the challenges. At times, she would attempt the activity but quickly become frustrated and even appeared embarrassed that she did not understand how to contribute to her team’s task. Interestingly, she shared details in the survey regarding her team’s difficulties when she explained, “We had problems with the coding and putting the wires in the correct places while building the robot.”

Participant 11 expressed in the survey, “Our team got into a couple of fights about how to do what, and sometimes the coding got difficult and we struggled. We would talk things over and come to an understanding. We would also try different things to find the right coding.” According to the interview, Participant 15 learned more about “communicating with people and problem solving.” Participant 17 stated in the survey that she “hate[s her] group,” but she later shared in the interview that “I learned problem-solving skills and teamwork skills.”

**Group F.** When observing Group F, the researcher noticed that three of the four participants actively coded the programs. Participant 12 reported that she did not use problem-solving skills, mainly because she was not very involved with the activity. On different days, the three participants would take turns with the building, coding, programming, and troubleshooting. All three of these participants felt that they had made contributions to the daily challenges, as shown with their sense of satisfaction and excitement over each daily success. In the interviews and surveys, no participant in any of the groups indicated that the tasks were impossible, but rather they stated that they worked together and completed the challenges. This statement is consistent with the observations, even though some participants maintained a higher level of involvement on a daily basis. Participant 19 stated that she learned about "coding and problem-solving because we went through a lot of problems with our robot. The people were pretty good. We all got along together."

**Subtheme 1B: Leadership and teamwork.** Early in the robotics activities, one or two leaders emerged in each group. Even though some other group members likely understood the coding as well as the leaders, they tended to allow the leaders to designate responsibilities and take command of the daily challenges. While some leaders demonstrated positive leadership qualities, such as encouraging other teammates to participate, other leaders tended to take control and preferred to do everything himself or herself. During the interviews, several participants even mentioned that they asked for help from Participants 7 (Group 4) or 10 (Group 3) when they could not complete the challenge, likely because they were both knowledgeable and friendly. The researcher feels that the positive leadership qualities in these two leaders helped the other participants feel comfortable asking for their assistance.

**Group A.** In Group A, the leader (Participant 8) did not enjoy sharing responsibility with others. While Participant 8 was very knowledgeable about the coding and robotics, he preferred to do everything himself. Although Participants 1 and 2 wanted to be a part of the activity, they both agreed that they did not understand it, so they let Participant 8 take the lead. Participant 8 stated, "Whenever I gave them something to code, they always asked me for help anyway." As noted from the observations, Participant 8 eventually took over most of the coding and troubleshooting, while the other participants lost interest and displayed frustration.

**Group B.** Participant 18 took the lead in Group B. He tried to involve others by directing them to do tasks, rather than asking for their input. As a result, Participant 5 quietly tried to offer help, but Participants 14 and 22 quickly lost interest. Encouraged by the teacher to include all group members in the activities, they began to participate more, but Participants 14 and 22 were observed to appear frustrated and confused, most likely since they were not involved during the first few days of the activities. At times, they became involved but mostly felt "lost" because they had not participated as much as Participants 5 and 18.

Participant 5 stated that "The leader was [Participant 18] because he knew how to build LEGOs." Participant 14 agreed, stating "[Participant 18] did everything. I guess he took the lead because he enjoys it more than I do. I didn't take the lead because I didn't really have much experience." Participant 18 supported the other participants' statements. "I was amazed about how you could build all those robots and code. I would improve on my team helping me because if you take the lead it's like you're mean to your group – like you don't think they're smart or anything, but I just want them to help." I was the leader "because I was mainly the one who knew what was going on about the project."

**Group C.** Participant 10 emerged as the leader in Group C and exhibited positive leadership skills, as he often encouraged others to help with the robot. Once he asked Participant 4, "Do you want to do the honors and connect it?" While Participant 4 had been reluctant to participate, she gladly connected the robot and showed excitement when it worked correctly. Another time, Participant 10 asked his team members, "What do you think we need to change?" Participant 20 had also been reluctant to help, but she responded and then worked together with the others to solve the problem. She demonstrated increased involvement and excitement through the 10 days of robotics activity, which was likely a result of Participant 10's encouragement to offer suggestions and participate with the building and coding. As a result of his knowledge and positive leadership skills, Participant 10 was often asked for help when other groups had difficulties with the robotics activities, including Groups 2, 4, 5, and 6.

Participant 3 indicated in the interview that Participant 10 "was the leader because he has the best ideas and has more experience with LEGOs." Participant 4 also shared in the survey that Participant 10 "took the lead because he knows a lot about LEGOs and coding, but everybody worked pretty good together." Participant 10 declared in the interview, "I kinda felt like I took the lead…because I felt like I was pretty good at it. We worked good together, but I probably took over more than I should've." Participant 20 stated in the survey, "[Participant 10] was the leader…because he knew how to build LEGOs—like bigger things." Participant 20 also encouraged teammates, and once said, "Good job, [Participant 10]!" and other positive remarks.

**Group D.** As shown in the survey and interview, Participants 6 and 9 both felt that Participant 7 took the lead because he knew more than the others. Participant 6 stated in the survey, "I feel like [Participant 7] took the leader because he knew how to do everything." Participant 7 stated, "I guess I took the lead because the people in my group were not helping me build." He was often observed working quietly, and sometimes he shared responsibility with others, but usually this team completed the challenges faster than other groups.

**Group E.** In the interview, Participant 11 acknowledged that

> I felt like we tried to work together most of the time, but we would have two people doing most of the building. Another person would try to figure out some of the programming. And we had one person [Participant 13] who wouldn't do as much as the others and I asked her if she wanted to do some of the programming, or if she wanted to do some of the building, and sometimes who would say yes and find something to do.

> And then other times, she would just not want to do this, so she said no. But other than that, I feel we all pretty well worked together to get it done.

When asked if she was the leader, Participant 11 responded, "I guess I was more of a leader than everyone else."

Participant 13 indicated that "[Participant 11] took the lead because she…seemed to understand the programming more. [Participant 15] seemed to do most of the building." As observed by the researcher, Participant 13 did not participate well in activities. Participants 15 and 17 agreed in the survey and interview that Participants 11, 15, and 17 worked on building and programming together, while Participant 13 did not participate at all.

**Group F.** Participant 12 indicated in the survey that Participant 19 was the leader: "[Participant 19] knew more about what she was doing." Participant 16 also stated in the survey, "[Participant 19] took the lead in designing the robot. She built most of the robot." Participant 19 also indicated in the survey that she took the lead, "because I built the robot and was the only one doing things for all of the activities. I made the group work together and made sure we got everything done." She specified she got others involved because "I needed some help in some things and so I kind of made them help me. I wasn't mean about it, though." Participant 23 revealed in the survey that "[Participant 19] was the leader because she built most of the robot." Later in the interview, Participant 23 stated that he felt he was the leader at the beginning, and then [Participant 19] took the lead. "I built the whole thing basically and then [Participant 19] started on the code."

According to the observations, these members worked well together, taking turns with the leadership role. Each day these participants were enthusiastic and demonstrated great teamwork skills as they involved each other in the activities. While they tried to involve Participant 12, she demonstrated very little interest in the activity and repeatedly chose not to be involved. In addition, the participants reflected on effective leadership qualities that helped their teammates to better work together and tackle the next challenge together.

While the data from Groups 1 – 5 consistently demonstrated the same leader(s) from each group, the researcher was surprised with the responses from Group F. Participant responses noted that Participant 19 was the leader, while observations showed that Participants 16 and 23 shared leadership roles. According to the observations, Participants 16 and 23 built and tested the robot, and when there was a difficulty, voluntarily returned during another class to solve the problem. In addition, they often programmed the robot and made changes to make the program work. This was the only obvious inconsistency among data sources that was noted in leadership roles among the groups. As can be seen in Table 13, the data results correlated as each leader was identified.

Table 13

*Leadership and Teamwork Skills During Robotics Activity Based on Surveys, Interviews, and Observations*

| Participant | Leader of Robotics Activities | | | Demonstrated Teamwork Skills | | |
|---|---|---|---|---|---|---|
| | Survey | Interview | Observation | Survey | Interview | Observation |
| Group A | | | | | | |
| 1 | | | 0% | X | X | 20% |
| 2 | | | 50% | X | X | 50% |
| 8 | X | X | 90% | X | | 60% |
| 21 | | | 20% | X | X | 50% |
| Group B | | | | | | |
| 5 | | | 60% | X | X | 80% |
| 14 | | | 0% | | | 30% |
| 18 | X | X | 90% | X | X | 80% |
| 22 | | | 0% | X | | 10% |
| Group C | | | | | | |
| 3 | | | 0% | X | X | 30% |
| 4 | | | 30% | X | X | 90% |
| 10 | X | X | 90% | X | X | 80% |
| 20 | | | 50% | X | X | 80% |
| Group D | | | | | | |
| 6 | | | 20% | X | | 60% |
| 7 | X | X | 90% | X | X | 70% |
| 9 | | | 10% | X | | 50% |
| Group E | | | | | | |
| 11 | X | X | 90% | X | X | 90% |
| 13 | | | 0% | | | 0% |
| 15 | X | X | 80% | X | X | 80% |
| 17 | X | | 40% | X | X | 70% |
| Group F | | | | | | |
| 12 | | | 0% | | | 20% |
| 16 | | X | 60% | X | X | 90% |
| 19 | X | X | 70% | X | X | 100% |
| 23 | | X | 90% | X | X | 100% |

Whether the participant was a leader or not, teamwork skills were also noted. Often the participant considered himself or herself to be the builder or programmer, while team members usually took turns writing on the daily challenge worksheets. As shown in Table 14, almost all participants took part in building or programming (coding) the robot during the activity. These participants also indicated that they displayed teamwork skills and felt a greater sense of enjoyment and satisfaction from their active participation in the activity.

