Improving student attitudes towards STEM education by building self-efficacy through robotics education

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IMPROVING STUDENT ATTITUDES TOWARDS STEM EDUCATION BY BUILDING SELF-EFFICACY THROUGH ROBOTICS EDUCATION

A dissertation submitted in partial satisfaction

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by

Kevin Obillo

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This dissertation, written by

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under the guidance of a Faculty Committee and approved by its members, has been submitted to and accepted by the Graduate Faculty in partial fulfillment of the requirements for the degree of

DOCTOR OF EDUCATION

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DEDICATION

Upon defending my dissertation I told my wife and daughter that WE did it. My wife and daughter sacrificed a lot for me to complete my dissertation, from the papers all over the dining room table, to having me miss certain family gatherings. It took all of us to get it done. Also, I dedicate this to my Mom and Dad. Their insistence and expectation that I complete school instilled the value of education in me. To my brother, Brent, his wife, Marie, I dedicate this to you, too. To my in-laws, Joanna & Mario, Patty, Santos & Blanca, Beatriz, Mariana, *y mis suegros,* Esperanza & Enrique , you also encouraged me, even allowing me to use your Wi-Fi for classes while at your house. To my nephews and nieces, Phoenix, Melissa, Jessica, A. J., David, Christina, Kailey, Klaudia, and Jacob, I hope this inspires you to always do your best. All of you encouraged me whenever I needed it. All of you gave me your unconditional love and support through the whole thing.

Most of all, I want to dedicate this to the wife of my youth. You are truly the love of my life. You sacrificed so much for me to finish. I love you!

To God be the glory. Freely ye received. Freely give.

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Finally, George and De Vida, we went through so much together. So many highs and lows both academically and personally. The long days in class and the long chats through our program were invaluable. Thank you!

VITA

EDUCATION

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CREDENTIALS

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ACADEMIC PAPERS AND CONFERENCE PUBLISHINGS

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January 2019	Hawaii International Conference on Education, Waikiki, HI *Summer Coding and Robotics, A Case Study*
December 2018	American Red Cross *Curriculum, Active Shooter, 50 Facilities*

PROFESSIONAL INSTRUCTION EXPERIENCE

1994-Present	5th Grade Teacher Santa Ana Unified School District and Tustin Unified School District
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PROFESSIONAL INSTRUCTION EXPERIENCE (CONT.)

	English as a Second Language, Community College Education Instructor Santa Ana College
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2013-2017	Administrative Designee, Individual Education Plan Meetings Lowell Elementary School

PROFESSIONAL LEADERSHIP EXPERIENCE

2007-Present	Instructional Leadership Team Santa Ana Unified School District - Lowell Elementary School
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2012-2014	Teaching Induction Practice and Support Provider Santa Ana Unified School District
2001-2017	Cooperating Teacher California State University, Fullerton
1996-2003 & 2004-2006	Girls Basketball Coach Santa Ana & Tustin High Schools, Frosh/Soph Junior Varsity and Varsity Assistant
2011-Present	Fundraising Committee - Faculty Advisor Lowell Elementary School
2005-Present	Jog-A-Thon Planning - Chairperson Lowell Elementary School
2014-Present	Robotics Club Founder/Sponsor Lowell Elementary School
2017-2018	Media Production Advisor Lowell Elementary School
2009-2014	Kids Run the OC Club - Founder and Coach Lowell Elementary School
2018	Family Art Night Lowell Elementary School

PROFESSIONAL ORGANIZATIONS

2017-Present	California Association of Bilingual Educators (CABE)
2016-Present	Phi Delta Kappa
2001-Present	Computer Using Educators
1995-Present	National Education Association

SPECIALIZED TRAININGS

August 2020	Advancement via Individual Determination (AVID)
May 2020	A Guide to Co-Teaching

SPECIALIZED TRAININGS (CONT.)

April 2019	Inclusive Leadership Training, CatalystX
April 2019	Essential Coaching Skills for Educators, Brandman University (online)
February 2019	Encouraging Creativity in the Classroom, Brandman University (online)
August 2018	Advanced Mentoring, Santa Ana Unified School District
2015-Present	Irvine Math Project
2016-2017	Project Foster
September 2013	Co-Teaching Models
August 2014	Cognitive Guided Instruction
2012-2013	Orange County Math Project-Fullerton
1998-2001	Nike Basketball Coaches Clinic

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2018	Spark Grant Recipient, Santa Ana Public Schools Foundation
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LANGUAGES SPOKEN

Bilingual	English and Spanish

ABSTRACT

The United States must grow its science, technology, engineering, and mathematics (STEM) trained workforce in order to fill the jobs projected to be in demand. One of the ways in which this can be done is to tap into the vast population of minorities and women who are underrepresented in the STEM fields. The United States has been looking for ways to improve STEM participation in these groups for many years now, through outreach, legislation and innovative academic programs.

The purpose of this research was to examine the impact that a robotics education enrichment program had on elementary, predominantly Latinx students in an inner-city public school in Orange County, California. The study was framed using self-efficacy theory to build approach behaviors towards STEM fields within these students. Student attitudes were measured using the S-STEM survey. In addition, field notes about the students, as well as notes from community of practice meetings amongst the co-sponsors were analyzed to see the impact of the enrichment program on students.

The S-STEM survey had no statistical change between pre- and post-treatment survey results. In addition, the subgroups of GATE students, EL students and female students were too small to analyze individually. However, the qualitative data showed some positive outcomes for most students.

Chapter 1: Introduction

Science, Technology, Engineering, and Math (STEM) education and careers are considered essential to the United States maintaining its lead in the future global economy. This is illustrated in the Department of Defense's 2018 Congressional Report about DoD STARBASE in which they state, "A large part, if not all, of America's greatness has been its global dominance in science and technology" (p. 6). It is because STEM fields are vital to America's defense and economy that STEM fields are considered to be some of the fastest growing jobs in the United States (Santiago, 2017), with the U.S. Bureau of Labor Statistics estimating 8.6 million STEM jobs in 2015 and projecting over 2 million STEM job openings by 2024 (Fayer et al., 2017). According to one estimate, STEM professions will have a 37% growth by the year 2030 (Lund et al., 2019). Job automation has the potential to displace 30% of workers in the same time period (Manyika et al., 2017), and many of the workers in these jobs will have to be retrained for the future workforce. Even traditional jobs, such as auto mechanics, will have to learn new skills as electric cars, which require fewer workers to build, less parts and less scheduled maintenance than internal combustion engine automobiles become more commonplace (Shama & Wayland, 2019).

However, U.S. schools are having a difficult time producing graduates who are qualified to fill STEM jobs (Forbes Magazine, 2013). To illustrate this point, according to the Higher Education in Science and Engineering (n.d.), the number of full-time graduate students enrolled in science or engineering programs in the United States rose 0.8% (2019). At the same time, the rate of temporary student visas, which allow foreign born non-citizens to attend U.S. universities, in these fields increased 2.1%, meaning that the rate of foreign students entering STEM majors in the United States is rising faster than the rate of American born students entering STEM

majors (Yamaner, 2018). In addition, while composing only 18% of the U. S. population over the age of 21, nearly 30% of workers in the STEM fields over the age of 21 are foreign born (National Science Foundation, 2019). To address this shortage, H.R. 4623, The Keep STEM Talent Act of 2019, was introduced to the House of Representatives in October, 2019 and is currently in the Subcommittee on Immigration and Citizenship (Foster, 2019). This bill would provide lawful permanent resident status for foreign-born nationals who have attained a master's level degree, or higher, at U. S. institutions of higher learning. These statistics underscore the fact that American universities are not producing enough STEM graduates to keep up with the demand, or availability, of STEM majors in graduate schools.

There are many ways in which U.S. policy makers seek to increase the number of students moving along the STEM pathway. In 1993, the U. S. Department of Defense initiated the DoD STARBASE program, in which the vision statement includes developing "highly educated and skilled American workforce who can meet the advanced technological requirements of the Department of Defense" (DoD STARBASE, 2018, p. 2). In fact, the shortage of qualified STEM field workers is, potentially, one of the biggest threats to America holding a place of leadership in the future economy (Beach, 2013).The 116th Congress (2019-2020) has several resolutions currently under consideration, or awaiting approval to become law, that are aimed at improving the pipeline for students to enter into STEM fields. These include H.R. 1665, Building Blocks of STEM Act (2019) which would fund research aimed to increase participation of females and underrepresented minorities in Pre-Kinder through 12th grade, in STEM fields. Another proposed bill is the STEM Research and Education and Transparency Act (2019). In this bill, the National Science Foundation would have one year to present evidence on the effectiveness and efficiency of the money spent on implementing STEM programs.

In addition, universities have implemented outreach programs, such as the *Robot Roadshow Program* and *Force and Momentum Program* to students as young as K-6 to elicit student interest in pursuing STEM fields (Matson et al., 2004; J. Velazquez, personal communication, October 11, 2019). One only has to look at the charter schools that brand themselves as STEM or the related science, technology, engineering, arts and mathematics (STEAM) schools, or the number of publics schools attempting to transition to a STEM or STEAM pathway to realize that schools as early as kindergarten are attempting to emphasize the STEM studies. High schools have also implemented outreach programs, such as MESA.

One of the ways in which schools are attempting to stress their dedication to STEM instruction in through the use of robotics instruction, as robots are viewed as highly interesting to students of all ages (Matson et al., 2004). As an illustration, robotics instruction was featured at over half of the displays at the subject school's recent district level educational showcase. Robotics Education (RE) refers to teaching the development and use of robots. This is in contrast to instructional robots, which are robots that are used to deliver instruction. There are numerous curriculum resources and competitive leagues for RE, including LEGO First, VEX Robotics Curriculum, Inteliteks Robotics Engineering Curriculum, Project Lead the Way, and many others (REC Foundation, 2019). This leads to the question, what is the impact of RE instruction on the students who are receiving it? Many of the researcher's colleagues, such as district gifted and talented education personnel and members of the subject school's staff echo the sentiments of Brandy Peters, 2018 Innovator, Garden Grove Educator Association, who believes that student classroom math and science test scores, as well as state and district level tests, have improved since starting a robotics and coding program (Ng, 2018). In addition, local municipalities have had RE workshops and private tutoring centers offer coding and robotics

classes. A simple Google search of “robotics education for children near 92703” revealed six individual franchises of robotics education providers within a 12-mile radius of the subject school (Google, 2019). The local University of California campus, the local California State University, as well as the local Community Colleges are all hosting STEM and robotics classes for children (California State University, Fullerton, 2019; Irvine Valley College, Community Education, 2019; University of California, Irvine, 2019). STEM education and robotics are offered as a means of recruiting and retaining students in mailers, banners and district websites. Local, state and national robotics competitions are hosted by such robotics providers as Lego, Vex IQ, Ozobot and Dash and Dot, amongst many others. However, some research indicates that there is a lack of a clear connection between robotics instruction and academic achievement (Hussain et al., 2006). On the other hand, gains have been reported in very specific areas, such as spatial reasoning (Julia & Antoli, 2015, sequencing abilities (Kazakoff et al., 2012), and collaboration and discussion in problem solving within teams of students (Yuen et al., 2014). While the impact of academic benefits of robotics programs is still being investigated by educators and scholars (Nugent et al., 2010; Ortz, 2015; Xia & Zhong, 2018), the impact that robotics programs have on students’ motivation to enter STEM fields is a compelling topic and may prove to be the most important benefit of elementary school robotics programs.

Demographic Misrepresentation

According to the 2010 United States Census, Latinx comprise 16% of the population in the U.S.; and in that same year, only 0.6% of engineers were Latinx females whereas 4% were Latinx males (Byars-Winston et al., 2015). Currently, large metropolitan areas have more than 60% of their elementary school-aged children identified as a racial minority subgroup (Mordechay et al., 2019), meaning that the future workforce will be heavily minority.

Furthermore, the State of California which has high-tech centers such as Silicone Valley and aerospace industry in El Segundo, the Latinx population represents an absolute majority of all students (National Center for Education Statistics [NCES], 2017). Despite the large number of Latinx students in California schools, Latinx are the most likely racial subgroup to not attain a college degree (NCES, 2017). Underrepresentation of Latinx students, along with females and other ethnic and racial minorities, may lead to the inability of the United States to sustain the STEM workforce necessary to carry the economy forward (Borman et al., 2016).

Recruiting and maintaining a workforce with ethnic and gender diversity can drive innovation and allow businesses to improve profitability (Hewlett et al., 2013; Mayer et al., 2018). Over 60% of children under 9 years old are classified as non-white, with most students in the state of California identifying as Latinx (Mordechay et al., 2019). This is significant to note, as it is projected that the Latinx may be the hardest hit population in regards to losing jobs due to automation. The greater Southern California area is defined as an Urban Core in which the rate of job growth will be some of the fastest in the nation (Mordechay, 2014). However, this growth is projected to be in fields such as technology, media, healthcare, real estate and finance, all jobs that benefit from a strong STEM background (Lund et al., 2019). The need for STEM backgrounds is once again imperative to impress upon our current students.

Problem Statement

The use of educational robots in the elementary school setting has grown significantly in the past few years. As an illustration, the researcher recently viewed recruitment videos for two separate school districts; both of which featured robotics as key aspects of the school curriculum. However, there is a lack of understanding about how best to implement the use of robotics education and what impact it has on student learning.

In this period of declining student enrollment, many schools and school districts are offering RE as a means of recruiting and retaining students. For example, students from the subject school have received postcards advertising open enrollment in neighboring districts, featuring such programs as dual language immersion, robotics and technology magnets. Furthermore, just as when computers were first introduced into the classroom and teachers did not know whether to teach computer programming or to teach software usage to students, teachers do not currently know if robots are better used to teach coding or to teach problem solving, as they would be used in an engineering setting (Cheng et al., 2018).