Table 14

*Involvement in Robotics Activity – Builder or Programmer*

| Participant | Builder | Programmer |
|---|---|---|
| Group A | | |
| 1 | | |
| 2 | X | X |
| 8 | X | X |
| 21 | X | |
| Group B | | |
| 5 | X | X |
| 14 | X | |
| 18 | X | X |
| 22 | X | |
| Group C | | |
| 3 | X | |
| 4 | X | |
| 10 | X | X |
| 20 | X | X |
| Group D | | |
| 6 | | |
| 7 | X | X |
| 9 | | |
| Group E | | |
| 11 | X | X |
| 13 | | |
| 15 | X | |
| 17 | X | X |
| Group F | | |
| 12 | | |
| 16 | X | X |
| 19 | X | X |
| 23 | X | X |

The researcher observed that throughout the activities, group members tended to allow the leaders to make decisions and designate responsibilities. Although the leaders had not been assigned, the members seemed to decide and accept these roles on their own. While some leaders did not share responsibilities well, others tried to encourage participants who were not actively involved. As shown in participant comments from the open-ended survey and focus groups, some leaders displayed positive qualities while others had difficulties with their roles.

**Theme 2: Self-Efficacy and Enjoyment in Relation to STEM Tasks and STEM Careers**

While some participants had expressed apprehension prior to beginning the robotics unit, most of them later reported an interest and enjoyment in the activities. As seen in Table 15, only two participants (13 and 17) did not indicate an interest or enjoyment in the activity, even though the observer noted that they seemed to enjoy it at times. While some challenges were difficult, the participants enjoyed working together with friends and conquering the daily tasks. Very likely, participants would not have enjoyed the activities as much if they had to work alone, since they often relied on each other to overcome the challenges.

The observer also noted that on most days, participants displayed excitement when their robots demonstrated new tricks as they solved daily challenges. Most participants became more motivated when their team solved the challenge, which in turn, gave them confidence to face the next task.

Table 15

*Interest and Enjoyment in Robotics Activity Based on Surveys, Interviews, and Observations*

| Participant | Interest in Robotics Activity | | Enjoyment in Robotics Activity | | |
|---|---|---|---|---|---|
| | Survey | Interview | Survey | Interview | Observation |
| Group A | | | | | |
| 1 | | | X | X | 20% |
| 2 | X | X | X | X | 60% |
| 8 | X | X | X | X | 80% |
| 21 | X | X | X | X | 70% |
| Group B | | | | | |
| 5 | X | X | X | X | 80% |
| 14 | X | X | X | X | 50% |
| 18 | X | X | X | X | 80% |
| 22 | X | X | X | X | 30% |
| Group C | | | | | |
| 3 | X | X | X | X | 40% |
| 4 | X | X | X | X | 70% |
| 10 | X | X | X | X | 60% |
| 20 | X | X | X | X | 70% |
| Group D | | | | | |
| 6 | X | X | X | X | 60% |
| 7 | X | X | X | X | 90% |
| 9 | X | X | X | X | 60% |
| Group E | | | | | |
| 11 | X | | X | X | 80% |
| 13 | | | | | 10% |
| 15 | X | X | X | X | 70% |
| 17 | | | | | 50% |
| Group F | | | | | |
| 12 | X | X | X | X | 20% |
| 16 | X | X | X | X | 80% |
| 19 | X | X | X | X | 100% |
| 23 | X | X | X | X | 90% |

**Group A.** In Group A, Participants 2, 8, and 21 displayed enjoyment in the activity on most days. Participant 21 stated in the interview, “I enjoyed it because when we would program it, I like trying testing it because it was actually fun.” Participant 2 also stated in the survey, “I enjoy STEM activities because it’s fun to learn and explore things in STEM.” Although

Participant 1 was less involved than the others, she still shared in the survey, “It was fun getting to work with the group.  Programming and building the robot was fun, too.”

**Group B.**  In Group B, Participants 5 and 18 demonstrated repeated enjoyment in the activity, as shown in the surveys, interviews, and observations.  Participant 18 stated in the interview, “I enjoyed it” when the robot said, “You did good.”  Participant 5 also stated in the survey and interview, “It was fun.”  In the survey, Participant 14 stated, “Program[ming] your robot to move and do cool tricks, I think it’s fascinating.”  Finally, Participant 22 stated in the survey, “It’s fun to be a part of something that keeps your mind stimulating.”

**Group C.**  One of the most successful groups was Group C, since they often completed their challenges and worked well together.  In Group C, Participants 4, 10, and 20 displayed enjoyment in the activity on most days, even though at times they appeared frustrated.  Once Participant 4 asked the teacher if we could work on robotics each day until the end of the semester.  When the teacher asked if she wanted to, Participant 4 responded with a big smile, “Yes!  I love doing this!”

**Group D.**  In Group D, Participant 9 was at first reluctant but later demonstrated increased involvement and showed enthusiasm at different times when her team solved the daily challenges.  For instance, after Participant 9’s robot completed a challenge, she once exclaimed, “This is so beautiful!”  Participant 6 shared in the interview, “I liked it because…it was just fun!”  Also, Participant 7 stated in the interview, “I enjoyed it because it teaches me stuff I didn’t know.”

**Group E.**  According to the observations, Participants 15 and 17 displayed enjoyment in the activity on most days, even though their survey and interview responses indicated otherwise.  At one time during the interview, Participant 15 reluctantly admitted, “When we were just doing the coding, I didn't like it. But then, after I [saw] how a Lego is moving [by coding on the computer], I thought, 'Oh, this is pretty neat.'"

**Group F.** In Group F, Participants 16, 19, and 23 also demonstrated much excitement when their team solved each daily task. In the survey and interview, Participant 16 stated, "It was a fun activity." Also, Participant 19 stated in the survey, "I love helping and problem-solving. I also love discovering new things. It was a fun activity and we learned a lot." Finally, Participant 23 stated in the interview, "I liked the robot part of it. I think it taught me a lot more stuff than I knew, really."

As shown in participant responses, participants enjoyed different aspects of the activities. Being able to work with a group was a notable aspect of the activities. Participant 1 (Group A) commented, "It was fun getting to work with the group." Participant 21 (Group A) stated that LEGO Robotics is "a fun thing to do with friends." Participant 3 (Group C) remarked, "I thought it was really fun and…we learned a lot from it. And I made bonds with my project members trying to work it all out." Participant 4 (Group C) commented, "I thought it was fun because I have not ever done it before, and it was fun trying something new, and I like being with my friends and playing and building the robot." Later, Participant 4 (Group C) asked, "Are we going to do this every day til the end of the semester?" When asked if she wanted to, she responded with a big smile, "Yes! I love doing this!" Participant 16 (Group F) said, "I enjoyed it because it's a lot easier to solve stuff if you're in a group than by yourself." Participant 19 (Group F) commented, "I enjoyed it because I like solving things and I like working with the group."

Some participants found exploring and being challenged a good aspect. Participant 2 (Group A) commented, "I enjoy STEM activities because it's fun to learn and explore things in

STEM." Participant 8 (Group A) remarked, "I enjoy STEM activities because they challenge my brain to do more, think harder, and look at the world in a unique way." LEGO Robotics activities are "hard but fun once you figure them out." Also, "robots can be used for many things humans can't do." Participant 10 (Group C) stated that he enjoyed these activities because "while you are doing them, you're constantly learning new things. Also, they allow you to try new things and experiment with them." Participant 12 (Group F) agreed, "I like to explore and discover things. It was cool."

Building and programming of the robots most interested some participants. Participant 14 (Group B) remarked, "I had more fun building the robot than programming. Programming your robot to move and do cool tricks, I think it's fascinating." Participant 18 (Group B) commented that he enjoyed it "because if you did it right and it worked out great, it felt like you did something right in the project and you felt good." Participant 9 (Group D) stated, "I liked the building part of it." At one point, she said, "This is so beautiful!" Participant 7 (Group D) remarked, "I really like it because I like coding and stuff." Participant 11 (Group E) stated, "It was interesting to learn how to put it together." Participant 1 (Group A) commented, "Programming and building the robot was fun, too." Participant 21 (Group A) stated, "I enjoyed it because when we programmed it, I liked testing it because it was actually fun." He was often standing up and VERY involved; he smiled a lot during the activities.

Being able to problem solve and have things turn out well was important. Participant 5 (Group B) remarked, "I enjoyed it because if you can actually do it…correctly…it can be really fun and you can make really cool and fun things." Participant 22 (Group B) stated, "I mostly like doing problem-solving and helping out because it's fun to be a part of something that keeps your mind stimulating. LEGO Robotics is a fun activity to do especially when you get your robot to work and move around." Participant 20 (Group C) responded, "I learned how to solve things better. I found it fun…and really cool."

Some participants did not like the amount of time for the activities or that fact that they had to think and problem solve. Participant 13 (Group E) stated, "My overall impression of LEGO Robotics is that they take a lot of time and require thinking. I don't think I really enjoyed it that much." Participant 17 (Group E) commented, "Boring. Torture. Pointless. I learned nothing of use. I learned to program a robot. I do not need to know this in life."

Several participants found the activities challenging, but still enjoyed them. Participant 15 (Group E) stated, "I learned how to communicate better. When we were doing the coding, I didn't like it. But then, after I [saw] how a LEGO is moving [by coding on the computer], I thought, 'Oh, this is pretty neat.' Overall, I enjoyed it." Participant 23 (Group F) commented, "I think it was pretty fun after we built it, but the building part was hard."

Although twenty-one of the participants enjoyed the activity, some of them were hesitant to pursue a STEM career, noting that they might not enjoy working with other people each day. These participants shared that they like having individual work and need their alone time, rather than always being a part of a group. They feared that they might not like their group members and could possibly get irritated with them, which is a main reason that some participants might not pursue STEM careers. Even participants who truly enjoyed their team members realized that in a STEM career, they might be working with people who are very different from themselves.

While most participants enjoyed the STEM activity, they also felt confident that they could complete STEM tasks. With the exception of one participant (13), the participants felt confident that they could perform the STEM tasks, as long as they are given enough time and can work in a group. Surprisingly, a few participants still felt that they might not be smart enough in math to complete STEM tasks, but nonetheless, they think that they would still enjoy them. Several participants also admitted that they had been very nervous and felt the STEM tasks would be too difficult, but they began to get easier during the activities. As their group solved the daily challenges, they started to understand it much better and gain more confidence. Only a few participants indicated that they are good with STEM tasks but do not enjoy doing them. Finally, several participants attributed their group's success to the members, stating that they solved the challenges effectively because their team members worked so well together.

It appears participants who have higher self-efficacy of STEM tasks and STEM careers tend to enjoy STEM activities (see Table 16). In addition, self-efficacy and enjoyment of STEM activities directly correspond with participants' plans to take AP or Advanced STEM classes as well as their interest in STEM careers. Several participants mentioned that they now feel more confident with coding, technology, communication, and problem solving, and so now they are more interested in STEM classes and careers.

Table 16

*Self-Efficacy, Enjoyment, and Plans to Pursue STEM Classes or Careers*

| Participant | Self-Efficacy of STEM Tasks | | Self-Efficacy in STEM Career | | Enjoyment of STEM Activities | | Plans to Take AP or Advanced STEM Classes | | Interest in STEM Career | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Survey | Interview | Survey | Interview | Survey | Interview | Survey | Interview | Survey | Interview |
| <u>Group A</u> | | | | | | | | | | |
| 1 | X | | | | X | X | X | X | | |
| 2 | X | X | X | X | X | X | X | X | X | X |
| 8 | X | X | X | X | X | X | X | X | X | X |
| 21 | X | X | X | X | X | X | n/a | X | X | X |
| <u>Group B</u> | | | | | | | | | | |
| 5 | X | X | X | X | X | X | X | | | X |
| 14 | X | X | | X | X | X | X | X | X | X |
| 18 | X | | X | X | X | X | X | X | X | X |
| 22 | X | X | X | X | X | X | X | X | X | X |
| <u>Group C</u> | | | | | | | | | | |
| 3 | X | X | X | X | X | X | X | X | X | X |
| 4 | X | | | | X | X | X | X | X | X |
| 10 | X | X | X | X | X | X | X | X | X | X |
| 20 | X | X | | X | X | X | | X | X | X |
| <u>Group D</u> | | | | | | | | | | |
| 6 | | X | | X | X | X | | X | | |
| 7 | X | X | X | X | X | X | X | X | X | X |
| 9 | X | X | X | X | | X | X | X | X | X |
| <u>Group E</u> | | | | | | | | | | |
| 11 | X | | X | | X | X | X | X | X | X |
| 13 | | | | | | | | | | |
| 15 | X | X | | X | | X | X | X | X | X |
| 17 | X | | X | | | | X | X | X | X |
| <u>Group F</u> | | | | | | | | | | |
| 12 | X | X | X | | X | X | | X | | X |
| 16 | X | X | X | | | X | X | X | X | X |
| 19 | X | X | X | X | X | X | X | X | X | X |
| 23 | X | X | X | | X | X | X | X | X | X |

**Theme 3: Impact on Personal Goals**

While most participants displayed increased interest and enjoyment in the robotics activities, the researcher also studied their attitudes toward STEM and effects on their long-term career goals. During the coding process, the researcher found that the robotics activity had an impact on most participants' personal goals, which is also a theme of the Social Cognitive Career Theory. In addition, the following subthemes emerged: (3A) Effect of robotics activity on feelings toward STEM; and (3B) Plans to take STEM classes or pursue STEM careers.

**Subtheme 3A: Effect of robotics activity on feelings toward STEM.** While all participants had a basic understanding of STEM concepts prior to the robotics activity, not many of them had participated in hands-on STEM activities. A few of them had observed family members who have STEM careers, so they had a greater awareness about STEM tasks. Prior to the activity, many participants had indicated that STEM tasks are difficult and challenging, expressing that only participants who excel in math and science will be successful in STEM careers. Data for these responses were taken from the surveys and focus group interviews.

**Group A.** The responses varied in Group A, with three participants stating that the robotics activity had a positive impact on their feelings toward STEM. Participant 2 shared in her interview, "Before I didn't know much about STEM, but now I know more and it interests me a bit more than it did before." Participant 8 wrote in the survey, "I am more interested because the robotics makes me wonder what activities a robot can do to improve daily life for me and everyone around me. Also, it makes me wonder how I can advance industry and science to make goods faster, smarter, and more eco-friendly." Participant 21 commented in the survey, "More cause I like doing hands-on activities…and it's fun to do LEGOs." On the other hand, Participant 1 stated in the survey, "I'm not changed about my opinion on it. I still don't really want to do these things although they are good things to learn."

**Group B.** Three of the four participants in Group B indicated a positive change on feelings toward STEM as a result of the robotics activity. Participant 5 shared in the survey, "Yes," it has encouraged an interest in STEM careers. Participant 14 responded in the survey, “I’m more interested in these activities.” Participant 18 stated in the survey, “More because I like discovering more things in LEGO Robotics. I’m interested in careers related to robotics because I like robotics a lot.” While Participant 22 indicated no change on the interview, she also stated, “They didn’t change because what I want to be has something to do with STEM.”

**Group C.** All of the participants in Group C indicated a positive change. Participant 10 commented in the survey, “I am more interested in STEM activities. I’ve been interested in engineering and computer things, but now that I’ve done this, I think I could really do well in this subject, and I just enjoy it.” Participant 3 indicated in the survey that she was more interested in STEM activities because “I got to learn what all people in STEM careers do, like robotics, technology, etc. Also, it has made me enjoy engineering and working…like problem-solving. My feelings have definitely changed for the better.” Participant 4 stated in the survey, “I’m more interested in STEM activities…because now that I’ve done that, I think it’s fun. I’m also more interested in engineering careers now.” Participant 20 specified in the survey, “The reason why I am more interested is I think I could do good at engineering. I think I could be better at problem-solving. I could invent new things. I’m more interested in technology and engineering now.”

**Group D.** Two of the three participants in Group D indicated a greater interest in STEM activities. Participant 7 stated in the survey and interview, “I am more interested in STEM activities. It was fun. Yes, it changed…I like it a lot better. I’m more interested in architecture as a STEM career…because of the designing of the robot.” Participant 9 stated in the interview, “I think I like it a little bit better.” On the other hand, Participant 6 indicated no change in the survey and interview, stating that she is not interested in STEM activities.

**Group E.** As shown in the surveys and interviews, all of the participants in Group E did not show increased interest in STEM activities. Participant 11 stated in the survey that she is not more interested in robotics, but she is more interested in other STEM careers, such as "astronomer and vet." Participant 13 states in the survey, "I am less interested in STEM activities because it requires…inventing and problem-solving, things that I've never been very good at." Participant 15 states in the survey that she is less interested in STEM activities "because it is more boring than I thought." She also has no interest in STEM careers. Participant 15 shared in the interview, "My opinion didn't change. I still don't really like it. It hasn't changed my mind at all [about STEM careers]." Participant 17 also stated in the interview, "My opinion didn't change from start to end. Disliked it in the beginning…disliked it at the end. "No, it hasn't changed my mind at all [about STEM careers]."

**Group F.** All of the participants in Group F indicated a greater interest in STEM activities, as noted in the survey, interview, or both. Participant 16 responded in the survey, "More interest in STEM activities. This activity was fun. I like seeing it…and it comes together." Participant 19 commented in the survey, "I am more interested in STEM activities. It was fun and I loved doing it. I love working out things. I want to do something with working out problems when I get older. I don't really know what career. It has changed for better for me." Participant 23 remarked in the survey, "More because it was fun and I really liked the robot activity. Yes, I'm more interested in STEM careers like engineering and programming things and dealing with machines. I'm more interested in engineering careers because of this activity." In the interview, Participant 12 did not change her opinion because she enjoyed STEM activities already: "I still feel the same as how I had felt…before. I liked it a lot before.

I still do." On the other hand, Participant 12 shared in the survey that she is "more interested" in STEM activities. "It sounds cool."

As a result of the LEGO Robotics activity, the majority of participants indicated a positive impact of their feelings toward STEM, as shown in Table 17. According to data collected from surveys and interviews, fifteen participants reported that they gained positive feelings toward STEM as an effect of participation in the robotics activity, four participants reported negative feelings (or feelings that had not changed) before the activity, two participants reported conflicting results (both positive and negative feelings), and two participants reported no change. As collected from surveys and interviews, participants' responses further support their increased positive feelings toward STEM as a result of the robotics activity.

Table 17

*Impact of Feelings Toward STEM as a Result of Robotics Activity*

| Participant | Positive Change | | Negative Change | | No Change | |
|---|---|---|---|---|---|---|
| | Survey | Interview | Survey | Interview | Survey | Interview |
| Group A | | | | | | |
| 1 | | X | | | X | X |
| 2 | X | X | | | | |
| 8 | X | X | | | | |
| 21 | X | X | | | | |
| Group B | | | | | | |
| 5 | | X | | | X | |
| 14 | X | | | | | X |
| 18 | X | X | | | | |
| 22 | | | | | X | X |
| Group C | | | | | | |
| 3 | X | X | | | | |
| 4 | | X | X | | | |
| 10 | X | X | | | | |
| 20 | X | X | | | | |
| Group D | | | | | | |
| 6 | | | | | X | X |
| 7 | X | X | | | | |
| 9 | | X | X | | | |
| Group E | | | | | | |
| 11 | | | | X | X | |
| 13 | | | X | | | X |
| 15 | | | X | | | X |
| 17 | | | X | | | X |
| Group F | | | | | | |
| 12 | X | | | | | X |
| 16 | X | X | | | | |
| 19 | X | X | | | | |
| 23 | X | X | | | | |

**Subtheme 3B: Plans to take STEM classes or pursue STEM careers.** Prior to the LEGO Robotics activity, participants completed skill and interest assessments in the Career Cruising program. Based on student questionnaires, a list of careers was suggested to the participants, and then they saved careers of interest to their portfolios. In addition, participants had the option to add or delete careers so that their lists of careers accurately reflected those in which they are most interested. After the robotics activity, participants again completed the assessments and made changes to their lists of careers of interest to them. As can be seen in Table 18, thirteen participants indicated an initial interest in STEM careers. While ten participants had no interest in STEM careers prior to the activity, five of them gained interest in STEM careers, while five of them did not have increased interest in STEM careers. Of the thirteen participants who were interested in STEM careers before the activity, eight of them indicated more STEM careers in which they were interested. A further breakdown of the results can be seen in Figure 2. In addition to the data provided, participant responses also supported the increased interest in STEM classes and careers as a result of the robotics activity.