While most of the literature about robotics education (RE) is focused on elementary school students, 61% sampled 60 or less students, thus limiting the ability to generalize the findings to the larger population (Xia & Zhong, 2018).

This study was not aimed at examining how well students learn to code robots, use robots to problem-solve, or even how well students build robots. Rather, it aimed to determine the impact that early robotics education, while using the engineering design process, has on elementary students' attitude towards STEM education.

The Engineering Design Process

The Next Generation Science Standards (NGSS) defines the engineering practice, crosscutting concepts, and disciplinary core ideas, as the three dimensions of science education (Next Generation Science Standards, 2019). The engineering design process is the dimension that this study seeks to examine most closely. It is the engineering design process in which problems are solved through five steps: identify the problem; imagine a solution, while defining limitations such as weight, cost, time or materials; design and build a model or prototype; test the prototype, which will be a robot or program in this case, but can otherwise be a computer or

simulation; and, finally, modify the solution through any necessary modifications. The improvements may be ongoing, or can stop when no longer needed (The Engineering Design Process, 2019)

The engineering process, or engineering design process (EDP), is defined in the Next Generation Science Standards (NGSS) as a key practice that is to be utilized across science education (Next Generation Science Standards, 2019). A simple example of the EDP is a group of students who have been tasked to build a tower out of popsicle sticks, pipe cleaners, and tape. The tower must be able to hold a tennis ball. The identified problem is that a tennis ball must be held at a maximum height above the table in a tower that is limited by the number of popsicle sticks, pipe cleaners, and tape provided. Students then plan and test this tower. Students may redesign and test the tower as time allows. Finally, the group must create their final copy.

The EDP is defined by the NGSS as the process of asking questions and defining problems, constructing explanations and designing solutions, defining constraints and limitations, developing possible solutions and testing and evaluating the design solution. This process can be repeated for an engineering problem as many times as necessary to maximize the impact of the solution (Next Generation Science Standards, 2019).

One of the biggest challenges in filling STEM positions is that there are few students in total, and specifically underrepresented minority students, with the least powerful segments of our population being the least likely to enter into STEM fields (Drew, 2015; Falco, 2017). It is the researcher's belief, that increasing a student's self-efficacy in STEM-related practices will improve that student's attitude towards STEM fields overall and, thus encourage them to not self-select out of, or determine that they are not able to compete in, STEM classes (Gnilka &

Novakovic, 2017). This is especially true to keep female and minority students in 5th grade on the STEM pathway (Watt & Eccles, 2002).

It is theorized that self-efficacy can come from a combination of four sources: performance, modeled experiences, social persuasion and emotional indexes (Bandura, 1997). A student's self-efficacy towards STEM is believed to lead to approach behavior, rather than opting out of the STEM pathway (Betz & Hackett, 2006). This belief comes from the Social Cognitive Career Theory (SCCT). In the SCCT theory, self-efficacy combined with expectations for a positive or negative outcome of effort inputted, lead to subject matter interest, which in turn leads to major and career decisions (Lent et al., 2000).

Purpose of the Study

The purpose of this study was to investigate the impact, of a robotics enrichment program on the attitudes of upper elementary school-aged students towards STEM fields. It is at this stage of education that a student will develop either positive or negative attitudes towards STEM fields, thus effecting their desire to enter into them. It is also at this age that there is a small gap between female and male achievement in standardized math scores, with 2013 National Assessment of Educational Progress (NAEP) results showing a difference between male and female fourth-grade students as a scaled score of one, while in twelfth-grade it shows a difference of three in the scaled score. In science, the 2015 NAEP shows that fourth-grade males and females both have a scaled score of 254, twelfth-grade males have a scaled score of 153, while females have a scaled score of 148 (National Center for Education Statistics, 2017). Both science and math test results suggest that the gap between female and male achievement is smallest in fourth grade and becomes larger by high school graduation.

An inferential, non-experimental, problem based qualitative case study design was used, and it involved collecting quantitative data first. Quantitative data were collected using the S-STEM survey which was given in a pre-test, treatment, post-test format. This data were analyzed to determine whether a robotics enrichment program had an impact on student attitudes towards STEM. The qualitative data were collected through observations during the Robotics Education program and during weekly Community of Practice (CoP) meetings by the four teachers. For the purposes of this study, a CoP is a meeting of teachers who meet to discuss their views on the effectiveness of their craft and how it impacts their students and their future learning (Marques et al., 2016). This social view of learning is consistent with the researcher's belief in the social constructivist view of education.

Rationale

The future economy will be based on STEM fields and students who lack basic understanding of STEM principles will be at a significant disadvantage. This holds true even in blue collar professions, such as truck drivers, warehouse workers, chefs, and skilled tradesmen. All of these fields are intricately linked to the STEM fields. One only has to look at the diversity of jobs being automated, such as port automation in Los Angeles (Roosevelt, 2019), machines that read X-rays (Herrell, 2007), and robotic umpires in baseball (Brandt, 2019) to realize that automation will impact the jobs of the future. According to one study, the fastest growing fields are in health care and STEM fields, estimating that STEM professions will grow by 37% in the next 11 years (Lund et al., 2019).

Diversity in STEM Fields

One of the problems faced today is lack of diversity in the STEM fields. Currently, the highest proportion of engineers is made up of white males. Asian, Latinx, Black, and Native

American males and females enter engineering at a much lower rate than their proportion of the population as a whole would suggest. This is a problem, as research suggests that companies with a diverse workforce are more innovative and report higher profitability (Ellison & Mullin, 2014; Hewlett et al., 2013; Mayer et al., 2018). For example, Latinx make up 16% of the total population in the United States, but make up only 4.6% of engineers in the workforce (Fouad & Santana, 2016). This lack of diversity has not allowed the United States to tap into the full potential of its population.

In addition, the growth of automation has the potential to displace over 7.4 million Latinx workers by the year 2030 (Lund et al., 2019), exposing the need for early interventions in bringing Latinx students into STEM fields. By learning the STEM fields at a young age, students are more likely to be able to adapt to a changing workforce (Bailey et al., 2019).

The researcher's hope is that this study will be used to help students feel more empowered to enter STEM majors and careers, thereby closing the race gap in STEM fields. This can be done by having students develop positive attitudes through successful and positive interactions with STEM projects as presented through "play" with the Lego Mindstorm robots.

Research Question and Hypothesis

In order to guide the research of this study, the following question is considered: What impact, if any, does a robotics enrichment program have on an Orange County, California elementary school students' attitudes towards STEM fields in a predominantly Latinx inner-city elementary school?

The null hypothesis is that students participating in the robotics enrichment program will show no significant difference in their attitudes towards STEM careers and majors. The

alternative hypothesis is that students participating in a robotics enrichment program will show a significantly more positive view regarding STEM careers and majors.

To focus this study, the following research questions were investigated:

- RQ1: What impact, if any, does a robotics enrichment program have on elementary school students' attitudes towards STEM at a predominantly Latinx inner-city elementary school located in Orange County, California?
- RQ2: What 21st century job skills, if any, do students develop in a robotics education program?
- RQ3: What impact, if any, does a robotics education program have on female, English Learners and GATE students?

Study Significance

Most of the research done to date on robotics in education has been done at the middle school level and beyond. The purpose of this study is to close the gap in research by examining elementary school aged children and how their education is mediated by robotics. This research will help to assess and justify the impact of robotics instruction in schools, or see if it is just another fad. Furthermore, studies that have been conducted have sought to determine if there was a correlation between robotics instruction and academic achievement in other subjects. While this is important, it is not the only reason to teach a topic or use an educational tool. Robotics instruction can be used to teach the engineering process, a crosscutting concept in the Next Generation Science Standards (NGSS). It is hoped that through introducing the engineering process in a fun and successful experience, students will develop positive attitudes towards STEM fields and seek to enter STEM majors and careers later in their education. Having a successful and fun experience in the robotics enrichment program addresses three of

the four self-efficacy acquisition strands in a positive manner. The strands addressed are performance, modeled experiences, and social persuasion. Emotional indexes may, or may not, be addressed depending on the student's individual experiences. By changing attitudes about STEM fields and majors in urban Latinx students, this may be possible to create generational change within the neighborhood and raise the economic status of the neighborhood as a whole.

Definition of Terms

Definitions of key terms are included to provide context for the reader of this research study. The following definitions are used:

Code: Used as a noun in this study, it is the direction that a programmer puts together so that the program, or robot, will perform a certain behavior.

Cross Cutting Concepts: In the Next Generation Science Standards, these are the concepts that are to be taught across grade levels and scientific topics. In this study, the concept of engineering is the most significant.

English Learner (EL): An English learner is a student who has parents who speak, or interact with electronic media, such as television and radio, in a language other than English and who has not been redesignated Fluent English Proficient.

Lego Mindstorm or Lego EV3: A robotics kit that is produced and sold by the LEGO corporation. It consists of a programmable body, touch sensors, motors, infrared sensors and assorted Lego pieces that may be assembled to the body.

Robotics Education (RE): The academic instruction of programming and application of robots.

Science, Technology, Engineering and Math (STEM) Education: A framework for teaching science, technology, engineering and math in a systematic way.

Science, Technology, Engineering, Art and Math (STEAM) Education: A framework for teaching science, technology, engineering, art and mathematics in a systematic way. Many schools are transitioning from STEM to STEAM as to better promote creativity in both artistic expression and in problem solving.

Assumptions and Limitations

The researcher in this study made several assumptions. First, the Chromebooks, Lego Mindstorms, motors and cables were all compatible and were in working order. Second, the App used is appropriate to the age group of participants and allowed students to successfully code the robots. Third, all the instructors involved were adequately prepared to instruct students in the use of Lego Mindstorms and the related App. Fourth, all students were able to fully complete the tasks given. Fifth, all students involved in the study answered honestly and completely all S-STEM survey questions. Sixth, all students and teachers in the study not only had access to the internet and Zoom, but were able to successfully use these platforms.

In addition to the above listed assumptions, there were also limitations to this study. First, there was a small sample size of eight students. The small sample size distorted the robustness of the results. Due to participant self-selection to the program, there was a chance that students joined the study just to be with their friends, or that students excluded themselves from the study due to classes being held outside of normal school hours. In addition, due to the expenses associated with running a robotics enrichment program, the study only included nine robots. One was used for demonstration purposes by the teachers, and the remaining robots were distributed to students at home. Due to COVID-19 restrictions and CDC guidelines, students were not allowed to share materials, or work together in an enclosed space. The teachers made the early decision that students would work with robots, one-on-one so as to allow students in the

program to have the opportunity to work on the robots themselves. The limit on the number of students limited the ability to generalize the results to other populations. Also, the time frame, 20 hours of instruction, is relatively short, meaning that in this enrichment program, students may not have enough time to gain the experiences necessary to form an opinion about STEM fields. Lastly, the participants are not disaggregated for socio-economic status, parent education level, Gifted and Talented Education status, or special needs status-all of which are critical predictors of academic success. The study of each of these sub-groups could yield useful results.

Nature of the Study

The researcher will be using an inferential, non-experimental, problem based qualitative case study to collect and analyze data in this study. The qualitative case study design was appropriate in this design for a number of reasons. The first of these was that the quantitative part of the study will be best used to analyze the outcome of the robotics enrichment on student attitudes towards STEM. However, there is little existing research on the effects of robotics on elementary aged students, which merits a qualitative approach (Creswell, 2014). In addition, the case study design will allow the researcher to examine different forms of data, and to best utilize his unique role of participant-observer.

Organization of the Study

This study is broken up into five chapters. Chapter 1 contains an introduction to the topic, problem statement, purpose of the study, rationale, research question, study significance, definition of terms, assumptions and limitations, and the nature of the study. Chapter 2 examines the existing literature about robotics and its impact on STEM studies. Chapter 3 explains the setting, participants, instrumentation, and data analysis of the research. Chapter 4 contains the

study’s results, while Chapter 5 contains the results, meanings and future recommendations to expand on this study’s findings.

Chapter 2: Review of the Literature

Introduction

This study was meant to determine the impact of using robots as an educational tool in an urban, predominantly Hispanic, elementary school on student attitudes towards science, technology, engineering and mathematics (STEM) fields. In order to best facilitate the review of the literature on this topic, it is important to have an overview of the importance of STEM in education and its impact on the 21st century workforce and employability of current students in the future. As the nature of work changes and automation, artificial intelligence, and disruptive technologies continue to develop, it becomes essential that students are prepared for future work, much of which will require STEM backgrounds (Lund et al., 2019). To better understand the impact of the changing economy, the literature regarding the underrepresentation of the Latinx and female populations in STEM fields will be explored. After that, the use of robotics in education will be reviewed. This will be followed by discussion of the self-efficacy theory, as well as its related Social-Cognitive Career Theory (SCCT). Finally, the Expectancy-Value Theory (EVT) will be reviewed, as self-efficacy theory, SCCT and EVT are conceptual frameworks that help the reader understand how an individual may make future career choices.

STEM Education

In 1983, the President Ronald Reagan's education secretary, Terrel H. Bell, released the groundbreaking report, *A Nation at Risk: The Imperative for Educational Reform*. In this work, the nation was warned that our once dominant position in commerce, industry, science, and technological innovation was being overtaken throughout the world. By 1999, the Commission on National Security recognized that future threats to America would come from non-traditional places. These include advances in information and biotechnologies, global connectivity,

electronic communication and that technology would not be able to detect all threats to our country. This warning has been leveraged over the past 35 years to create educational reform. In 2012, 36 states had a strong presence of engineering skills in their education standards, with 11 having explicit engineering standards. Of the 11 with explicit engineering standards, only six, which include Connecticut, Indiana, Massachusetts, Minnesota, Oregon, and Tennessee have them in grades K-5 (Carr et al., 2012). In addition, California, along with Washington, D.C. were the only jurisdictions to receive a report card grade of "A" from the Fordham Institute for Educational Excellence for the rigor in K-12 science standards, while 26 received grades of "D" or "F" (Finn & Magee, 2012). The efforts to improve science instruction have ranged from the No Child Left Behind Act (NCLB), to the Every Student Succeeds Act (ESSA), and the implementation of Next Generation Science Standards (NGSS). In addition, advances in teacher preparation to teach STEM methodologies have been implemented in some universities and school districts (Nadelson & Seifert, 2017). While these legislations are part of a larger effort to improve participation in STEM fields, policies to address high school math preparation and the gender gap will also be highly effective in addressing the shortage of STEM workers (Green & Sanderson, 2017).