Table 18

*Interest in STEM Careers: Pre-Activity and Post-Activity (Career Cruising)*

| Participant | Pre-Activity | Post-Activity |
|---|---|---|
| Group A | | |
| 1 | None | Animator<br>Zoologist |
| 2 | Engineering Technician | Chemical Engineering Technician; Engineering Technician |
| 8 | Aerospace Engineer; Architect; Race Car Technician; Chemical Engineer; Industrial Engineer; Mechanical Engineer; Mechanical Engineering Technician; Mining Engineer; Naval Architect; Nuclear Engineer; Petroleum Engineer | Aerospace Engineer; Aircraft Mechanic; Architect; Combat Engineer; Environmental Engineer; Race Car Technician; Chemical Engineer; Industrial Engineer; Mechanical Engineer; Mechanical Engineering Technician; Mining Engineer; Naval Architect; Nuclear Engineer; Petroleum Engineer |
| 21 | Physical Therapist | Physical Therapist; Veterinarian |
| Group B | | |
| 5 | None | None |
| 14 | Marine Biologist; Microbiologist; Veterinarian | Marine Biologist; Microbiologist; Veterinarian; Veterinary Technician |
| 18 | None | Civil Engineer |
| 22 | Anesthesiologist; Physical Therapist | Anesthesiologist; Physical Therapist |
| Group C | | |
| 3 | None | Ob-Gyn; Physical Therapist; Surgical Technologist |
| 4 | None | Dental Hygienist; Veterinarian |
| 10 | Aerospace Engineer; Aircraft Mechanic; Architect; Chemical Engineering Technician; Chemist; Computer Hardware Engineer; Computer Scientist; Electronics Engineer; Engineering Technician; Geneticist; Industrial Engineer; Industrial Machinery Mechanic; Information Security Analyst; Materials/Metallurgical Engineer; | Aerospace Engineer; Aircraft Mechanic; Architect; Avionics Tech; Chemical Engineering Technician; Chemist; Civil Engineer; Computer Hardware Engineer; Computer Scientist; Electrical Engineering Tech; Electronics Engineer; Electronics Engineering Technician; Engineering Technician; Geneticist; Industrial Engineer; Industrial Engineering Tech; Industrial Machinery |

| | | |
|---|---|---|
| | Mathematician; Mechanical Engineering Technician; Mining Engineer; Naval Architect; Nuclear Engineer; Perfusionist; Petroleum Engineer; Stationary Engineer | Mechanic; Information Security Analyst; Machinist; Materials/Metallurgical Engineer; Mathematician; Mechanical Engineering Technician; Mining Engineer; Naval Architect; Nuclear Engineer; Perfusionist; Petroleum Engineer; Power Plant Operator; Stationary Engineer |
| 20 | Aircraft Mechanic; Combat Engineer; Electrical Engineer; Electrician; Power Plant Operator; Video Game Developer | Aircraft Mechanic; Combat Engineer; Computer Support Person; Electrical Engineer; Electrician; Power Plant Operator; Video Game Developer; Web Developer |
| <u>Group D</u> | | |
| 6 | Veterinary Technician | Anesthesiologist; Veterinary Technician |
| 7 | Mechanical Engineering Technician; Welder | Mechanical Engineering Technician; Welder |
| 9 | Nurse; Public Health Nurse | Nurse; Public Health Nurse |
| <u>Group E</u> | | |
| 11 | Gerontologist; Hospital Service Worker; Marine Biologist; Veterinarian | Astronomer; Gerontologist; Marine Biologist; Surgeon; Veterinarian |
| 13 | None | Agricultural Technician; Doctor; Nurse; Veterinarian; Veterinary Technician |
| 15 | None | None |
| 17 | Biochemist; Biologist; Botanist; Chemist; Veterinarian; Veterinary Technician | Biochemist; Biologist; Botanist; Chemist; Veterinarian; Veterinary Technician |
| <u>Group F</u> | | |
| 12 | None | None |
| 16 | None | None |
| 19 | Dental Lab Technician; Optometrist; Surgeon | Dental Lab Technician; Optometrist; Surgeon |
| 23 | None | None |

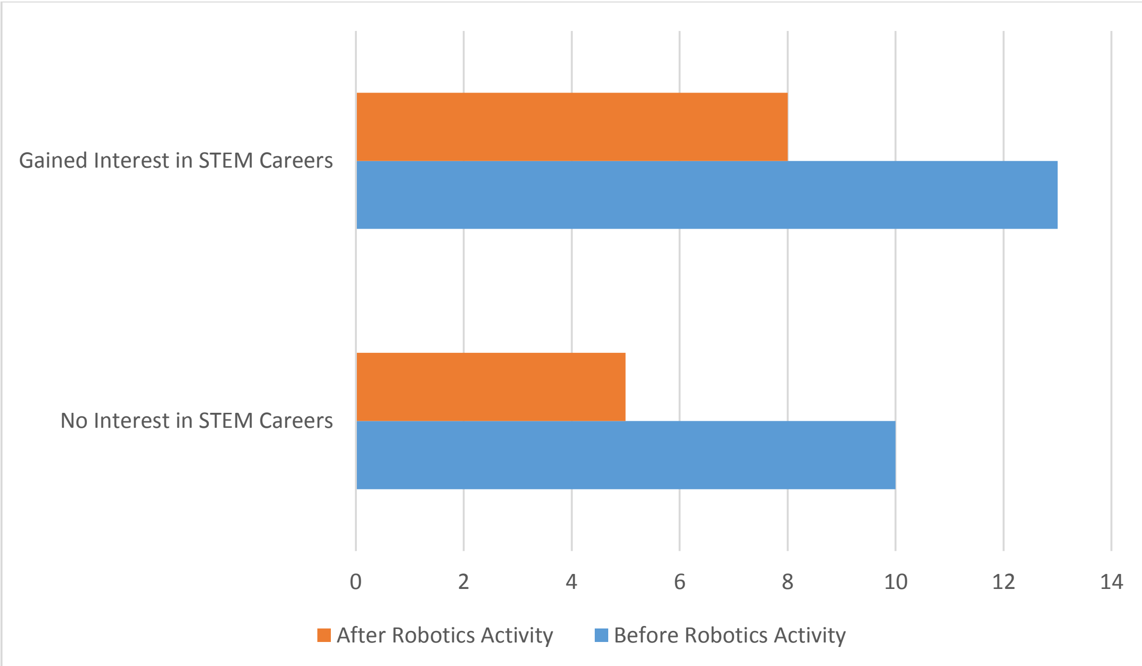


*Figure 2.* STEM career interests: Pre-activity and post-activity (Career Cruising).

**Group A.** Three of the four participants in Group A indicated an increased interest in STEM careers or plans to take Advanced or AP STEM classes. Participant 2 stated, "I'm interested in STEM careers. Mostly ones dealing with computers or actual science. I plan to take Science and Math AP or Advanced classes in high school." Participant 8 commented, "[Robotics] has encouraged me to go into any technology career. Or possibly building, too. I'm interested in working at Apple or something like that. I want to go to college to get at least a master's degree so I can be an engineer." Participant 21 responded that he planned to take "AP Science. It has shown me how to build stuff, how to program it, and you need that stuff in engineering." While Participant 1 is not interested in a STEM career, she enjoyed the creative aspect of the Lego Robotics. She explained during the interview, "Lego Robotics…kinda reminded me of…designing because you make things out of Legos. I'm kinda leaning more towards arts stuff and creative careers like that."

**Group B.** All of the participants in Group B expressed interest in STEM classes or careers. Participant 5 acknowledged in the interview, “[The robotics activity] probably pushed me a little bit more towards engineering …and technology.” Participant 14 commented that she was interested in “AP Math or Science.” Participant 18 commented, “I might do engineering because I think I’m good at it because I’ve tried it.”

**Group C.** All of the participants in Group C voiced interest in STEM classes or careers. Participant 3 stated in the survey, “Being an engineer with robotics has really been cool and I would like to be able to do that. I’m interested in AP Science or Technology classes.” Participant 4 mentioned in the interview that she wants to take “classes that will help me to become a vet.” Participant 10 shared in the survey, “I’m most interested in architectural, engineering, and possibly a medical career. I plan to take AP Science, Math, and Computer Science classes.” Participant 20 remarked in the survey, “I am most interested in technology. I plan to take AP Computer Science.”

**Group D.** Two of the three participants in Group D professed interest in STEM classes or careers. Participant 7 shared in the survey, “I want to be an architect or a video game coder. Possibly interested in engineering field, too. I plan to take AP Computer Science.” Participant 9 stated in the interview that she plans to take AP “Science because I want to be in the health field.” On the other hand, Participant 6 stated in the survey that she is “not interested in taking STEM classes or having a STEM career.” This is contradictory to her interview response, in which she states that she plans to take a “Science” AP class.

**Group E.** In Group E, three of the four participants plan to pursue STEM careers, but they do not involve robotics. Participant 11 stated in the interview that she plans to be an “artist or astronomer or vet” and take “all [AP classes] except Social Studies.” Also, Participant 13 shared in the interview that she plans to pursue "any career that involves animals, but I haven't exactly decided yet." Participant 15 indicated in the survey and interview that she plans to be a Physical Therapist or Nurse, and she plans to take "Science and Math" AP classes. Last, Participant 17 shared in the survey and interview that she plans to be a Vet, Vet Tech, or Author and wants to take "Science and Math" AP classes.

**Group F.** All of the participants in Group F plan to pursue STEM careers and take STEM Advanced or AP classes. Participant 12 commented in the interview, "I want to go into the medical field, like being a baby nurse. I plan to take AP Science." Participant 16 stated in the survey and interview that she plans to pursue a career in the "health field" and wants to take AP classes that are "anything but English." Participant 19 shared in the survey, "I'd like a career in math. I love it and working out things. I plan to take AP Math and Science classes." Participant 23 stated in the interview, "I'd want to be an architect because I like designing my own things. I plan to take AP Math…because you really use math for a lot of stuff."

### Theme 4: Changes for Robotics Activities

In order to improve future instruction, participants were encouraged to share their thoughts and suggestions about the LEGO Robotics activity. Participants made suggestions for changes they would like to see in the robotics activity. While some of the suggestions can be useful, others might not be feasible for all teachers.

**Group A.** Participant 1 suggested in the survey, "Easier coding and programming." Participant 2 stated in the survey, "I'd suggest adding tips about coding and programming." Participant 8 suggested in the survey, "Explain what every block is and what it does." While this was explained at the beginning of each challenge, this student tended to begin working instead of listen to the introduction. Participant 21 wanted to see a "Remote control."

**Group B.** Participant 5 shared in the interview, "Having longer to do the activity. Not that long, but maybe an extra day because a lot of people fell behind. Then on the other hand, some people get done easily, so that would leave them a whole day of doing nothing." Participant 5 also indicated in the survey, "Cooler robots and different kinds in different groups." Participant 22 commented in the survey, "That there would already be a robot made for participants instead of building one." Participant 14 responded in the survey, "Easier programs is my number one, so I could've helped them out with the computer." Participant 18 (the leader) responded, "Nothing because it was good the way it is. Cool and fun."

**Group C.** Participant 3 shared in the survey, "Maybe make the time longer." Participant 4 also shared in the survey, "Have more time to do stuff. Have everyone doing something. Have the robot to cooperate better." Participant 20 commented in the survey, "We should be able to get more time to do the worksheet. Some of the tasks should be easier." Participant 10 commented in the survey, "Maybe include some challenges where you have to disassemble and rebuild the robot. After you built the robot, everything else was programming. Besides that, I think everything else was ok for learning the different functions of the motor and sensor blocks. Also, if it had been more structured. Maybe put some different activities in it as we go."

**Group D.** Participant 7 suggested in the survey, "Let people choose the groups." Participant 6 commented in the interview, "I think that it was fine, but I wish they would make some videos…the actual LEGO people…because then you could know what to do." Participant 7 added, "I'd say they need to make a video on what each block does to help you." Participant 9 shared in the survey, "I really don't think any changes."

**Group E.** Participant 11 had several suggestions in the survey and interview:

> Make the activities more interesting and have more thorough instructions for the coding. Be more in depth on what to do in instructions. They were very vague on how you were supposed to do it—what you were supposed to do. They would only give you so much information, then you had to practically figure out how to get the robot to move a certain way with no idea how to do it. Not step by step, but at least a little more helpful than it was. More informative.

Participant 13 also added suggestions in the survey, “Some changes that I suggest for this LEGO Robotics activity is to have more things that you can do with the robot.” Participant 17 stated in the survey, “NOT doing it. Make it have less programming. Let people do it who care.” Participant 15 remarked in the survey, “To make the directions clear enough.”

**Group F.** Participant 12 noted in the survey, “I can’t think of any.” Participant 16 commented in the survey, “Nothing. The activity was fun as it was.” Participant 19 also shared in the survey, “Nothing. It was very fun.” Finally, Participant 23 remarked in the survey, “I wouldn’t suggest any changes. I think it was good enough.” When asked if they prefer directions or the freedom to solve challenges as they wish in the interview, Participant 23 responded, “Step-by-step directions. I like that.”

Some participants indicated they would like a longer time period to solve each daily challenge, while others had suggestions for coding and programming. Some participants indicated more structure and guidance for the activities would be helpful, yet they also realized that they would not have been able to use as much creativity and problem-solving skills to solve each challenge. At one point, the Interviewer explored the changes further by stating, “I think one of the reasons that it didn’t provide step by step directions, or why [I] didn’t add more structured instructions, is so that you can be creative. Different groups sometimes built it and saw the challenge in different ways." This resulted in additional comments by the participants. Participant 10 responded, "Yeah, that's an important part in this task…creativity."

The researcher felt that most participants agreed that they liked the activities but would have liked slightly more structured directions, while others felt that a variety of robot challenges would have been interested. Some participants felt that the difficulty level was too high, while many participants did not think that any changes were necessary. As noted, most leaders in the groups felt that the robotics activities were satisfactory and recommended few or no changes.

## Summary

In this chapter, procedures for data collection and analysis were explained. As the researcher coded the data from the observations, surveys, interviews, and Career Cruising results, the following four themes emerged as a result of participation in the LEGO Robotics activities: (a) Theme 1: increased confidence and self-efficacy toward STEM tasks, with the subthemes of (1A) problem-solving skills and (1B) leadership and teamwork; (b) Theme 2: self-efficacy and enjoyment in relation to STEM tasks and STEM careers; (c) Theme 3: impact on personal goals, with the subthemes of (3A) effect of robotics activities on feelings toward STEM and (3B) plans to take STEM classes or pursue STEM careers; and (d) Theme 4: suggestions for changes for robotics activities. In Chapter 5, these themes will be further discussed, including the discussion of major findings, implications of the study, and recommendations for future research.

CHAPTER V

DISCUSSION

## Introduction

The purpose of this study was to investigate the instructional use of a robotics educational curriculum on middle school participants' attitudes toward and interests in STEM and their experiences with LEGO Robotics activities. The findings of this study revealed four major themes: (a) Theme 1: increased confidence and self-efficacy toward STEM tasks, with the subthemes of (1A) problem-solving skills and (1B) leadership and teamwork; (b) Theme 2: self-efficacy and enjoyment in relation to STEM tasks and STEM careers; (c) Theme 3: impact on personal goals, with the subthemes of (3A) effect of robotics activities on feelings toward STEM and (3B) plans to take STEM classes or pursue STEM careers; and (d) Theme 4: suggestions for changes for robotics activities. The following section will provide a discussion of the findings for each theme.

## Discussion of Major Findings

### Theme 1: Increased Confidence and Self-Efficacy Toward STEM Tasks

Based on the concept of self-efficacy in the Social Cognitive Career Theory, the first theme developed as a result of (Subtheme 1A) problem-solving and (Subtheme 1B) teamwork skills. Participants gained knowledge and confidence as they solved daily problems with their teammates, and in turn, they became more motivated as they faced new challenges. Several participants admitted that they felt the robotics activities would be difficult, but they increasingly became easier as they completed the tasks. The degree of satisfaction usually corresponded with the level of involvement from these problem-solving activities and interaction with teammates.

As participants faced the daily challenges, leaders emerged in each group. Several leaders demonstrated positive leadership qualities that encouraged their teammates to participate and better work together, which reflected positive teamwork skills. They often shared responsibilities and boosted others' confidence when they contributed ideas. Such teams involved all members, as they created, programmed, built, and performed troubleshooting skills. Consequently, these teammates often reported higher enjoyment, confidence, and satisfaction from their active participation in the robotics activities. On the other hand, leaders that were overbearing tended to do the work themselves, and so some group members did not gain as much experience with problem-solving and teamwork skills. As a result, these participants developed little confidence and self-efficacy toward the robotics tasks.

Throughout the daily activities, participants applied problem-solving skills to build and program robots, as well as to work with difficult team members. Sometimes team members were problematic, unwilling to compromise, or even unwilling to help. When participants were asked how they overcame the challenges that they faced, they likewise reported issues with the robot as well as team members. Although some participants were initially reluctant, at some point during the activities, twenty-two of the twenty-three participants were observed to contribute to the team's tasks, as they demonstrated problem-solving skills. Critical thinking and problem-solving skills refer to the ability to apply both original and innovative approaches to solve a variety of problems (P21 Partnership for 21$^{st}$ Century Learning, 2015). While most participants stated that there were problems with building, coding, or teamwork, they all indicated that they overcame these difficulties. Because of these accomplishments, they gained a sense of satisfaction, as they faced these obstacles and solved problems as a team. These findings correspond to studies in current literature, showing a positive link between a middle school robotics curriculum and student STEM learning, critical thinking, collaboration, creativity, and self-efficacy (Ardito et al., 2014; Eguchi, 2016; Nugent et al., 2010; Yuen et al., 2014). The researcher found that participants who were actively involved in solving daily challenges reported a higher degree of satisfaction and confidence, thereby demonstrating that problem-solving and collaboration skills contributed to a higher level of confidence and self-efficacy from the robotics activities.

**Theme 2: Self-Efficacy and Enjoyment in Relation to STEM Tasks and STEM Careers**

A second theme that emerged from the data is that participants experience self-efficacy and enjoyment in relation to STEM tasks and STEM careers. While the first theme discussed the participants' confidence in regards to STEM tasks, this theme discusses the participants' enjoyment and satisfaction in these activities. If students enjoy STEM tasks, then they may be more likely to consider STEM careers.

Although some participants expressed concern and apprehension before starting the robotics unit, most of them later reported an interest and enjoyment in the activities. Only two participants reported that they did not like the activities, even though the researcher noted that they seemed to be involved and excited at times. Overall, the data reflected that the participants overwhelmingly took pleasure in the activities and enjoyed working with each other. Participant descriptions of the activity included positive comments, such as "really cool," "beautiful," "pretty neat," "stimulating," "fun trying something new," " fun thing to do with friends," and "fascinating." The participants' pleasure appeared to develop from successfully solving the challenges as well as having fun with teammates.

According to the study data, participants who have higher self-efficacy of STEM tasks and positive outcome expectations tend to develop an interest in and enjoy STEM activities. As interests increase, they often develop goals that intensify one's involvement in particular activities (Brown & Lent, 2013; Leong, 2008). Self-efficacy and enjoyment of STEM activities directly corresponded with participants' plans to take AP or Advanced STEM classes and their interests in STEM careers. Several participants shared that as a result of their enjoyment and increased confidence in STEM tasks, they are now more interested in STEM classes and careers.

These findings support current research findings that students tend to demonstrate enjoyment in creative and design-based activities such as robotics programs (Blanchard et al., 2015). The collaborative STEM activities can provide a greater interest and motivation to pursue STEM careers (Gura, 2011; Welch & Huffman, 2011). Many students might not understand the role that engineers play in society and can benefit from real-world connections for them to learn about the skills and education required for STEM careers (Blanchard et al., 2015). Robotics offers opportunities for fun and excitement in a classroom, and encourages interest in technology-related careers (Johnson & Londt, 2010). Studies indicated educational robotics activities resulted in increased interest and enthusiasm in STEM and STEM careers (Ayar, 2015; Blanchard et al., 2015; Eguchi, 2016; Kandlhofer & Steinbauer, 2016; Williams et al., 2012).