There are a number of practices currently in use that are meant to alleviate the shortage of STEM workers in the United States. One that is currently in place is the Department of Defense's STARBASE, a program which is designed to raise learning and occupational awareness of STEM fields for both teachers and students by hosting 4th and 5th grade students at 60 military installations at a cost of 30 million dollars (DoD STARBASE, 2018). At the state level, Senate of California Resolution 15 proclaimed the week of April 7-13, 2019 to be Women and Girls in STEM Week. Though mostly symbolic in nature, Women and Girls in STEM Week

acknowledges the importance of encouraging females to enter STEM fields. Further recruitment of females to the STEM fields is being done by the Ad Council and their "She can STEM, So can you" ad campaign (The Ad Council, 2018). The Society of Hispanic Professional Engineers (SHPE) offers mentorships to both students and professionals either in, or considering, STEM fields. They offer *Noche De Ciencias* (Science Night), a STEM career fair offered to middle and high school students that demonstrates STEM careers and how parents can support their children to develop STEM awareness and have given out over $300 thousand in scholarships (Society of Hispanic Professional Engineers, 2019). In addition to these programs, universities are also offering community outreach programs such as the University of California, Irvine's physics assemblies. These assemblies are conducted by a combination of teacher education students and science majors. The hands-on and highly engaging assemblies are designed to further enhance student understanding of, and interest in, STEM fields (Avila, 2019). This is in addition to the various camps and programs offered by the local colleges and universities aimed at K-12 students (University of California, Irvine, 2019; 2021).

In addition to the above-mentioned practices, Congress has several bills under consideration aimed at improving STEM participation, from both the student/worker perspective, and the educator's point of view. On a search conducted on December 4, 2019 of Congress.gov using the phrase "STEM education" revealed that the 116th Congress of the United States has 110 bills either introduced, in committee, or under review, while a search of "education" yielded 3,325 results. While 110/3,325 bills may seem like STEM education has a very small percentage of Congressional concern, the results from the "education" search included topics such as substance abuse education and eliminating implicit bias in education. The bills under consideration for STEM reform include H.R. 4623, Keep STEM Talent Act of 2019 in which

foreign born individuals with advanced degrees in impacted STEM fields will receive legal, permanent status. S 737, Building Blocks of STEM, would grant more money to the National Science Foundation to research and implement programs to further encourage underrepresented minorities and females to enter STEM fields. HR 3309, STEM K to Career Act, introduced in June 2019, would seek to address training and attracting more STEM teachers through student loan forgiveness, above the line tax deductions for STEM materials and tax credits for STEM teachers. The State of California is also seeking to attract STEM teachers, and the California Assembly is considering AB 578, Teachers: The California Stem Teaching Pathway Act of 2019, which would provide up to 27 million dollars of one-time grants for teachers and students enrolled on a STEM pathway. All of these reforms would attempt to fortify STEM education in the United States to ensure a competitive workforce in the 21st century.

To understand the importance of STEM fields, it is essential that one understands just what STEM education entails. According to the STEM Education Act of 2015, STEM education is defined as “education in the subjects of science, technology, engineering and mathematics, including computer science” (Public Law 114-59, 2015 § 2). However, this definition can be fairly inadequate because STEM education includes a variety of subject matters and is best taught when integrated across the curriculum with multiple applications (Nadelson & Seifert, 2017). There are nine major dimensions to an effective STEM lesson. These include having engaging and motivating contexts, having an engineering design component, integrating science and math into an applied concept, having student centered instruction in which students either develop the problem to be solved, or the solution to the problem, themselves, having performance and formative assessments to ensure student understanding, and using the 21st

century job skills which include: teamwork, effective communication and organization (Walker et al., 2018).

STEM education has become an important issue in education because of current projections about the 21st century workforce. According to one study, for example, approximately 33% of job losses during the 2008-2009 Great Recession were caused because of a skills gap, defined as the difference between the skills held by the workforce and the skills desired by employers (Foroohar, 2017). In addition, the Great Recession's impact varied greatly across different localities within the United States (Mordechay, 2020a), shifting the nature of many jobs.

An example of this is the changing nature of auto manufacturing. Traditional cars need workers who build transmissions and internal combustion engines, neither of which are necessary in electric cars that use direct drive. Instead, automakers are looking for workers with an updated skill set that know how to work more closely with advanced technologies, batteries and electrical systems (Gifford, 2019). National Educator Association President Dennis Van Roekel cites bolstering the nation's STEM curriculum as critical to having a competitive edge in the rapidly changing global economy (2012). While some educators and policy makers have attempted to amend STEM to include art education, as evidenced by House Resolution 3344, the STEM to STEAM Act, this study focusses on only the STEM fields. Previous studies have indicated that explicit and systematic instruction in the STEM fields does positively impact student attitudes towards STEM (Guzey & Aranda, 2017; Mooney & Laubach, 2002).

No Child Left Behind and Every Student Succeeds Act

In April of 2015, Senator Lamar Alexander introduced legislation to reauthorize and revise the No Child Left Behind Act (Public Law 114-95, 2015). According to the Congress.gov website, this law, commonly known as the Every Student Succeeds Act (ESSA), was passed in

December 2015 with an 81-17 vote. In the ESSA, states were given much more power to decide how students are assessed, allowed for more STEM professional development and encouraged the use of federal funds for teachers to better use and implement computers in the classroom (Gamoran, 2016). The goal of ESSA is to ensure that all students are college and career ready, including being prepared to enter into STEM majors, and even into non-degree requiring STEM fields (Adler-Greene, 2019). In order for students to be prepared for both college and career, the ESSA encouraged the implementation of the Common Core State Standards (CCSS), which standardized the expectations of what students are to learn by grade level in reading, writing, math and English language development, with especially rigorous standards in mathematics.

Despite the implementation of the ESSA, there remains persistent achievement gaps in the American education system that threaten America's economic growth. Four of the major achievement gaps are as follows: American students versus other high achieving nations, Black and Latino students compared to Caucasian and Asian students, students of different socio-economic statuses, and students of similar backgrounds and abilities who are attending schools in different systems and regions (Auguste et al., 2009). In addition to the previously mentioned achievement gaps, the United States Department of Education defines the achievement gap as the difference between a subgroup that scores below the average standardized test scores in language arts or math and the highest scoring subgroups on the same tests (The Glossary of Education Reform, 2013). The different subgroups may include students of different ethnicities, social-economic status, or program participation. In order to grow America's economy to its fullest potential, it will be imperative to close these achievement gaps.

Next Generation Science Standards

The Next Generation Science Standards (NGSS) were developed with the intention of modernizing science instruction in order to improve science education and to better prepare and engage students in more challenging and in-depth science, computing and engineering courses. The ultimate goal is to ensure that all students graduate prepared for college and careers (Kirst, 2014). The NGSS does this through crosscutting concepts, science and engineering practices, and disciplinary core ideas. This includes the engineering standards across curricular areas, rather than as a stand-alone subject, takes into account the National Academy of Engineering recommendations (Carr et al., 2012). The crosscutting concepts look at the four domains of science taught in K-12 schools: life science, physical science, earth and space science and the engineering design process [EDP] (Next Generation Science Standards, 2019). The science and engineering practices reflect on the work scientists and engineers do in order to understand the world, as well as how scientists and engineers design and build products that integrate this understanding. Finally, disciplinary core ideas refer to basic scientific knowledge that is important for understanding core scientific and engineering concepts that build upon one another throughout one's education. Within the context of this study, the EDP will be explored the most.

In the Next Generation Science Standards, EDP is a problem-based activity in which students systematically identify a problem, look for ideas, develop solutions, and share solutions with others (Next Generation Science Standards, 2019). The process is intended to be repeated multiple times with each solution being better than the last. Design evaluation is a critical thinking skill that can be developed through practice. In addition, the engineering design process can be used to facilitate teamwork, group problem solving, creativity, critical thinking skills and

communication skills (Guzey & Aranda, 2017), all identified as highly desirable work skills in the 21st century (Bughin et al., 2018; Lund et al., 2019).

21st Century Skills

Employers of the 21st century workforce have made it clear that there are four main, non-academic skills in their employees. These have often been referred to as the 4 Cs. The 4 Cs include critical thinking, communication, collaboration and creativity (Kivunja, 2015). In another study, these four skills are augmented by knowledge construction and self-regulation (Stehle & Peters-Burton, 2019). Furthermore, one can add leadership to the original 4 Cs to desirable 21st century skills (Brown, 2019). These same skills have been noted in a study of around 142,000 job advertisements. Within these advertisements, 28% requested oral communication, 23% were seeking written communication, 22% asked for collaboration and 19% sought problem solving, which may be correlated to creativity (Rios et al., 2020).

It is important to understand how the 4 Cs of 21st century job skills are defined. Critical thinking is often used interchangeably with problem-solving skills. It is a skill in which individuals can come across a unique situation and develop a unique or improved solution to that problem (Stehle & Peters-Button, 2019; van Laar et al., 2020). Collaboration can be described as the ability to work interdependently with other people (Kivunja, 2015; Van Laar et al, 2020). This can be in person, or in a virtual setting. Communication is the skill of effectively sharing information. This is divided into written and spoken communication (Kivunja, 2015; Rios et al., 2020; Van Laar et al., 2020). Finally, creativity is defined as using existing information in a new or unique way (Van Laar et al., 2020).

STEM Fields Projections

STEM field occupations are growing at a rapid rate (National Science Foundation [NSF], 2014; Santiago, 2017). According to the NSF, women and underrepresented minorities in the STEM fields are making progress in entering STEM careers; there is still room to grow to achieve a thorough representation of the diversity of the American workforce. For example, women made up 23% of science and engineering workers in 1993, and 28% in 2010. However, the number of women in computer sciences and math fields has decreased over this same period from 31% of the workforce to 25%. Whites have shown a decline in the workforce, comprising 84% of the STEM workforce in 1993, while comprising 70% in 2010. Currently, Asians have doubled their participation in the STEM workforce going from 9% in 1993 to 19% in 2010. Latinx comprise a little over 5%, while African-Americans make up a little less than 5% of the STEM workforce. The rest of the STEM workforce is made up of Native groups or multiracial individuals (NSF, 2014). Current statistics suggest that while progress is being made in diversifying the STEM workforce, Latinx currently make up 7% of those employed in STEM fields, while comprising 16% of the workforce as a whole. African-Americans are up to 9% of the STEM workforce, while making up 11% of the total workforce (Graf et al., 2018). Black and Latinx individuals with STEM degrees are less likely to work in STEM fields and are more likely to work in the less highly compensated areas of STEM than their White and Asian counterparts (Gatchair, 2013; Santiago, 2017). However, these statistics can change quickly, as the general population of the STEM workforce is aging, opening the door to a demographic transition as baby boomers age. In addition, The U.S. Bureau of Labor Statistics estimates that there were nearly 8.6 million STEM jobs in 2015, representing 6.2% of U.S. employment, with 93% of these jobs having wages above the national average. It is also projected that there will be

over 2 million STEM related job openings between 2014 and 2024 (Fayer et al., 2017). In order to help fill the positions, one projection estimates that the number of Bachelor of Science degrees in STEM fields awarded to women and underrepresented minorities must increase by 34% (Lawner et al., 2019).

Latinx in STEM

While STEM fields are seen as increasingly important, it is significant to note that fewer females and underrepresented minorities, including Latinx, are preparing for and entering into STEM fields (Fouad & Santana, 2016; Moller et al., 2015; Santiago, 2017). Those who do enter the STEM fields tend to work in lower level STEM careers with lower earning potential (Santiago, 2017). One possible explanation is that the social networks necessary to enter into higher paying STEM fields is weaker for Latinx than their White and Asian counterparts (Gatchair, 2013). These social networks include minority-owned companies, having peers already established in STEM careers or having mentors to help guide them in career decisions (Gatchair, 2013; Lundmark, 2004).

One of the largest obstacles to Latinx students pursuing STEM careers is lack of success in early education (Moller et al., 2015). On the 2016 California Standards Test in Science (CST), examining the data for English Learners (ELs) revealed that only 16% of fifth-grade, 18% of eighth-grade, and 8% of 10th-grade English learners scored proficient or advanced on the 2016 science CST. In contrast, 62% of Fluent English Proficient (FEP) or English Only (EO) students in fifth grade, 66% of FEP and EO students in eighth grade, and 54% of FEP and EO students in 10th grade — scored proficient or advanced in 2016 (West, 2017). Furthermore, many Latinx students are dissuaded from taking advanced math and science courses by peers, teachers or counselors (Drew, 2015).

In addition to the above-mentioned challenges to Latinx students, as well as Black and Native American students, are underrepresented in Gifted and Talented Education (GATE) programs (Lamb et al., 2019; Peters & Engerrand, 2016). In 2009, Latinx individuals made up 22.3% of students, and 15.4% of GATE students. In 2011, Latinx students were 25% of total students, with 16% identified GATE students (Ford, 2014). The stated purpose of the GATE program is to build elementary and secondary schools' ability to meet the needs of their gifted and talented students (U. S. Department of Education, 2005). The GATE program is intended to meet the social, emotional, and academic needs of GATE students. Academically, the GATE program is to be more rigorous than the traditional program and should provide more opportunities to develop higher order thinking skills, self-efficacy in problem-solving and develop creativity, all 21st century skills (Ramos, 2010). When properly implemented, the GATE program is key to helping individuals reach their full potential both intellectually and economically and may help close the achievement gap between underrepresented minorities and their higher performing peers (Ford, 2014).