Another interesting finding was that while most participants enjoyed the activity, some shared feelings of hesitation toward STEM careers due to collaboration with others. The researcher found that 21 of the 23 participants enjoyed the activity, but some were tentative about pursuing STEM careers, noting that they might not enjoy working with other people each day. Many of these participants stated that they prefer working alone and probably would not enjoy working with a group all of the time, especially since some members might be unwilling to participate or even be uncooperative when working together. Even the participants who got along well with their teammates in the robotics activity realized that in a job situation, they might have group members who can be challenging. As a result, they might not choose a STEM career because they feel that collaboration is an inherent part of everyday work responsibilities.

**Theme 3: Impact on Personal Goals**

Although all of the participants had learned about STEM concepts and careers, few of them had experiences in hands-on STEM activities. In fact, none of them had participated in a robotics activity that included building, programming, and troubleshooting. Since some of them had family members with STEM careers, a few participants had a greater awareness of STEM tasks. Prior to the activity, most participants had indicated that STEM tasks are difficult and challenging, stating that only people who excel in math and science will be successful.

For Subtheme 3A, the researcher explored the effects of robotics activities on feelings toward STEM. According to the study data, fifteen of the twenty-three participants (65%) reported that they had gained positive feelings toward STEM as a result of the robotics activity. Such positive comments indicated that they gained problem-solving and collaboration skills, enjoyed the activities, and felt more confident with STEM tasks. As a direct result of the robotics activities, several participants stated that they are now interested in STEM activities, classes, and careers. One participant shared, “I am more interested in STEM activities. I’ve been interested in engineering and computer things, but now that I’ve done this, I think I could do really well in this subject, and I just enjoy it.” Another participant expressed, “I’m more interested in engineering careers because of this activity.” With a majority of participants indicating a positive change, the researcher feels that the robotics activity might be a worthwhile, valuable endeavor that may enhance students’ understanding of STEM concepts.

For Subtheme 3B, the researcher also explored plans to take STEM classes or pursue STEM careers. While most participants indicated an increased interest in STEM tasks, they also reported a greater interest in STEM careers. Based on the results of the Career Cruising program, participants had the opportunity to save careers of interest to their portfolios both before and after the robotics activity. While thirteen participants had an interest in STEM careers prior to the activity, ten participants were not interested in STEM careers. Of the thirteen participants who were interested in STEM careers before the activity, eight of them indicated additional STEM careers in which they were interested after the activity. After the robotics activity, five of the participants who did not have an initial interest gained interest in STEM careers. Participants' responses also supported the increased interest in STEM classes and careers as a result of the robotics activity. As one participant shared, "[Robotics] has encouraged me to go into any technology career. Or possibly building, too. I want to go to college to get at least a master's degree so I can be an engineer." Another participant reported, "I might do engineering because I think I'm good at it because I've tried it." Yet another participant reported, "Being an engineer with robotics has been really cool and I would like to be able to do that." Other participant responses reflected increased interests in Advanced and AP STEM classes, as well as STEM careers, as a result of the robotics activity.

These findings are consistent with research indicating specific, hands-on STEM activities contribute to a greater understanding of the curriculum and interest in STEM topics and careers, as such experiences promote higher student engagement and motivation (Finnerty; 2013; Gura, 2011; Kandlhoger & Steinbauer, 2016; Thiry et al., 2011). Robotics activities have been shown to increase STEM content knowledge and develop positive interests and attitudes for STEM fields of study and careers (Ayar, 2015; Gura; 2011; Kandlhofer & Steinbauer, 2016;

Welch & Huffman, 2011; Williams et al., 2012). In other studies, robotics activities have provided first-hand experiences with STEM concepts, and developed and maintained student interest in robotics, computing, and engineering careers (Ayar, 2015; Qidwai et al., 2013; Ruiz-del-Solar, 2010). Middle school programs providing STEM instruction to solve real-world engineering problems should establish connections between classes and future careers, which can increase students' desire and interest in STEM courses in high school and college, and stimulate a desire to pursue some STEM careers (Donovan & Sullivan, 2012; Kutch, 2011; Wu-Rorrer, 2015).

**Theme 4: Changes for Robotics Activities**

A goal of this research is to suggest ways to improve instruction for a robotics curriculum in middle school. In order to improve future teaching, participants were encouraged to share their thoughts and suggestions about the LEGO Robotics activity. Most of the participants were satisfied with the instruction, but others indicated that they would have liked a longer time period to solve each daily challenge. Also, some participants indicated more structure and guidance for the activities, yet they also realized that they would not have been able to use as much creativity and as many problem-solving skills to solve each challenge. While some of the suggestions might prove useful, others might not be practical for all teachers.

A few participants indicated that they would have liked more detailed instructions prior to the daily challenges. Although the teacher provided an introduction to each task, and then a brief video tutorial (addressing the function of new blocks) and class discussion, some participants preferred more specific directions prior to the task. Also, some participants found the tasks to be very difficult and requested that the challenges be made easier and less complicated, but these were often students that were less involved with the challenges. Most participants realized that the lessons were not very structured so that they could use their own creativity to solve the challenges in different ways, which they mostly enjoyed. In addition, the short timeframe of the 10-day robotics unit was a limitation, since a few participants suggested having more things to do with the robot. If the unit had lasted longer, more functions and tasks for the robot would have been explored.

While other robotics curricula are available, the researcher chose LEGO Robotics based on the attraction and appeal of the LEGO brand. Also, other middle school teachers had experienced success with LEGO Robotics activities. After researching various robotics platforms, the researcher found that LEGO MINDSTORMS provides a range of versatility as well as wide array of topics that can be taught, as it excites and educates young students (Cruz-Martin et al., 2012; Karp et al., 2010). In addition, LEGO Robotics are affordable, durable, and the popular choice by most teachers as they guide and motivate students to discover solutions to their own problems (Gura, 2011). Overall, this toy provides playfulness yet educational meaning as students cultivate creativity, knowledge, and problem-solving skills (Shih et al., 2013).

The researcher found that participants enjoyed the robotics activities, and while the activities were stimulating and sometimes difficult, participants gained a sense of satisfaction as they solved challenges with their teammates. The LEGO robots and workbook were appropriate for middle school students, and the level of guidance allowed for greater collaboration as they gained problem-solving skills. Research has shown that the “learning by doing” approach is universally popular with students (Qidwai et al., 2013, p. 524), also demonstrated in this study. In addition, this study supported the theory that students appreciate more enjoyable learning as they foster their creativity to complete learning goals (Williams et al., 2012). Overall, the participants were satisfied that the activities challenged them in a way that allowed them to develop their creativity and problem-solving skills. As a result, the researcher is satisfied that the LEGO Robotics curricula and level of guidance are suitable for middle school students and would make few or no changes when teaching this unit to a comparable group of students.

## Social Cognitive Career Theory Framework

This study was based on the theoretical framework of Social Cognitive Career Theory (see Table 19), which focuses on three aspects of career development: (a) formation of career interests, (b) selection of career and academic options, and (c) performance and persistence in career pursuits (Lent et al., 1994). To better understand career development, SCCT focuses on the three variables of self-efficacy, outcome expectations, and goals, as well as their interaction with a person's environment, to determine a person's career interests and goals (Lent et al., 1994; 2000). According to SCCT, people are more likely to develop interests in areas in which they feel competent and anticipate positive results (Lent et al., 2000; Leong, 2008). Since teachers seek ways to encourage students to develop an interest in STEM topics, Table 19 provides suggestions for implementing a robotics curriculum in the middle school classroom.

In this study, middle school participants gained hands-on experiences in a robotics activity, which led to an increased interest in STEM courses and careers. The participants also reported a higher self-efficacy as they worked with teammates to use problem-solving skills to overcome challenges. According to Lapan (2004), self-efficacy has an important effect on shaping goals and actions, as they influence career interests. Students who participate in related career activities are more likely to set and pursue career planning goals as they develop a greater interest and develop more confidence (Rogers & Creed, 2011; Rogers et al., 2008). In this qualitative study, the data reflect the self-efficacy variable of the SCCT model, as students gain greater interest in STEM careers as a result of positive, hands-on robotics experiences. If students continue to nurture and develop their STEM interests, then it is likely that many of them will develop higher confidence and outcome expectations, and eventually set personal goals related to STEM classes and careers.

Table 19

*Theme Alignment with SCSS Theoretical Framework*

| Theme | Theoretical Framework Theory | Implication for Educators |
|---|---|---|
| 1. Increased confidence and self-efficacy toward STEM tasks<br>1A - Problem-solving skills<br>1B - Leadership and teamwork | Self-efficacy | As students collaborate to solve problems, they often develop a greater sense of self-efficacy toward STEM tasks from their personal performances in the robotics activities. The researcher recommends robotics activities as a method to increase students' confidence in STEM tasks. |
| 2. Self-efficacy and enjoyment in relation to STEM tasks and STEM careers | Self-efficacy | As they experience personal accomplishments and positive feedback from each other, students usually develop a greater sense of enjoyment for STEM tasks. The researcher recommends implementing robotics activities as an enjoyable way to stimulate interest in STEM tasks and STEM careers. |
| 3. Impact on personal goals<br>3A - Effect of robotics activity on feelings toward STEM<br>3B - Plans to take STEM classes or pursue STEM careers | Outcome expectations and personal goals | Since students usually feel successful after completing the STEM activities, they are more likely to choose STEM classes and careers. As they make plans to consider STEM careers, they tend to see their career decisions as leading to positive outcomes, such as self-satisfaction, approval from self and others, and attractive work conditions (having fun, working in groups, and earning good salaries). The researcher recommends robotics activities as a hands-on approach to introducing students to career options in the STEM career cluster. |
| 4. Changes for robotics activities | Self-efficacy and outcome expectations | Based on students' self-assessment and reflection on the LEGO Robotics activities, most students feel that the level of difficulty, time allotted, and assigned challenges are appropriate for middle schoolers. Therefore, the researcher recommends no changes for the LEGO Robotics curricula. |

## Implications of the Study

While other studies have been conducted on similar topics, this qualitative research is unique because it investigated the impact of an in-class robotics curriculum on middle school students' attitudes and interests in STEM. Similar studies involved different participants, such as high school or undergraduate students, or even different curricula, such as a summer robotics camp. Yet other studies examined the impact of a robotics curriculum on students' problem-solving, creativity, and collaboration skills; enjoyment of STEM tasks; and their STEM knowledge. While the researcher hoped for positive reactions to the robotics unit, she was pleasantly surprised with the participants' excitement and enjoyment throughout the activity. In addition, participants demonstrated a greater interest in STEM courses and careers as a result of this hands-on activity, as shown in responses from the observations, surveys, Career Cruising results, and focus group interviews.