Underrepresentation in GATE programs has numerous causes. One cause is social inequality. Social inequality refers to the barriers to education set up within society, including ethnic identity, gender, socio-economic status and even geographic location (Ford, 2014). Another potential barrier to entering the GATE program is the manner in which students are identified (Ford, 2014; Lamb et al., 2019; Ramos, 2010). Only 32 states have mandatory GATE identification and services (Lamb et al., 2019), and identification procedures do not have a clear set of standards across states, or even districts (Ramos, 2010). Some of the other barriers to identification are test bias, selective referrals and deficit-based thinking (Lamb et al., 2019; Peters & Engerrand, 2016). To combat the prejudicial effects of screening, some schools in New

York have begun to engage in a non-screened GATE admissions process (New York City Department of Education, 2021).

Upon graduating high school, nearly half of Latinx students start at two-year colleges, and those who enroll in four-year universities enroll in less selective colleges, which have lower graduation rates (Gándara, 2018; Krogstad, 2016). Less selective colleges and universities may also provide fewer opportunities for gainful social networks. Many Latinx students see community colleges as an opportunity to enter into higher education, yet only about one-third of those who initially enroll in community college transfer to a four-year university within five years (Jabbar et al., 2017). Students entering two-year colleges were often placed into as many as four remedial math classes before entering transferrable math classes, delaying their entry into regular college courses and creating frustration (Santiago, 2017). Expectancy Value Theory suggests this delay can also create negative feelings about entering STEM fields. However, policies regarding placement in remedial classes changed in January 2018 with AB 705 which stated that no student would be denied entrance into transferable math classes unless he or she was highly unlikely to succeed in these classes. While 30% of White students and 41% of Asian students transferred to a four-year university within seven years, only 17% of Latinx students did the same (Gándara, 2018). California Community College Chancellor Eloy Ortiz acknowledges that there is not enough progress being made in increasing the percentage of students completing their degrees or transferring to four-year universities (Gordon, 2019). In addition, the Community College geographically nearest to the subject school has a lower graduation rate (25% vs. 27.37%) and lower transfer rate (8.51% vs 17.66%) than similar schools (Santa Ana College, 2019). Despite all of these challenges, Latinx students are poised to be the largest ethnic group in the Fall 2020 University of California system's history (Smith & Rosales, 2020).

In addition to the above-mentioned challenges of graduating from a four-year college or university, Latinx students face the problems of a language barrier, family responsibilities, job demands, financial needs and academic under-preparedness (Gándara, 2018; Kruizenga et al, 2018). First generation students also have the difficulty of unfamiliarity with the university system. For example, many first-generation students focus on re-reading text and memorizing for comprehension. However, a more effective method of studying is summarizing reading in one's own words or developing questions about the reading and answering them (Nurhayati & Fitriana, 2018). Furthermore, many begin college without knowing how to develop a research topic, start the research process or even how to use a research library (Mireles-Rios & Garcia, 2019). Many first-generation family members also don't understand how best to support their children. First-generation students report that, while parents don't get in the way of their studying or doing work, they don't understand the scheduling, or don't understand why it takes so long to graduate, and are hesitant to take out student loans (Jabbar et al., 2017.)

Latinx Females in STEM

While there are factors in STEM education that may make pursuing a STEM field potentially easier for a Latinx student, there are institutionalized barriers that may prevent them from entering these fields. For example, Latinx students are consistently tracked into lower level science classes in high school, thus making them less prepared to enter higher classes in college. While both math and science classes can be remediated in college, the very fact that remediation is necessary may create an obstacle that is difficult for underrepresented minorities to overcome (Fouad & Santana, 2016; Green & Sanderson, 2017; Santiago 2017). Another potential barrier is the experience of racial discrimination, which leads to lower motivation and academic achievement (Hall et al., 2017). Some females believe the stereotype that females are not as good

at math and science as males, thus self-selecting out of these fields before giving themselves a chance to enter them. This may be attributed to a self-concept developed early in life in which teachers, parents and other influential adults help shape beliefs about which fields offer the most opportunities for success (Beach, 2013). In addition, many female students are unaware of the female math and science pioneers who have come before them, such as Marie Curie, Jane Goodall, and Dorothy Johnson Vaughan (Drew, 2015).

There are three main pillars that Latinx families try to instill in their children. These are respect, education and family (Aldoney & Cabrera, 2016). These beliefs tend to foster the 21st century skills of cooperative learning, teamwork and shared inquiry (Gándara, 2018). These cultural beliefs are usually helpful, but for Latinx females, the barrier of family responsibilities is especially burdensome. This takes form in a number of ways. Latinx females have higher expectations to help around the house, help care for other family members and to complete household chores. Oftentimes, college choices are bound to a geographic area near the family's home (Jabber et al., 2017). In addition, females have less freedom to act outside the home and family unit (Cupito et al., 2014). This lack of freedom conflicts with opportunities to participate in after-school organizations, classes and extra-curricular activities, which are some of the most important ways for students to feel connected to school, and an indicator of school success (Gándara, 2018). Furthermore, the strong cultural bond of family may discourage some Hispanics from entering STEM fields, as these jobs are perceived as incompatible with raising a family (Green & Sanderson, 2017; Valentino et al., 2016).

The problem of under-preparedness is exacerbated by the large number of Latinx students attending schools in high poverty areas, in which teachers are frequently less experienced. Less experienced teachers generally teach in high poverty areas because these classes are viewed as

the most difficult to teach. Because of the perceived difficulty of working in high poverty areas, teachers with more seniority are able to "select" from available positions at "more desirable" schools before newer hires (Beach, 2013). In addition, these schools are not funded at a high level in California because the funding formula is based on property taxes and property values. Impoverished neighborhoods have lower property values, and systemically have lower funding per pupil (Gándara & Contreras, 2010). These underpin a vicious cycle, where poverty and racial segregation interact to perpetuate inequality (Mordechay & Ayscue, 2018; Orfield et al., 2003).

This opportunity gap has been theorized to be highly influenced by a gap in early education, as students of all ethnicities tend to make academic progress at a similar rate (Davis-Kean & Jager, 2013; Gándara, 2006;). Due to the initial achievement gap, it is important to provide early interventions to enable Latinx students to potentially close the gap. It is also important to recruit and retain highly qualified teachers. These teachers should engage in collaborative communities of practice, and be caring and competent enough to engage Latinx students in a desire to enter the STEM fields (Moller et al., 2015).

The discrepancy between Latinx workers earnings in STEM careers versus their White counterparts is much smaller than in the general workforce. Latinx males earned 5.5% less than white males in STEM fields, compared to 10.3% less in all other fields; whereas Latinx females earned 12.7% less than white males, compared to 20.7% less in all other fields (Oh & Lewis, 2011). Many policymakers are seeking interventions that will encourage more Latinx students to pursue STEM careers because of the economic rewards and to better diversify the ideas, experiences and perspectives of the businesses that are serving an increasingly diverse population (Hewlett et al., 2013; Mayer et al., 2018. These include such interventions as mentoring programs, summer programs on college campuses providing STEM majors, offering

more challenging entry level STEM courses at the community college level, university outreach programs for elementary school-aged children, and ensuring multiple opportunities to engage in all of these interventions (Hall et al., 2017; Hernandez et al., 2017; Hinojosa et al., 2016; Ilumoka et al., 2003; Santiago, 2017).

An important aspect of Hispanics joining the STEM community is the feeling of belonging to, and identifying with, the scientific community. Two of the most important aspects of human identity are to have both a sense of uniqueness and a sense of belonging. This causes students as young as 5- to 7-year-old and 11- to 13-year-old, to have their academic performance negatively impacted by a stereotyped identity (Ambady et al., 2001; Tuijl & Walma Van Der Molen, 2015). Underrepresented minority students in undergraduate school report that they are more likely to pursue STEM careers if mentored by competent individuals (Byars-Winston et al., 2015). This is the result of a student experiencing academic dissatisfaction in order to maintain their ethnic, or gender identity (Estrada et al., 2011). To combat the effect of stereotypes on academic performance, it is important that students have a healthy sense of self. This is especially true of Hispanics, who need this healthy ethnic identity to have a strong sense of career decision self-efficacy (Chihara & Nakamura, 2017; Ojeda et al., 2011). In addition, Latinx students in educational settings may face social identity threat. In a social identity threat, such as in an educational setting, students feel devalued due to the stereotypes associated with their race and divert cognitive functions from comprehending academic tasks to coping with countering the stereotypes (Chihara & Nakamura, 2017). Two interventions that have been successful in countering negative stereotypes in Latinx students is for students to write positive affirmations about what is important to them and to have a successful Latinx engineer serve as a role model for minority students (Chihara & Nakamura, 2017). Another is having Latinx role models in the

STEM fields (Lawner et al., 2019). This demonstrates to students that someone of the same heritage, language and culture, often with similar challenges, can contribute to the STEM fields.

Researchers have also come to the conclusion that dual-language immersion programs benefit students through higher self-esteem, higher academic motivation, and greater long-term academic success than native English speakers in English-only classrooms (Gándara, 2018; Ojeda et al, 2011). In contrast to homogeneous groupings in K-12 settings, ethnically diverse campuses in university settings help to strengthen academic achievement (Antonio, 2001; Hall et al., 2017).

Education in the STEM fields can provide English Learner students with more opportunities to gain in academic achievement. One instance is the way in which STEM lesssons are presented, containing more diagrams, hands-on activities, graphs and tables, and equations than other curricular areas. In addition, many of the academic words in STEM areas are Spanish cognates (West, 2017). Cognates are words that sound similar in two languages and have similar meanings in both languages. For example, the words chemicals and *químicas* are cognates, as are the words atomic and *atómica.* On the other hand, there are false cognates, such as the words soap and *sopa* (soup). Learning to use cognates allows Spanish speakers to not only have access to English words, but gives the learner the feeling that they already know important information about science and that their culture has contributed to the scientific knowledge base, thus giving a sense of belonging.

Robotics in Education

Over the past 5 years the Santa Ana Unified School District has seen a dramatic rise in robotics education. Robotics education and educational robots may seem to be interchangeable terms, but they are not. Robotics education deals with teaching the concept and use of robots,

while educational robots are robots used to present curriculum (Xia & Zhong, 2018). At a September 18, 2019, district showcase for summer enrichment programs, 21 K-5 presentations out of 45 consisted of a STEM or STEAM focus, with seven having some sort of robotics component. The balance of the presentations consisted of a stock market class, two children's museum classes, a cooking club, and the rest were reading, writing, or math interventions, or grade level specific booster classes (Santa Ana Unified School District, 2019). These opportunities for elementary students to interact with robots may be useful in enhancing problem solving skills, teamwork, computational thinking, project management and collaboration and can serve to increase interest in in STEM fields and computer sciences (Casey et al., 2017; Nabeel et al., 2017; Nugent et al., 2015). Robotics has been so effective in developing teamwork and project management that the large majority of students in one study said that they preferred working in teams than working alone (Nemiro, 2020).

While educational robots have demonstrated the potential to positively impact attitudes towards STEM fields (Kvenlid et al., 2017; Nugent et al., 2015), a large portion of robots used in K-5 settings are for robotics education (Xia & Zhong, 2018). This is, perhaps, due to the emphasis on coding in various literature and the belief in the importance of coding in the community at large (Sokoler, 2018). However, it is the researcher's belief that robotics education and educational robotics are not necessarily mutually exclusive. For example, a curriculum in which Lego Mindstorms was used to teach mathematics, fifth-grade students showed an increase in mathematical ability, with the additional benefits of knowing how to program the robot and how to load the program onto the robotic brick (Hussain et al., 2006). Another example is the teaching of Newton's Laws of Motion. Once again, Lego Mindstorms

were used for instruction, and there was in increase in the amount of knowledge attained, while at the same time students learned how to use the robot's touch sensor (Williams et al., 2007).

There are many considerations when purchasing robots to be used in robotics education. These include accessibility, durability, supportability, and compatibility, as well as the use of color, ultrasonic, and touch sensors (Choudhery et al., 2016; Kvenlid et al., 2017). Another consideration is if the coding interface is accessible to the student population (Casey et al., 2017). For all of these reasons, Lego Robotics is the most widely studied robotics education platform, with 90% of studies in Benitti's (2012) literature review of robotics education employing Lego robotics.

The current research includes a positive impact of robotics on the use of such diverse topics as problem solving in ratio and proportion problems (Ortz, 2015), using robots as a manipulative in solving fractional operation problems (Sheehy, 2017), sequencing ability in early childhood (Kazakoff et al., 2012), enhanced problem solving and communication skills, including working in cooperative groups (Nabeel et al., 2017; Nugent et al., 2016; Yuen et al., 2014), remediating the understanding of parallelism and perpendicularity in 10-year old students, and boosts in self-efficacy in STEM fields (Nugent et al., 2016).

Robotics education has also had a positive impact on students from special populations. Robotics has also proven beneficial to students with disabilities. Students with disabilities show a greater understanding of teamwork, solving real world problems, and increased interest in studying science following robotics instruction (Lindsay, 2019). As for English Learners, robotics education has helped eighth grade students retain concepts in the scientific disciplinary core ideas, as well as learning scientific vocabulary (Robinson, 2005).

In another case study, Lego robots were used to teach nine- and ten-year old students to build and program a robot to "dance." This activity effectively engaged students with standards related to number sense, geometric shape, measurement, and angles (Francis & Poscente, 2016). In addition, students have the ability to engage in authentic practices, allowing them to plan, assemble and operate robots (Afari & Khine, 2017; Alonzo, 2019; Moltenbrey, 2006).

Another attractive aspect of robotics education is entering into robotics competitions. The subject school recently competed in its first Vex IQ Robotics Competition. In addition to Vex IQ Robotics Competitions, Lego has its FIRST Competition League. Teachers who have competed in Lego competitions report that students display better understanding of computational thinking and the engineering design process (Alonzo, 2019).

However, there is some research that suggests no, mixed, or minimal, impact of robotics education. These include topics such as problem-solving math and logic problems. A report at the Human Factors and Ergonomics Society's 57th Annual Meeting found that college students did not develop any new problem solving strategies when using robotics, but that they relied solely on trial and error (Huang et al., 2013). In fact, one study stated that there was little empirical evidence that robotics education makes an impact in K-12 education (Williams et al., 2007). A summer robotics program in an urban middle school indicated an increase in student attendance the following year, but did not detect an increase in math achievement in the same students (Mac Iver & Mac Iver, 2019).

In a review of extant literature, it was found that the most prevalent use of robots in education is in Language Education, with the second being robotics education (Cheng et al., 2018). However, some of the beneficial uses of robotics education exist outside of the STEM fields. In one study, the most observed student behavior was engaging in collaboration and

discussion, with the least observed behavior being programming, engineering and debugging the robots (Yuen et al., 2014). Another study indicated that students are motivated to learn with robotics, with 89% of students who participated in an intervention desiring future education in robotics (Choudhery et al., 2016). While the use of robotics education looks promising, the single most important aspect of success in their use is the manner in which the teacher implements the robotics curriculum (Xia & Zhong, 2018). Since success in robotics education is so dependent on teacher implementation, it is important to review which measures can be taken to ensure educators are ready to teach such curriculum.

Teacher Preparation

In order to integrate STEM education in general, and robotics in particular, into the general curriculum, teachers must be prepared to implement said curriculum. To this end, the only way to find the time to do this, and to most effectively give real-world STEM experience is to integrate both aspects into the existing curriculum (Blackley & Howell, 2019). Engaging pre-service teachers in robotics helps these teachers increase their emotional engagement in, and promote improvements in attitudes towards, STEM activities (Kim et al., 2015). Pre-service teachers who learn robotics education are more likely to teach the EDP in elementary schools (Kaya et al, 2017). To help teachers be effective robotics instructors, interventions such as RoboSTEM engage in example-based learning to help (Kim et al., 2019). In this program, peer teachers provide examples that help teachers learn what is needed to teach robotics through modeling. This social constructivist approach allows teachers to learn robotics education in communities of practice. Programs such as these allow teachers to make better educational use of their robots.

Lego Robotics

With the popularity of Lego Robotics in education, it is important to note what makes them so popular. Lego Robotics offer a diverse and authentically engaging learning experience for students. Teachers can use them in many ways, ranging from highly directed and heavily scaffolded to more challenging and independent. They can be used in groups or individually. The variety of motors and bricks allows for great flexibility and creativity in the way students design and build robots (Blackley & Howell, 2019). The variety afforded by Lego Robotics allows to students to develop different solutions for the same problem, thus allowing higher order thinking skill of evaluating which is best and why (Danahy et al., 2014).

There are many considerations when purchasing robots to be used in robotics education. These include accessibility, durability, supportability, and compatibility, as well as the use of color, ultrasonic, and touch sensors (Choudhery et al., 2016; Kvenlid et al., 2017). Another consideration is if the coding interface is accessible to the student population (Casey et al., 2017). For all of these reasons, Lego Robotics is the most widely studied robotics education platform, with 90% of studies in Bennitti's (2011) literature review of robotics education employing Lego robotics. Ease of use is immediately evident, as eight- and nine-year old students are able to build a basic Lego robot in 45 minutes (Francis & Poscente, 2016). This is possibly due to students' familiarity with standard Lego brick construction, as well as the easily followed written Lego directions.

Self-Efficacy

Self-efficacy can be the belief that one can successfully complete tasks that are important to the individual or that certain behaviors will lead to certain outcomes (Bandura, 1997; Estrada et al, 2011). In this study, self-efficacy is used to frame the development of career intentions in

individuals that may lead to the pursuit of STEM careers. In this definition intentions are seen as long-term goals (Ng & Lovibond, 2020). Self-efficacy can be strong, in which case an individual strongly believes in his or her own ability to accomplish a task. Self-efficacy can also be non-existent. When self-efficacy is non-existent an individual has no belief that he or she will be able to complete a particular task successfully. An individual can have strong self-efficacy in a broad range of activities or pursuits, or in just a few (Bandura, 1997; Eccles & Wigfield, 2002). For example, one can have high self-efficacy in sports, and not in playing a musical instrument. Self-efficacy is influenced by four sources of information that an individual uses to synthesize one's own beliefs. These include: (a) vicariously comparing one's own achievements with those who are believed to be successful at the same task, (b) social pressures and verbal persuasions that helps one believe that one possesses the necessary skills to be successful, (c) mastery experiences that demonstrate an individual's talents, and finally (d) affective states from which individuals judge their own capabilities (Bandura, 1997). It is theorized that higher levels of self-efficacy lead to "approach" behaviors as opposed to "avoidance" behaviors (Betz & Hackett, 2006). Approach behaviors describe activities in which an individual will participate, while avoidance behaviors are those in which an individual will not participate. In addition, when self-efficacy is high in behaviors used to avoid tasks, then the avoidance behavior is more likely to be chosen (Ng & Lovibond, 2020). To put it simply, an individual will gravitate to those tasks that he or she feels can be successfully accomplished. The significance of this theory is that students who have high self-efficacy in STEM fields are more likely to take STEM classes and pursue STEM careers.

Individuals make judgements about how likely they are to complete a task with a certain degree of mastery by comparing one's own achievements with those of an individual who is

believed to be successful at that task (Bandura, 1997). For example, a student who sees a respected teacher struggling with a sample problem on the board may feel that he or she cannot possibly complete a similar problem. In addition, if a student sees a sibling, relative or friend complete the same problem with relative ease, then the student may believe that he or she will likely complete the problem successfully. Being successful in a scientific task may also help one identify oneself in a manner more aligned to the scientific community (Estrada et al., 2011). This creates a situation in which the student has the expectations that he or she will successfully attain a scientific career.

Social pressures can be described as feedback loops in which an individual either has influences that continue to reinforce the idea that one can be successful in a particular domain, or not (Estrada et al., 2011; Lent, 2007; Senge, 2006). In this model, students who achieve well in STEM tasks will receive the feedback that they are doing well. This may include verbal praise, good grades, encouragement, and even financial support (Lent, 2007). This, in turn, leads to greater feelings of self-efficacy, which may lead to greater mastery, leading to greater reinforcement. This feedback continues and becomes a reinforcing loop, leading to high self-efficacy in the individual (Hunter, 2016; Senge, 2006). Interestingly, one of ways that ethnic minority students in college build self-efficacy is by having a diverse friendship group (Hall et al., 2017).

On the other hand, students may feel that there are barriers in their lives which make them feel less self-efficacy. These may include feelings of having lower skills than necessary to be successful, existence of gender or racial barriers, or the lack of financial or emotional resources (Estrada et al., 2011; Lent 2007). These feelings can also lead to a feedback loop in which an individual feels increasingly less self-efficacy towards STEM fields. Lower self-

efficacy towards STEM fields may lead to students creating academic intentions in which individuals do not seek to enter STEM fields.

Mastery experiences can be defined as performance accomplishments. In self-efficacy theory performance accomplishments are the ability to successfully complete meaningful tasks, build self-efficacy more powerfully than any other input, especially when these accomplishments are specific and challenging (Eccles & Wigfield, 2002; Fouad & Santana., 2016). On the other hand, successes should not always come easily. It is important that there are some setbacks that must be overcome in order to build perseverance and a growth mindset (Bandura, 2011). Having a growth mindset feeds the idea that the most important early intervention to ensure that students enter STEM fields is to give students the necessary cognitive tools and skills to be successful in math and science classes. These tools and skills are especially important for students in gateway classes that lead to the higher math and science classes. These classes, such as algebra 2 and chemistry or biology explicitly and implicitly serve as gatekeeper classes to advanced STEM classes like calculus, microbiology and computer science, which are necessary classes to graduate with STEM degrees and to gain employment in STEM fields (Estrada et al., 2011; Fouad & Santana, 2016).

Affective reactions to different tasks influence self-efficacy. Individuals may reflect on events as either being benign or disturbing (Bandura, 1997). This will, again, lead to either approach or avoidance behaviors, respectively. When building self-efficacy, it is imperative that the individual has the emotional and cognitive ability to frame memories of past events in such a way that the individual is building approach behaviors towards a task. Significantly, one literature review found that the second most significant predictor of postsecondary STEM success in reviewed studies was students' reported self-efficacy in STEM. All studies that

examined the relationship between interest or confidence in STEM and postsecondary STEM success found a statistically significant positive relationship, though the specific measures used were based on survey responses and differed across studies (Hinojosa et al., 2016).

Social Cognitive Career Theory

While not a focus of this study, the Social Cognitive Career Theory (SCCT) is an expansion of Albert Bandura's self-efficacy theory that explains how self-efficacy is used by individuals to select career paths (Betz & Hackett, 2006; Lent et al., 2011) that is worth exploring as it further explains how high self-efficacy in the STEM fields may lead students to have approach behaviors towards STEM. In the SCCT, self-efficacy influences a career path because individuals who feel that he or she can successfully complete tasks within a given field will naturally gravitate towards that field and contribute to the selection of tasks and goals (Lent et al., 2011; Turner et al., 2017). While it has been suggested that self-efficacy is the most important variable in contributing to SCCT (Lent et al., 2011), self-efficacy combined with outcome expectations of success, and the commitment to attaining one's goals, predispose individuals to gravitate toward a particular field, especially when combined with a feeling of belonging to that particular field. Self-efficacy and outcome expectations in Latinx students are different for rural and urban Latinx students, with students from rural areas perceiving more barriers than those in urban areas (Ali & Menke, 2014). In addition, the perceived, or real, access to social support can directly influence self-efficacy (Byars-Winston & Rogers, 2019; Fouad & Santana, 2016; Tuijl & Walma Van Der Molen, 2015; Turner et al., 2017). The feeling of belonging can be positively impacted through the use of earlier success in a particular field, focus on receiving parental support, and guidance, and the use of mentoring (Byars-Winston et al., 2015; Fouad & Santana, 2016). Any of the aforementioned variables can be seen as a support

or barrier, depending on the perception of the individual (Hall et al., 2017). It has been suggested that higher SES students perceive less barriers, and feel more supported than their lower SES counterparts (Turner et al., 2017).

Mentoring is one method that can give a sense of belonging. For first year female college engineering students, having a female mentor not only provided a more positive academic experience, they also have much higher retention in engineering programs, but are more likely to keep their post-degree aspirations of entering engineering fields (Dennehy & Dasgupta, 2017). Mentoring female undergraduate students also helps to promote a sense of belonging to the scientific community, or scientific identity (Hernandez et al., 2017). The sense of scientific identity is helpful in building self-efficacy, leading to improved motivation and long-term persistence in the STEM fields. Mentoring is also important in younger students. STEM UP! is a program designed to partner STEM-industry mentors with pre-college students. The students who participated were more likely to be interested in STEM subjects, as well as have greater confidence in STEM classes (Ilumoka et al, 2003).

Another method of providing a sense of belonging is having a large amount of role models within the field, allowing for a feeling of belonging by knowing that others that have a similar ethnicity to oneself, have a similar background to oneself, or speak the same home language as oneself have been successful in that field (Byars-Winston& Rogers, 2019). Mentoring is a tool that can be used to build self-efficacy in female students, especially for those who have a female mentor. Female students mentored by a female report more positive academic experiences and are more likely to maintain their desire to enter the engineering fields upon graduation (Dennehy & Dasgupta, 2017). Furthermore, the most significant intervention to encourage students to enter STEM fields is to ensure success in gateway science and math

classes as early as possible, thus raising self-efficacy (Fouad & Santana, 2016). Ways to increase early success in gatekeeper classes can be through in-school or after-school STEM programs, STEM competitions, and family education nights. Family education nights help a student's support system understand STEM outcome expectations, how to overcome educational and social barriers, and role models can speak about STEM careers (Turner et al., 2017). In addition, having graduate students mentor first year university students helped first generation students understand how to navigate graduate school both from a personal standpoint and from an academic standpoint. This includes balancing work, school, family life, scheduling, and even how to apply for admission (Mireles-Rios & Garcia, 2018).

Conclusion

STEM careers are rapidly growing and are centrally linked to both U. S. national security and future career earning potential and the power of young people (Beach, 2013; Drew, 2015). According to the Bureau of Labor Statistics, STEM occupations have above average growth. Some projections have STEM fields with the highest potential for job growth over the next 11 years (Bughin et al., 2018). According to multiple reports, ranging from those put out by the National Educators Association to the National Science Foundation to the Bureau of Labor Statistics, STEM fields will have thousands of positions that will go unfilled if the United States does not meet those needs through educating its population. Congress estimates that there will be 1,400,000 new technology jobs by 2020, with just under one million going unfilled by graduates from U. S. schools (STEM Opportunities Act, 2019).