Through participation in these hands-on, engineering-based robotics activities, participants gained a better understanding of STEM. As a result of these experiences, the researcher also acquired a better understanding of participants' perceptions of this STEM-based curriculum. Since 65% of participants indicated a positive change, the results indicate that the robotics activity can be a worthwhile, beneficial endeavor that might enhance students' understanding of STEM tasks. As a result of the study, other teachers might consider using STEM-based robotics activities in other areas of the curriculum.

In addition to Career Technologies teachers, other middle and high school educators can incorporate methods to introduce students to robotics. Administrators and curriculum specialists can enlist teachers, local college students, or professional volunteers to provide ways to stimulate interest in robotics activities, either through after-school clubs, local competitions, or summer camps.  Robotics can also be introduced in other areas of the curriculum, such as interdisciplinary math and science activities.  As school counselors discuss career options, a robotics unit can also provide students with meaningful STEM connections as they build and program robots to solve real-world challenges.

The researcher concurs that if teachers are to motivate students to consider STEM careers, it should begin at the middle school level (Kier et al., 2014).  While this might be considered a relatively young age to begin career explorations, students can greatly benefit from such fun, worthwhile activities such as LEGO Robotics to gain hands-on STEM skills.  In addition, the curriculum was appropriate for middle school students, providing difficult challenges that were conquered with the help of their teammates, often providing a strong feeling of satisfaction.  Along with hands-on robotics activities, students should learn about STEM tasks and careers so that they can begin to determine if such careers are suitable for their own interests and goals.  The researcher anticipates that this study will further contribute to the body of literature that supports the use of robotics and other STEM activities in middle school classrooms, with the additional benefit of establishing a connection between STEM activities and interest in STEM classes and careers.

## Recommendations for Future Research

Since the fields of technology and Career Technical Education are constantly changing, the research should evolve to reflect those advancements.  With the relatively new curriculum of Career Cluster Technologies, the need for worthwhile, hands-on activities are essential to educate students about the many career opportunities that will be available to them in the future.  It is the researcher’s hope that future studies will continue to include middle school participants as they begin to develop their career interests.

Although this study provided positive results, several limitations should be addressed for future research. First, there was a short timeframe for the study. A longer robotics unit, such as 4-6 weeks, might yield more interesting results. Second, this study included many high-performing students. A different study with a more diverse population could be beneficial. Third, the observation tool has not been used in a formal study, so another instrument might produce different results. A fourth recommendation is to use additional observers to spend more time studying each group. A fifth recommendation is to replicate this study with a different robotics curriculum to determine if the “novelty effect” of LEGO Robotics was indeed a subjective reason that the participants exhibited a high degree of excitement for the activity.

As an unanticipated result of this study, the researcher noticed that several students experienced an “aha” moment during the robotics activity. An aha moment is defined as a “moment of sudden realization, inspiration, insight, recognition, or comprehension” (Merriam-Webster, 2017). While many students became frustrated at different times, they also became very excited when they discovered how to solve the challenges. Since other hands-on activities might produce similar results, a study that examines the frequency or occurrence of aha moments during robotics or other STEM activities might produce interesting findings.

Since a limitation was a short timeframe for this study, another suggestion for future research is to extend the robotics unit to 4-6 weeks. Many additional resource books are available that provide a variety of LEGO robotics projects, but such activities are usually less structured than the ones used in this study. Since students will have a basic knowledge of building and coding LEGO robots from the activities provided in this study, they will be more prepared to undertake more difficult challenges. In a longer study, the book *The LEGO Mindstorms EV3 Discovery Book: A Beginner’s Guide to Building and Programming Robots* by

Laurens Valk would be a suggested added resource to provide challenges that range from beginner to advanced programming as they learn to build progressively sophisticated robots. During Weeks 3 – 6, students could be allowed to choose additional challenges from this resource in order to further develop their programming and problem-solving skills as they select activities of interest to them.

Future research might also include a longitudinal study that follows middle school participants throughout their high school and college careers. While other experiences might alter or contribute to these participants' interests in STEM, the researcher would like to know if they maintain their excitement and interest in STEM. If many of these participants choose STEM careers as a result of the middle school robotics unit, then robotics and possibly other STEM activities can be shown to be valuable, worthwhile contributions to the K-12 curriculum.

## Conclusion

This study investigated the instructional use of a robotics educational curriculum on middle school students' attitudes toward and interests in STEM and their experiences with LEGO Robotics activities. Twenty-three middle school participants were divided into six groups of four students each, as they participated in a 10-day LEGO Robotics unit. Based on the findings, this robotics unit had a positive impact on students' attitudes and increased interests in STEM. Data collected through observations, surveys, Career Cruising assessments, and focus group interviews support this assertion.

The researcher coded all data using both open and focused coding methods, and through evaluation the following themes and subthemes developed:

- Theme 1 - Increased confidence and self-efficacy toward STEM tasks
    - Subtheme 1A - Problem-solving skills

    - Subtheme 1B – Leadership and teamwork
- Theme 2 - Self-efficacy and enjoyment in relation to STEM tasks and STEM careers
- Theme 3 - Impact on personal goals
    - Subtheme 3A - Effect of robotics activity on feelings toward STEM
    - Subtheme 3B - Plans to take STEM classes or pursue STEM careers
- Theme 4 - Changes for robotics activities.

These themes align with the current research on robotics in the classroom, development of career interests, and the framework upon which this study was developed, which was the Social Cognitive Career Theory. The hope is that this study helps to improve on the instruction of Career Explorations classes in middle schools as well as promotes the implementation of hands-on, STEM activities that stimulate an interest in STEM classes and careers.

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# APPENDIX A

## Focus Group Interview Questions

**Focus Group Interviews**
**Semi-structured Questions**

1. Do you feel that your group was successful in completing the robotics activities? Why or why not?

2. Did all of your group members equally contribute to the project? If not, describe what happened.

3. Do you feel that you were a leader in the group activity? If not, why not? If so, describe how you led the group.

4. Did you enjoy the robotics activity? Why or why not?

5. Thinking back to when you and your team members were building a robot, who took the lead in designing and building? Why do you feel this person took the lead?

6. What did you learn from the LEGO Robotics activity?

7. What are some suggestions for improvement in this LEGO Robotics activity?

8. How well do you feel that you can complete STEM tasks?

9. Do you think that you would be successful in a STEM career? Why or why not?

10. How do you feel about STEM activities?

11. Have your feelings toward STEM changed as a result of this robotics activity?

12. In what career or careers are you most interested?

13. Which advanced or AP classes would you like to take in high school? (AP classes are Advanced Placement classes that are offered in high school. At the end of each course, students can take an exam to try to receive college credit.)

14. How do you feel about college?

15. Has your participation in the LEGO Robotics activities encouraged an interest in any careers related to STEM? If so, in what careers are you interested?

*Sources: Bocanegra et al., 2016; Brown & Lent, 2013; Fraser & Vernola, 2014; Grubbs, 2013; Leong, 2008; Miller & Lauterbach, 2014; Welch & Huffman, 2011; Yuen et al., 2014;

# APPENDIX B

## Pre Open-Ended Survey

## Pre Open-Ended Survey

Directions: Please take your time and respond honestly and thoughtfully to each question. Write at least 3 sentences for each question response.

1. What do you think STEM means?

2. What do you think you would learn in STEM classes?

3. Do you enjoy activities like inventing, exploring, discovering, helping, and problem-solving activities?

4. If someone were working in a STEM-like job, what sorts of things would they be doing?

5. What LEGO Robotics activities have you done at school?

6. What LEGO Robotics activities have you done at home or anywhere else? If somewhere else, where did you do them?

7. In what career or careers are you most interested?

8. Which advanced or AP classes would you like to take in high school? (AP classes are Advanced Placement classes that are offered in high school. At the end of each course, students can take an exam to try to receive college credit.)

9. How do you feel about college?

10. How well do you feel that you can complete STEM tasks?

11. Do you think that you would be successful in a STEM career? Why or why not?

*Sources: Bocanegra et al., 2016; Brown & Lent, 2013; Fraser & Vernola, 2014; Grubbs, 2013; Leong, 2008; Miller & Lauterbach, 2014; Welch & Huffman, 2011; Yuen et al., 2014;

APPENDIX C

Post Open-Ended Survey

## Post Open-Ended Survey

Directions: Please take your time and respond honestly and thoughtfully to each question. Write at least 3 sentences for each question response.

1. What do you think STEM means?

2. What do you think you would learn in STEM classes?

3. Do you enjoy STEM activities? Why or why not? (STEM stands for Science, Technology, Engineering, and Math. STEM activities include things like inventing, exploring, discovering, helping, and problem-solving activities.)

4. If someone were working in a STEM-like job, what sorts of things would they be doing?

5. Thinking back to when you and your team members were building a robot, who took the lead in designing and building? Why do you feel this person took the lead?

6. What kinds of problem(s) did you have?

7. How did you solve your problem(s)?

8. What is your overall impression of LEGO Robotics activities?

9. What did you learn from the LEGO Robotics activity?

10. What are some changes you might suggest for this LEGO Robotics activity?

11. How well do you feel that you can complete STEM tasks?

12. Do you think that you would be successful in a STEM career? Why or why not?

13. In what career or careers are you most interested?

14. Which advanced or AP classes would you like to take in high school? (AP classes are Advanced Placement classes that are offered in high school. At the end of each course, students can take an exam to try to receive college credit.)

15. How do you feel about college?

16. As a result of the LEGO Robotics activity, are you more or less interested in activities such as inventing, exploring, discovering, helping, and problem-solving activities? Please explain.

17. As a result of the LEGO Robotics activity, are you more or less interested in STEM activities? Please explain.

18. Has your participation in the LEGO Robotics activities encouraged an interest in any careers related to STEM? If so, in what careers are you interested?

*Sources: Bocanegra,et al., 2016; Brown & Lent, 2013; Fraser & Vernola, 2014; Grubbs, 2013; Leong, 2008; Miller & Lauterbach, 2014; Welch & Huffman, 2011; Yuen et al., 2014;

APPENDIX D

STEM Interest Inventory Observation Tool

Day of Observation ______________
Group # ______________

STEM Interest Inventory
Observation Tool

Add comments in the appropriate boxes to describe each behavior during the group activity.

| Behavior | Participant 1<br>_______________ | Participant 2<br>_______________ | Participant 3<br>_____________ |
|---|---|---|---|
| Stays focused on the task | | | |
| Makes valuable contributions to the task | | | |
| Encourages others | | | |
| Shares responsibility with others | | | |
| Discusses and listens to others with respect | | | |
| Shares useful ideas | | | |
| Enjoys the activity | | | |
| Suggests solutions to problems | | | |
| Makes compromises with others to meet desired outcome | | | |
| Displays positive attitude toward others & the task | | | |
| Is a "team player" throughout the activities | | | |
| Is a "leader" throughout the activities | | | |

* *Adapted with permission from: Dr. Karen Franker (2015)*
www2.uwstout.edu/content/profdev/rubrics/secondaryteamworkrubric.html

APPENDIX E

Robotics Curriculum

## LEGO MINDSTORMS EV3

### 10-Day Unit

As teachers implement the LEGO MINDSTORMS EV3 Core Set into their curriculum, they must first have a basic knowledge of the EV3 programming environment. While most activities are loosely structured, they are designed so that teachers can introduce the concept and make adjustments as they feel necessary for different classes. Students must be given the freedom to explore new challenges as they become more familiar with the EV3 unit, since these activities are based on “learning by doing.” Additional tutorials can be found in the EV3 software environment for both students and teachers. The following activities are based on “My EV3 Course” on www.mind-storms.com and the book *Classroom Activities for the Busy Teacher: EV3* by Damien Kee (2013) and are reproduced with his permission. Teachers should obtain a copy of this workbook for more detailed instructions and diagrams to share with students throughout the activities.

The following standards will be met from the Alabama State Course of Study Standards for Career Cluster Technologies I (Alabama Department of Education, 2008):

- Identify how new products and systems can be developed to solve problems or help do things that require technology.
- Explain how technology is linked to creativity and innovation.
- Illustrate how technology systems can be connected to one another.
- Explain how a product, system, or environment developed for one setting may be applied to another setting.
- Describe the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

- Identify creative attributes of design, including brainstorming, modeling, testing, evaluation, and modifying.
- Demonstrate technology design processes for solving problems in and beyond the laboratory and classroom
- Using tools, materials, and machines safely to diagnose, adjust, and repair systems
- Using computers and calculators in various application
- Designing instruments to collect data
- Describe how pathways lead students through secondary and postsecondary training towards a credential.
- Identify employment opportunities associated with the clusters.

**Days 1 & 2, Lessons 1 & 2**

**Objective:** Students will understand how to build a program by assembling and configuring programming blocks as they complete the Robot Educator lessons in their own time. Students also learn how to download a program to the EV3 robot and how to run the program on the robot. Students will also learn how to protect their robots and learn the basics of flowcharting.

**Equipment & Materials Needed:**

- 1 EV3 robot kit per group
- 1 computer per group
- Masking tape and tape measure
- *Classroom Activities for the Busy Teacher: EV3* by Damien Kee (2013)

**Activities:** Introduce the EV3 programming environment that is included with the education version of the LEGO MINDSTORMS EV3 (education version) kit. Students will complete the lessons in their own time.

**Day 3, Lesson 3 (RileyRover Basics – Chapter 2)**

**Objective:** Construct a robot that can maneuver around an obstacle course.

**Description of Project:**

NASA is in need of a new planetary rover to explore a newly discovered planet called Tobor-3. You have been hired to develop and construct a robot that can roam and explore the planet's surface. It must follow a set of commands and be thoroughly tested to ensure that it will perform to its expectations. It must be fully functional on its own.

**Equipment & Materials Needed:**

- 1 EV3 robot kit per group
- 1 computer per group
- Masking tape and tape measure
- *Classroom Activities for the Busy Teacher: EV3* by Damien Kee (2013)
- Photocopies of the worksheet *RileyRover Basics*

**Activities:**

- Describe the Project (see above).
- Discuss each group's RileyRover robot.
- Explain the "Move Steering" Block and highlight its different block inputs:
    - Steering
    - Power
    - Rotations/Degrees/Seconds
    - Brake at End
- Complete the activities on the *RileyRover Basics* worksheet.

**<u>Day 4, Lesson 4 (How Many Sides? – Chapter 9)</u>**

**Objective:** Students will understand basic geometric shapes and angles of a polygon as they attach a drawing device to their robot and plot out geometric shapes.

**Description:** Once on Tobor-3, your robot will be required to identify interesting geological formations for later analysis. Your robot will be required to mark off an area so that a passing satellite can easily identify the item in question. Initially you will be required to draw a square, but will then move onto other shapes and designs.

**Equipment and Materials Needed:**

- 1 EV3 robot kit per group
- 1 computer per group
- Large marker
- Large sheet of paper
- Photocopies of the worksheet *How Many Sides?*

**Activities:**

- Describe the Project (see above).
- Explain the following concepts:
  - Loop Block
  - Example program of driving robot in a square
- Complete the activities on the *How Many Sides?* Worksheet.

**<u>Day 5, Lesson 5 (Help, I'm Stuck – Chapter 10)</u>**

**Objective:** Students will learn to equip their robot with a Sensor to help it detect obstacles.

**Description:** Once on Tobor-3, your robot will undoubtedly come up against obstacles in its path. NASA is worried about a particular cliff wall that is blocking the robot's progress. They have asked that you demonstrate your robot's ability to detect such obstacles and navigate away from them. It is important that your robot does not physically touch these obstacles as we do not wish to damage the robot or contaminate our research environment.

**Equipment and Materials Needed:**

- 1 EV3 robot kit per group
- 1 computer per group
- Photocopies of the worksheet *Help, I'm Stuck!*

**Activities:**

- Describe the Project (see above).
- Explain the following concepts:
    - SONAR sensors
    - Move Steering Block
    - Wait Block
    - Compare and Change
    - Loop Block (review)
- Complete the activities on the *Help, I'm Stuck!* Worksheet.

**<u>Day 6, Lesson 6 (Let's Go Prospecting! – Chapter 11)</u>**

**Objective:** Students will learn to use the color sensor to identify different colored surfaces. Students will also gain experience with the Switch programming block

**Description:** NASA is very impressed with your robot's ability to navigate the surface. They are hoping that you can use a sensor on your robot to help them detect some mineral deposits of EV-itrium they believe are on the surface. These minerals are easy to spot due to their bright green appearance.  Your task is to navigate a geological section, locate the mineral, stop, and announce that a mineral has been found.

**Equipment and Materials Needed:**

- 1 EV3 robot kit per group
- 1 computer per group
- Different colors of paper
- Photocopies of the worksheet *Let's Go Prospecting*

**Activities:**

- Describe the Project (see above).
- Explain the following concepts:
  - Wait Block (review)
  - Color Sensor parameters
  - Example program
- Complete the activities on the *Let's Go Prospecting!* Worksheet.

**<u>Day 7, Lesson 7 (Going Up and Going Down – Chapter 14)</u>**

**Objective:** Students will learn to use the Gyro Sensor to keep track of the steepness of the terrain.

**Description:** NASA has discovered a good deposit of minerals in a valley far below.  Your robot design can only safely descend and ascend slopes of 20 degrees.  If go anymore, then there is a very real risk that the robot will topple over.  Devise a program that will enable the robot to drive along a slope, but stop and reverse if it becomes too steep.

**Equipment and Materials Needed:**

- 1 EV3 robot kit per group

- 1 computer per group
- A ramp with the ability to vary the angle of the slope.  (It can be as simple as a wooden plank and several books.)
- Photocopies of the worksheet *Going Up and Going Down*

**Activities:**

- Describe the Project (see above).
- Explain the following concepts:
    - Wait block (review)
    - Gyro Sensor Attachment
    - Change Input Parameters
- Complete the activities on the *Going Up and Going Down* Worksheet.

**<u>Day 8, Lesson 8 (Prepare the Landing Zone – Chapter 16)</u>**

**Objective:** Students will learn to use the Gripper Attachment to move objects.

**Description:** NASA has discovered a good landing site for further spacecraft, but unfortunately it still contains several large obstacles.  Use your robot and an appropriate attachment to clear the area.

**Equipment and Materials Needed:**

- 1 EV3 robot kit per group
- 1 computer per group
- Objects to be moved (such as empty drink containers)
- Photocopies of the worksheet *Prepare the Landing Zone*

**Activities:**

- Describe the Project (see above).

- Explain the following concepts:
    - Gripper Attachment
    - Ultrasonic Sensor (review)
    - Medium Motor Block
- Complete the activities on the *Prepare the Landing Zone* Worksheet.

**Days 9 & 10, Lessons 9 & 10 (Final Project – not in book)**

**Objective:** Students conceive their own original challenge, not necessarily on the theme of planetary exploration) and try to make a corresponding program that they can test. The students' idea must be approved by the teacher. The students must maintain documentation of robot's objective, steps taken, challenges encountered, and additional notes and submit to the teacher.

**Equipment and Materials Needed:**

- 1 EV3 robot kit per group
- 1 computer per group
- Materials will vary depending on project

APPENDIX F

IRB Approval Letter

THE UNIVERSITY OF **ALABAMA** | Office of the Vice President for Research & Economic Development
Office for Research Compliance

November 16, 2016

Tracy Hinton
ELPTS
College of Education
The University of Alabama
Box 870302

Re: IRB # 16-OR-400 "The Effects of a Robotics Educational Platform on STEM Career Interests in Middle School Students"

Dear Ms. Hinton:

The University of Alabama Institutional Review Board has granted approval for your proposed research. Approval has been given under expedited review category 7 as outlined below:

*(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.*

Your application will expire on November 15, 2017. If your research will continue beyond this date, complete the relevant portions of the IRB Renewal Application. If you wish to modify the application, complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, complete the appropriate portions of the IRB Study Closure Form.

Please use reproductions of the IRB approved informed consent form to obtain consent from your participants.

Should you need to submit any further correspondence regarding this proposal, please include the above application number.

Good luck with your research.

Sincerely,

[redacted]

Chair, Non-Medical Institutional Review Board
The University of Alabama

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