This problem is compounded through the underrepresentation of women and minorities entering STEM fields. In order to address this problem, 20 states and the District of Columbia, have adopted the NGSS. In addition, 22 states have adopted science curriculum based on the

NGSS (NSTA,n.d.). Furthermore, to help integrate more underrepresented minorities and women into the STEM fields, it is imperative that educators help build self-efficacy in the STEM fields, and help students feel a sense of belonging within STEM fields and demonstrate the value of pursuing the STEM fields. This is particularly important for Latinx, who now make up a quarter of the nation's public-school enrollment, by far the largest minority group (Gándara, 2018; Gándara & Mordechay, 2017). In California, by far the most populous state and with one of the largest economies in the world, Latino's are a majority in the public schools (Mordechay & Orfield, 2017).

The importance of insuring that younger children are exposed to the STEM fields through early interventions cannot be understated. According to Conceptions of Career Choice and Attainment model, by 6th grade, over 50% of students have reached the interaction stage of career choice and attainment. At this level, students have already learned that the career choice is tied directly to matching personal interests and abilities to career choice (Howard & Walsh, 2010). Early success in STEM activities, in this case working with robotics education, should help students have educational aspirations to enter into STEM fields. It is the researcher's intent to discover what impact, if any, the use of robotics education has on attitudes towards STEM.

It is within the self-efficacy theory that the researcher believes that a well-designed robotics education program can have a positive impact on underrepresented minorities in an elementary school setting. Students will be given challenging tasks, provided by role models who speak like them and have a similar background. These skilled instructors will be able to scaffold instruction in such a way that challenging tasks are both attainable, but also fun and engaging. This innovative program can spark others to emulate its results, helping to close the diversity gap in STEM fields, and keeping America's lead in innovation.

This study sought to better understand how Latinx youth at an inner-city school in Orange County, California might be impacted by an early intervention robotics enrichment program on their attitudes towards the STEM fields. It is anticipated that, if there is a positive correlation between the robotics enrichment program and attitudes towards STEM fields then this program can be expanded to form a long-term solution to the underrepresentation of the Latinx population in the STEM fields.

Chapter 3: Methodology

Introduction

The purpose of this study was to examine the impact that a robotics enrichment program at a predominantly Latinx inner-city elementary school has on students' attitudes towards STEM fields. The original planning for this research project was completed on March 6, 2020. At the time, the plan was to have a mixed-method study involving 24-32 students, working in teams of three to four students each, working in a face-to-face setting as part of a summer enrichment program. The first inclination that things would change was on March 13, 2020 when the subject school moved to a distance model of education to flatten the curve of the COVID-19 pandemic. The subject school was scheduled to return to in-person learning following Spring Break. However, on March 25, 2020, the district's superintendent released a video announcing that the return to in-person learning would be pushed to a later, yet to be determined date.

On April 15, 2020, a district press release stated that all in-person learning would be cancelled through the end of the 2019-2020 school year, and through the summer. This led the researcher to consider modifications to this project. In addition to the summer program being changed to distance learning, the district announced that all summer enrichment programs would be cancelled in favor of academic intervention programs. This meant that the robotics enrichment program would have to take place in the fall of 2020.

However, on July 14, 2020, the district issued another press release that stated that the virtual education model would continue into the fall of 2020. This caused the researcher to pivot away from the originally planned face-to-face mixed methods model. The program's teachers, in agreement with the researcher, decided to follow CDC and district guidelines to eliminate shared materials between students by having each student involved in the program have a robot

delivered to their house. While this decision would severely limit the manner in which students would collaborate, it did allow each student to have their own robot to manipulate and use.

From a pedagogical standpoint, students would no longer be able to engage in the EDP as completely as they had in past robotics programs. In previous years, students would complete the Hour of Code program to learn basics to block coding and five programming challenges to practice coding. Upon completing the challenges, students would apply the EDP to designing a robot to solve a problem that each group had identified. This would follow the normal EDP of identifying a problem, designing a solution to the problem, testing that solution, and redesigning the potential solution to better solve the problem. In the past traditional settings, this would allow the EDP to be applied to both the physical robot, as well as its program.

In the revised methodology, the teachers decided that sending entire Lego EV3 kits to student's houses would lead to the potential loss of too many robots, or their parts. Therefore, a simple Lego rover was built by the teachers and sent home. In addition, spare parts to attach the touch sensor and infrared sensor were also sent to students. The teachers wrote 12 challenges involving the rover and the spare parts. This allowed the students to go through the EDP in their codes, but not in the physical robots.

The decision to move from a mixed-method study to a case study was based on a number of factors. One of which was the effect the small sample size would have on the quantitative data. This study met the important characteristics that define a case study. The first was that it focused on an individual program (Hancock & Algozzine, 2017; Yin 2018). Second, the program being researched was held in its natural setting, as allowed by the COVID-19 pandemic (Hancock & Algozzine, 2017). It was bound by the geography of the school and the fall semester term. Finally, sources of information came from multiple sources (Hancock &

Algozzine; Yin, 2018). This included direct observation of students, weekly teacher meetings, and continuing the use of the S-STEM survey.

In the first phase of the study, data regarding student STEM attitudes were collected from eight participants at a public elementary school, using the S-STEM survey on September 22 and 23, prior to their participation in the robotics-enrichment program. Because of the COVID-19 pandemic, students participated in this program through distance learning that integrated Zoom and Google Classroom. In the past, students worked in groups of four per robot, but in this case all participants received their own robots, and they were not able to work in face-to-face groups. In the second phase, students received 5 weeks of daily robotics education in which students completed work in The Hour of Code and challenges in robotics programming. After completing student participation in the enrichment program, students retook the S-STEM survey on October 19 and 20. During, and following, the treatment, the researcher took field notes about the experiences of the students. After every week of instruction, the researcher held a community of practice meeting with various co-sponsors of the program to debrief and to plan. The community of practice has been a regular practice of the robotics club sponsors for the past 2 years. After all 20 hours of instruction took place, the researcher held semi-structured interviews with the other co-sponsors, and held a final community of practice meeting. The community of practice meetings served as focus groups, and the data were analyzed and organized so as to allow the researcher to give a detailed description of the school's robotics club and the impact, if any, it had on student attitudes towards STEM.

This chapter provides a description of the methods and procedures that were employed to address the above-mentioned purpose, and the question listed below. This chapter begins with the research question, followed by explaining the research design and the theoretical framework.

It then introduces the setting, curriculum and participants, and discusses the instrumentation to be used. Lastly, it reviews the data collection and storage, and finally discusses the researcher's background and biases.

Research Question

This study sought to determine if a robotics enrichment program would influence underrepresented minorities and females to pursue the STEM fields. In order to focus this study, the researcher sought to answer the following research questions:

- RQ1: What impact, if any, does a robotics enrichment program have on elementary school students' attitudes towards STEM at a predominantly Latinx inner-city elementary school located in Orange County, California?
- RQ2: What 21st century job skills, if any, do students develop in a robotics education program?
- RQ3: What impact, if any, does a robotics education program have on female, English Learners and GATE students?

Research Design

This is an explanatory, non-experimental, problem-based case study. It was explanatory because it sought to explain the cause-and-effect relationship between building self-efficacy in the STEM fields and students pursuing the STEM fields (Hancock & Algozzine, 2017; Yin, 2018). As is the case for all case studies, it is bound by its location at the subject school, and by time, as the research was completed between the start of the school year and the end of the first quarter of the school year (Hancock & Algozzine, 2017). This study took place in as natural a setting as the COVID-19 pandemic induced distance learning allowed. The study was non-experimental because the variables were not manipulated by the researcher, and students were

accepted on a first-come, first-served basis, based on the number of available and working robots. In addition, it did not split students into two randomized groups in which one group was a control group and the other was an experimental group (Clark & Ivankova, 2016; Creswell & Gutterman, 2019). This study primarily dealt with the problem of improving student attitudes towards, and likelihood to engage in, the STEM fields, making this an applied, or problem-based, research project (Hanckock & Algozzine, 2017).

Access to the research setting is one of the most important factors in conducting the research (Hanckock & Algozzine, 2017). The researcher was able to gain this access due to previous association with the robotics club at the subject school, through gaining permission from the subject district's research and evaluation department and through the university Institutional Review Board (IRB) approval. The researcher, and the other teachers involved in the program, had a pre-existing relationship with the school and community in this study, allowing them to have already built relationships with the students involved.

The study began by using the S-STEM survey as pre-treatment data instrument. The researcher then used follow up interviews and community of practice (CoP) meetings with robotics club sponsors to help form a detailed and complete description of the robotics education program, and its effects of student attitudes towards STEM fields. The case study format mirrors the researcher's belief that student information cannot be deeply understood through quantitative data alone. Therefore, this study employed a case study design, in which quantitative data and qualitative data are combined to give a rich description of this case (Creswell, 2014). Quantitative data were collected first, using the S-STEM survey. Following the initial survey, students received 20 hours of robotics instruction, over a four-week period, using the Lego Mindstorms. Because of the COVID-19 pandemic, this was done through distance learning

employing Zoom and Google Classroom, thus creating a strict limit of eight participants, the number of functional robots that were working and available, while saving one additional robot to use for demonstration purposes.

During the instruction period, the researcher kept field notes about significant actions and expressions that were observed through distance learning. The researcher decided to observe the setting by watching and looking for evidence of students either becoming excited about the STEM fields, or being turned away from the STEM fields. In addition, the researcher would look for the 21st century job skills of communication, collaboration, critical thinking, and creativity. Having the focus to look for these topics allowed the researcher to look for answers to the research question. In addition, it has been the club's sponsors' practice to engage in a community of practice discussion every week, or after approximately 4 hours, of instruction to debrief and plan the next lessons. This year, the robotics club had four total co-sponsors, including the researcher. The researcher met with each co-sponsor once each, and had a final community of practice meeting following the final class meeting. The community of practice meeting, as well as individual meetings, served as focus group meetings and were recorded, analyzed and reported. Finally, students were given a post-treatment S-STEM survey, which was analyzed and compared to the pre-treatment data. The researcher gleaned information from the interviews and communities of practice/focus groups by taking immediate notes about them, which were coded and recorded for analysis. The data went through an open coding process in which the researcher will search for important commonalities. This data were re-coded, with the researcher looking for common themes. These themes were then categorized in such a way as to give insight into how the data revealed the impact of the robotics program.

In order to reduce the effect of the researcher's biases, the researcher used triangulation of data. This was done through a number of steps. One of these was to give a summary of the findings to the other teachers involved in the study. This allowed them to corroborate the findings and increase the study's validity (Gibbert & Ruigrok, 2010). In addition, the researcher related the findings of this study to other literature, further enhancing the study's reliability (Hanckock & Algozzine, 2017). The researcher decided to keep the S-STEM survey in the study to help give other data points to triangulate data.

Finally, the data were reported in a richly descriptive case study. While not a traditional mixed methods study, this case study may be a conduit towards educational equity, that would not otherwise be found in a quantitative study. The search for social justice is at the heart of mixed-method research (Mertens, 2012), and this study sought to inform policy that would attract more females and minorities to the STEM fields. While not maintaining the original mixed-methods design, the case study design did allow for the original goal of social justice. This framework examined the personal, interpersonal, organizational, community and social relationships that impacted this system (Clark & Ivankova, 2016). Through the mixing of quantitative and qualitative data, the researcher sought to create a rich and detailed description of the robotics club and its impact on students (Timans et al., 2019) and help to promote meaningful innovation in education (Stahl et al., 2019).

Theoretical Framework

The theoretical framework employed in this study was that working within a student's zone of proximal development (ZPD) allows a child to build self-efficacy regarding the engineering field in general, and robotics in particular. The ZPD is characterized as the area between what an individual can do independently and what that same individual can do while

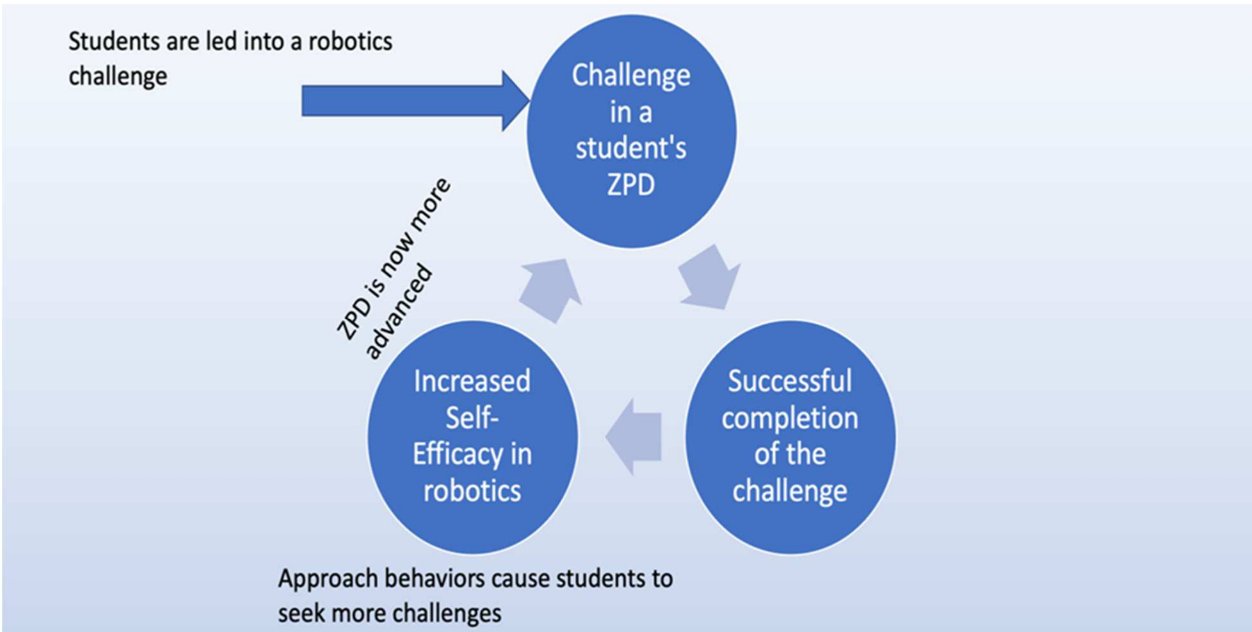
assisted by a more knowledgeable other (Eun, 2019; Vasile, 2011). The student then assists himself or herself through either spoken or inner dialogue to solve the problem (Vasile, 2011). This is to say that students learn best when they have enough knowledge to understand almost completely something or to complete a task. Because the knowledge or task are nearly attainable, the student only needs a slight push, or support, from the teacher, or any other more knowledgeable person, to complete the task independently and to complete the learning. It is in this zone that students internalize knowledge and create new skills (Eun, 2019). In addition, the ZPD has been studied for students using math tools for fractions and the researcher believes that the use of robotics as a tool for mathematical discourse compares favorably to using robotics to facilitate learning in the ZPD (Abtahi, 2018). Using the ZPD to improve self-efficacy is significant because students are able to successfully complete a previously unattainable task while working slightly below the frustration level (Bandura, 1997). The model of building self-efficacy in this study is illustrated in Figure 1. In this Figure, one can see the feedback loop of students completing challenges in their ZPD can build approach behaviors towards STEM fields. This loop continues to build self-efficacy and capacity in the STEM fields.

In order to assist the building of self-efficacy, students in the program had instructors from the subject school who are of similar ethnic backgrounds to them and who are bilingual in both English and Spanish. In addition, students were recruited from two of the co-sponsors classes; including the researcher's (see Figure 1). There was also a conscious effort to have multiple female teachers as sponsors. This provided students with role models with whom they are familiar. While the instructors are not professionals in proper STEM fields, they are STEM teachers and can help provide the motivation and inspiration for students to pursue STEM fields. The use of mentors has proven to be successful in both the professional, university and high

school setting to attract and retain a diverse population in STEM fields (Dasgupta & Stout, 2014; ; Hernandez et al., 2017; Hutton, 2019).

Figure 1

Feedback Loop of Building Behaviors Through Self-Efficacy



Setting

This study took place in the fall of 2020, in the midst of the COVID-19 pandemic, which undoubtedly has had significant social and educational consequences for many students (Herold, 2020; Mordechay, 2020b). It was also following a summer of social unrest caused by the killings of George Floyd, Breonna Taylor, and the unmasking of years of social inequity caused by racial inequality and in the middle of a contentious Presidential election. The school has been employing distance learning since March 13, 2020, and has no plans to return to on-campus classes until at least April 2021 (Press Release, Jerry Almandarez). The subject school is a public elementary K-5 school in Santa Ana, located in Orange County, California. Santa Ana is located 15 minutes south of Disneyland off Interstate 5 and sits on 27.27 square miles. It is the center of

government for Orange County, housing the Ronald Reagan Federal Building, the Orange County Superior Court, and numerous historical homes. According to the United States Census (2019), there are 332,318 residents living in the city, of which 7.4% are under 5 years old and 26.9% are under 18. 76.8% of students identify themselves as Hispanic. Over half of the residents are renters and 81.4% of residents report speaking a language other than English at home. For residents age 25 and older, 59.6% have a high school diploma, and 15.0% hold a bachelor's degree or higher. 15.7% of the population lives in poverty.

The neighborhood around the subject school is home to the Boys and Girls Club of Santa Ana, named the Joe McPherson Center for Opportunity. The Boys and Girls Club houses a Teen Center, a full basketball court, as well as a technology hub and available tutoring. There is a park with a public swimming pool within two miles one direction, and a park with basketball courts within one mile the other direction. Unfortunately, the proximity to the county jail and county government offices leaves the second park with a large homeless population. This park is also a receiving ground for recently released inmates. The 2010 Census revealed that the area has 65,445 residents, with a median age of 31.5. Of these residents, only 49% of those old enough to graduate have received a high school diploma. The median household income is $52,970, with 22.4% of the population living below the poverty line.

During the 2019-2020 academic year, the subject school educated pre-kindergarten students through fifth grade. Data for the 2020-2021 school year are not yet available. It has both a Spanish/English Dual Language Academy and a Structured English Immersion (SEI) program, nine of the classes offer SEI curriculum, while 16 offered the dual language curriculum. There three other classes, one a K-1, a 2-3 and a 4-5 that offer a special curriculum for mild/moderate special education students with autism. The subject school enrolled 709

students, of whom 91% received free lunch. 98.7% of students identified as Latinx. African-Americans, American Indians and Asians each comprised 0.3% of the population (California Department of Education, 2019). The population also had 46 special education students who were educated in a full inclusion model, and 26 gifted and talented education students. 73.1% of students were identified as English Learners (California School Dashboard, 2020). As for the staff, out of 31 credentialled Pre-K thru fifth-grade teachers, 27 self-identified as Latinx, with both administrators also self-identifying as Latinx. In addition, of these 32 faculty members, including the principal, one identifies as bilingual in English and Arabic, 28 identify as bilingual in English and Spanish, and the remaining three identifying as having limited Spanish proficiency but fluent English proficiency. Furthermore, all four members of the office staff, the community worker, six activity supervisors and three out of four cafeteria workers were fluent in Spanish. Five of six of the instructional assistants self-identified as bilingual in English and Spanish, with the remaining one identifying as English only.

The subject school has offered a Robotics Club and Robotics Summer Enrichment program for the last 5 years that has been run by teachers who hold a multiple subject clear credentials as both an after-school program one to two days per week and an 80-hour summer enrichment program. These teachers have investigated robotics education independently, without formal training. They have engaged in a community of practice (COP) every 2 weeks during the robotics program to debrief on past meetings and to plan future meetings. The robotics programs have used Ozobots, Dash and Dots, Sphero, Vex Robots and Lego Mindstorms. Lego Mindstorms are the most widely used in the program. While the 90 Ozobots represent the most numerous robots at the school, The Lego Mindstorms are able to support 30 students working in groups of three to four. The robotics club sponsors include: the researcher, who is a male, fifth-

grade structured English immersion bilingual Spanish-English Filipino-American teacher; a female fifth-grade, dual language, bilingual Spanish-English Latinx teacher who taught third grade the year before; a female Mild/Moderate special education, bilingual Spanish-English Latinx teacher who attended the subject school as a child; and a female, kindergarten, dual language, bilingual Spanish-English Latinx teacher who was recently transferred to another school and is able to participate through the Zoom platform.

Currently, the administration at the subject school is attempting to rebrand the school to be a Science, Technology, Engineering, Arts and Mathematics (STEAM) focused school that also has a Dual Language Academy. To this end, the school opened a Maker Space prior to the previous school year. A Maker Space is a room dedicated to allowing students to have the tools and materials to engineer objects of their own design. At the subject school this room also houses the school's robotics program. The school has hosted Family Math Nights, Family Robotics Nights and a Family Art Night over the past three years. While this has been the beginning to becoming a STEM focused school, the change to becoming a STEAM Dual Language Academy, admittedly, has been slowed by the COVID-19 pandemic.

With this backdrop of a large Latinx population, coupled with the 91% of student enrollment comprised of the socioeconomically disadvantaged (California School Dashboard, 2020), the importance of this study should be underscored for a number of reasons. First, engaging the subject school's students with early access to STEM education may encourage students to enter into STEM fields and help increase the number of Latinx in the STEM workforce. Furthermore, by 2030, conservative estimates state that 33% of jobs may be eliminated through automation. This is especially true in the fields of food preparation and retail operations, which are overrepresented by the Latinx population (Lund et al., 2019). One potential

solution is to train students to be prepared for the 21st century workforce. The demand for technical skills is accelerating, as well as the demand for creativity, critical thinking, and complex processing (Bughin et al., 2019). All of the previously mentioned skills can be developed through STEM education.

Curriculum

The name of the enrichment program to be used is Robotics and Coding. It met for one hour daily, after school, 5 days per week, for four weeks. The robotics part of this curriculum focused on using the Lego Mindstorm robots. Students were given pre-built rover robots that they could program as part of the engineering process. According to the Next Generation Science Standards (NGSS, 2019), the engineering process involves defining a simple problem that reflects a need or want that has specific criteria for success and specific limitations in time, space, materials and cost. One may seek to continuously improve the solution, thus making better products periodically, or choose that a particular solution does not need further enhancement because the solution to the original problem is adequately met. The problems defined were given to students as a series of 12 challenges that began with having the robot moving one meter and stopping and finished with students moving to an object one meter from the starting spot, capturing the object with the robot's mechanical arm and moving the item 10 cm to another spot. In previous enrichment programs at this school, students have built and programmed Lego Mindstorm robots to fold t-shirts, frost cookies and to dump trash. In this year's iteration of the program, the teachers-built robots as a rover, with an articulating arm. It was decided that sending home complete kits would result in the loss of too many loose parts.

The Lego Mindstorms were used because they are the most researched commercially available educational robot on the market. A peer reviewed literature review found that a full

66% of peer reviewed studies about the teaching of robotics cited Lego Mindstorms as the robot used (Xia & Zhong, 2018). Lego Mindstorms is popular amongst educators for a number of reasons, including outstanding customer support, brand familiarity and high-profile competitions. The subject school uses Lego Mindstorms because of the connectivity to existing hardware, the number of Lego Mindstorms already in possession due to previous grants, and the program instructors' familiarity with these robots.

The learning objective in the initial lesson was to define coding. For the purposes of this study, coding was defined as the use of a set of directions to perform a particular task. In order to illustrate this, students used block coding in the Hour of Code website. Block coding is a method of programming that uses preprogrammed blocks that students can modify for their purposes. The self-guided website, The Hour of Code, in which students participated in Course D was used to practice coding (https://hourofcode.com/us/learn). This program has become popular with students and teachers because of the ease of use and game-like interface and has been used to help build self-confidence in problem-solving strategies (Kalelioğlu, 2015). The Hour of Code students to learn and practice the basics of block coding. For example, a block may be a motor block in which the student inputs the duration that the motor is to run, along with the amount of power the motor is to exert. The block code used in Course D teaches topics such as debugging, directional movement and programming loops through the use of puzzles. Puzzles included helping a farmer clear a plot of land, fill holes, a pirate collecting flags on a tennis court and designing patterns on a grid. All of the skills learned in this course were translatable to the Lego Mindstorm programs. Upon completion of this module, students were allowed to discuss what went well, what was troubling and what surprises they had. Admittedly, the conversation in Zoom was mostly done in the chat. The teachers reinforced the idea that students did not

necessarily know how to complete all of the puzzles previous to this activity, but were now able to do so. The teachers also tied the idea of coding to STEM careers, and discussed potential jobs related to coding.

Figure 2
Photo by Kevin Obillo
Pre-Built Rover

The next phase of the enrichment program involved a pre-built rover (see Figure 2) that included an arm that can be raised and lowered. In addition, students were given a touch sensor and connection cables to be able to further expand the robot. Students were instructed on what each of the motors could do, and the basics of how to use the Lego program and import the program into the Lego Mindstorm brick, or robotic brain, to be run. Students were given the task to discover how to connect the robots to their chromebooks via Bluetooth, which they eagerly did and shared with one another. Students were then given 12 challenges that they moved through at their own pace. At the start of each class meeting, students reported on which challenge they were working, and students were allowed to ask each other how they were able to

complete each challenge. Students were then given time to work on their challenges, with the club sponsors observing and offering help as needed. These activities were challenging, but not impossible for students to complete Students received immediate feedback of success or failure by watching their robot run the program, allowing students to act as engineers and building self-efficacy in programing the educational robots.

The next step was to go over the Engineering Design Process. It is here that students were consistently called engineers, as they designed a robotics program that fulfilled the objectives of each challenge. As students moved through the challenges, they saw that they were able to build on previous knowledge gained from each challenge, allowing students to work in their ZPD and build self-efficacy.

Participants

Prior to selecting participants, the researcher familiarized himself with the District's board policy regarding research in the school and also interviewed the Director of Research and Evaluation. This interview allowed the researcher to successfully apply for, and gain, approval for this project to take place in the District and the subject school (see Appendix A). Students were recruited out of two fifth-grade classrooms, both taught by robotics club sponsors, at the subject elementary school on a volunteer basis. They were incentivized by the promise of raffle tickets being issued to students for every class they attended, and for participating in the surveys. The prizes for this raffle were ten $10 gift cards to Target, to be raffled at the end of the study. Students were enrolled in the enrichment program in the order that applications were received until eight students were enrolled. There were always two sponsor teachers in each class, one male and one female, to try to ensure that the models for each gender were represented. This was important to allow the females in the class to feel valued and feel more allowed to participate in

the class. In addition, each instructor was bilingual in English and Spanish, allowing students to see that their culture is valued. Furthermore, each of the instructors involved has previous experience in both sponsoring a robotics club and teaching a robotics enrichment. Having experienced teachers, of both genders, who are bilingual in the school's dominant languages, ensures that many of the obstacles to entering the STEM fields faced by Latinx students can be mitigated. In addition, all of these factors should help isolate the enrichment curriculum itself as a variable in the effect on STEM attitudes.

Human Subjects Consideration

Working with minors requires extra considerations to ensure their safety and privacy. Pepperdine University's Institutional Review Board (IRB) has set up procedures to help ensure both safety and privacy. In addition, the cooperating school district has procedures and permissions put forth by the Research and Evaluation department that must be adhered to before gaining Board approval. Parental consent forms (see Appendix B and Appendix C) to collect data will be passed out, and it will be made clear that students will not be excluded from the enrichment activities if the parent elects that their child will not participate in the study. Parental consent was collected either through electronic means, or through traditional mail to accommodate for distance learning. Furthermore, parents were informed that any data collected would keep anonymously so as not to reveal the students' identities. Parents were also be assured about the nature of the study, its duration both in length of program and time of day, anonymity, voluntary participation, and potential benefits. All of this information was provided in both English and Spanish, and included the researcher's contact information so as to answer any questions. The co-sponsors of the robotics education program agreed that the weekly COP

meetings could be recorded and used to collect data. In addition, the researcher took field notes after every class session.

Instrumentation

The pre- and post- treatment measurement device is the Measure of Student Attitudes Toward Science, Technology, Engineering, and Math, sometimes knows as the S-STEM survey, (2015) created by Unfried, Faber, Stanhope, and Wiebe. The S-STEM survey has also been used successfully in Ke and Carafano's (2016) study, in which the impact of a flight simulator on student attitudes towards STEM fields was investigated. The survey is a 37-item test that measures both attitude towards STEM fields and career interest in STEM. The attitude section measures items on a 5-point Likert-type response scale, ranging from strongly disagree to strongly agree. Items measuring career interest are measured on a 4-point scale, ranging from not at all interested to very interested.

There are two versions of the survey, one for upper elementary students (Grades 4-5) and one for Grades 6-12. For the purposes of this study, the focus will be on the upper elementary version of the study. The survey itself was piloted for upper elementary students by surveying 4,232 students, with 768 results being used with 50.2% self-reporting as male and 9.8% self-reporting as Hispanic or Latinx (Unfried et al., 2015). Using Chronbach's alpha (.83-.87), the Measure of Student Attitudes Toward Science, Technology, Engineering, and Math is found to have a sufficient amount of reliability in the upper elementary grades. In addition, the upper elementary scale was found to have little variance between fourth and fifth grade responses (Unfried et al., 2015). However, the author does report the possibility of selection bias in those who take this survey, and this may be the case in this project also, as the students who volunteer to be involved in the enrichment program may already have a predisposition to STEM fields.

Data Collection and Management

Data collection took place before the beginning of the 20 hours of enrichment instruction, which was held in a virtual Zoom classroom, as dictated by Pepperdine IRB, Centers for Disease Control and the subject district's COVID-19 safety protocols (see Appendix D). The S-STEM survey was put on Google Forms by the researcher, which was then pushed out on Google Classroom. Students were given time during the first enrichment meeting to complete the survey. Data were collected through Google Forms onto Google Sheets, where it will be saved as pre-test data. Students used an anonymous identification number to differentiate respondents and each question was read to the group, with questions and answers fully explained, as needed. The S-STEM survey was translated into Spanish using the expert committee method of translation. The expert committee method uses translators who are experts in both the original language and the target language (Epstein et al., 2015). The expert committee consisted of two dual-language immersion teachers from the subject school and a person trained, and certified, in translation by the County of Orange. The expert committee approach is considered to be an improvement on the back-translation approach due to its increased accuracy and efficiency (Behr, 2017; Epstein et al., 2015). Following the 20-hour enrichment activities, the researcher again pushed out the S-STEM Survey through Google Classroom. Each student again took the S-STEM survey as a post-test during the final meeting of the enrichment class, with data being saved to Google Sheets, through Google Forms. All data from both surveys were then downloaded onto a flash drive and deleted off the Google Drive. The flash drive was then stored in a locked fire box in the researcher's home. The researcher analyzed the results using IBM SPSS for Windows (Version 2.7).

Concurrently with the robotics instruction, the researcher took field notes about the day's class. On a weekly basis, the co-sponsors engaged in a COP meeting, form which more data were collected. Questions that were asked during the COP meetings included the following: What difference did you see in the way students problem solved? Did you see any difference in student belief that they could solve problems? Did you see any difference in the way students saw themselves in regards to coding the robots? Did you notice a difference in the way the females in the group approached this subject? The GATE students? The English learners? What impact do you think the instruction is making in student abilities?

The COP meetings were held via Zoom, which were recorded as MP4 files and transcribed into a Word document through rev.com audio to text transcription services. The teacher's names on these files were converted to pseudonyms to protect their identities. These files were then entered into Hyper Research, with each teacher being a listed as a code. While analyzing the teacher generated data, the researcher recognized a number of descriptive codes. Some of these descriptive codes included critical thinking, motivation, females in STEM and self-efficacy. Just as with student data, the teacher centered codes were analyzed in an elaborative coding process the elaborative coding process was selected to allow the researcher to corroborate research by previous researchers (Saldaña, 2016). The coded data was used to illustrate the theoretical frameworks of 21st century job skills, female role models and self-efficacy.

Recruitment for the study began in the sixth week of school; parental information meetings and distributing and collecting consent forms took place by the seventh week of school, and the 20 hours of instruction will take place in weeks eight thru 12 of the school year.

Chapter 4: Results

This chapter contains the results of the inferential, non-experimental, problem based qualitative case study. This study sought to determine if a robotics enrichment program will influence underrepresented minorities and females to pursue the STEM fields. In order to focus this study the researcher seeks to answer the following research questions:

- RQ1: What impact, if any, does a robotics enrichment program have on elementary school students' attitudes towards STEM at a predominantly Latinx inner-city elementary school located in Orange County, California?
- RQ2: What 21st century job skills, if any, do students develop in a robotics education program?
- RQ3: What impact, if any, does a robotics education program have on female, English Learners and GATE students?

The purpose of this inferential, non-experimental, problem based qualitative case study was to examine the impact, if any, that a robotics enrichment program had on students' attitudes towards STEM fields had at a predominantly Latinx inner-city elementary school. It employs pre- and post-treatment data from the S-STEM survey, quotes from participants, and notes from COP meetings. These data points are used to illustrate the robotics education program being studied (Hancock & Algozzine, 2017). The internal credibility of the results was protected through careful examination of the way the data was collected. This includes ensuring that descriptive validity of the data remained factual (Onwuegbuzie & Leech, 2006). The observational data about students were based on what was said and done, with quotations being taken as accurately as possible. In addition, the researcher was cognizant of researcher and confirmation bias when analyzing the data. The purpose of being aware of these biases was to

ensure that internal legitimacy was not threatened by the researcher's prior experiences or expectations with robotics education (Onwuegbuzie & Leech, 2006). Furthermore, the legitimacy of the data was made more trustworthy through triangulation. In triangulation of data, multiple and different methods of collecting data are employed. In this case, data were collected from persistent observations of what students said, COP meetings amongst the teachers, and from the S-STEM survey results.

Table 1 displays the frequency counts for the demographic variables. Table 2 displays the psychometric characteristics for the 10 scale scores. To answer the research question, Table 3 displays the Wilcoxon matched pairs test comparing the five scale scores at pretest and then again at posttest.

Descriptive Statistics

Table 1 displays the frequency counts of selected variables. The eight students who participated in this study were all fifth graders. The study was limited to eight students to satisfy COVID-19 safety protocols, and IRB requirements, in which students were learning from home, and were not to share materials. There were nine total robots available, so the program's teachers made the decision that each student participating in the robotics program should have a robot at home, and the teachers should have a robot with which to model. Nearly two thirds (62.5%) of the participants were male, while the remaining (37.5%) were females. The student enrollment in this study was evenly split between GATE students (50.0%) and general education students (50.0%). Three fourths (75.0%) were enrolled in a Structured English Immersion (SEI) class and one fourth (25.0%) were enrolled in a Dual Language Spanish/English program. Of these students, one (12.5%) was of Filipino descent, with the remaining seven, (87.5%) being of Latinx descent (see Table 1).

Table 1

Frequency Counts for Demographic Variables of Students

Variable	Category	*n*	%
Gender			
	Male	5	62.5
	Female	3	37.5
GATE Status			
	Yes	4	50.0
	No	4	50.0
English Level			
	English Only	2	25.0
	English Learner	1	12.5
	Redesignated FEP	5	62.5
Dual SEI			
	Dual	2	25.0
	Structured English Immersion	6	75.0

Note. $N = 8$.

Table 2

Psychometric Characteristics for the Scale Score

Scale Score	Items	*M*	*SD*	Low	High	*α*
Pre-Treatment Math	8	3.53	0.83	2.25	4.75	.92
Pre-Treatment Science	9	3.74	0.60	3.00	4.67	.89
Pre-Treatment Engineering and Technology	9	3.99	0.34	3.56	4.44	.72
Pre-Treatment 21st Century Skills	11	3.91	0.54	2.82	4.36	.92
Pre-Treatment Total	37	3.80	0.37	3.32	4.30	.89
Post-Treatment Math	8	3.56	1.14	1.13	4.75	.97
Post-Treatment Science	9	3.90	0.65	3.11	4.78	.87
Post-Treatment Engineering and Technology	9	4.26	0.82	2.78	5.00	.95
Post-Treatment 21st Century Skills	11	4.08	0.88	2.73	5.00	.93
Post-Treatment Total	37	3.97	0.79	2.49	4.73	.98

Note. $N = 8$.

Table 2 displays the psychometric characteristics for the 10 scale scores. Cronbach alpha reliability coefficients ranged in size from α = .72 to α = .98 with the median sized coefficient being α = .92. This suggested that all scales had adequate levels of internal reliability (Colman & Pulford, 2008; Field, 2013).

Table 3 displays the frequency counts of selected variables of the program's teachers. There were four teachers who participated in this study, and all have previously taught in robotics education programs at the subject school. One fourth (25.0%) of the participants were male, while the remaining three (75.0%) were females. The ethnic background of these teachers was one fourth (25.0%) male, and three fourths (75.0%) female. One fourth (25.0%) taught in a dual language Spanish/English program, and one fourth (25.0%) taught Mild/Moderate Special Education, and the last two (50.0%) taught in the Structured English Immersion (SEI) program. All four teachers self-report as being bilingual in English and Spanish.

Table 3

Frequency Counts for Demographic Variables of Teachers

Variable	Category	*n*	%
Gender			
	Male	1	25.0
	Female	3	75.0
Ethnicity			
	Latinx	3	75.0
	Filipinx	1	25.0
Program Taught			
	Dual Language	1	25.0
	SEI	2	50.0
	Mild/Moderate Special Education	1	25.0

Note. $N = 4$.

Answering the Research Question

The following question was considered: What impact, if any, does a robotics enrichment program have on an Orange County, California elementary school students' attitudes towards STEM fields in a predominantly Latinx inner-city elementary school? The null hypothesis was that students participating in the robotics enrichment program would show no significant difference in their attitudes towards STEM careers and majors. The alternative hypothesis was that students participating in a robotics enrichment program would show a significantly more positive view regarding STEM careers and majors.

To answer this question, Table 3 displays the Wilcoxon matched pairs tests for the five scale scores. Wilcoxon tests were used instead of the more common paired *t* test due to the sample size ($N = 8$). Inspection of the table found none of the five tests to be significant at the $p < .05$ level. These findings provided support to retain the null hypothesis (see Table 4).

Table 4

Wilcoxon Matched Pairs Tests for Selected Scale Scores

Scale Score	Time	*n*	*M*	*SD*	*z*	*p*
Math Score					1.19	.23
	Pretest	8	3.53	0.83		
	Posttest	8	3.56	1.14		
Science Score					1.34	.18
	Pretest	8	3.74	0.60		
	Posttest	8	3.90	0.65		
Engineering and Technology					1.36	.18
	Pretest	8	3.99	0.34		
	Posttest	8	4.26	0.82		
21st Century Skills					1.41	.16
	Pretest	8	3.91	0.54		
	Posttest	8	4.08	0.88		
Total Score					1.40	.16
	Pretest	8	3.80	0.37		
	Posttest	8	3.97	0.79		

Note. $N = 8$.

Qualitative data were collected throughout the study. Students began each of 20 class sessions which were held over a four-week period, with a five-minute introduction. During the introduction students were asked which challenge they would be working on. They could also request help from their peers or from the teachers. Following the introductions, students were allowed to work on their challenges during the final ten minutes of each session students were asked to reflect on either the day's work or discuss how they felt the day's work would help their future. The use of multiple observations over time allowed the researcher to obtain a deep understanding of the individuals in the study. Field notes about student interactions were taken as close to the end of class as possible by the researcher following class meetings so as to eliminate errors and omission of information (Creswell & Gutterman, 2019).

Due to the COVID-19 pandemic, and district and CDC guidelines, all classes were held via Zoom. Many of the students chose not to work with their cameras or microphones on during the Zoom classes, so most of the notes were taken during the initial check-in or during each session's debriefing conversation at the end of class. This potentially affected the study because it was much more difficult to observe student interactions with each other, and with their robots, during the enrichment meetings.

Field notes were taken in a notebook and were later transcribed by hand into a Microsoft Word document. It was during this initial hand transcription that first cycle coding took place. Attribute coding was used to describe the demographic information of the speaker for any codes the researcher transcribed, thus allowing the researcher to remove the student names from the notes. Attribute coding had the added advantage of allowing the initial data to be attached to subgroups for analysis and interpretation (Saldaña, 2016). Next, the text was entered into Hyper Research. Hyper Research is a qualitative data management system, in which the researcher

creates cases and codes. The cases and codes are used to organize data and allow the researcher to manipulate the data into groupings that are more easily read and interpreted. Each student was considered a case. While reading through the data in Word, different descriptive codes emerged, and these were created as codes within Hyper Research. Descriptive coding was selected for its ease of use when identifying a topic (Saldaña, 2016). These descriptive codes included such topics as self-efficacy, collaboration, excitement for STEM, and sense of accomplishment, among others. These codes were meant to reveal insight into the students' thinking and emotions during the program (Saldaña, 2016). Finally, the student qualitative data were analyzed in an elaborative coding process to develop the information relative to the theories of self-efficacy and 21st century job skills.

Qualitative data from the teachers were collected during weekly COP meetings. These meetings were held at the end of the week to discuss the week's observations, and included the researcher, as well as the teachers who were involved in instruction that week. These meetings were held via Zoom, which were recorded as MP4 files and transcribed into a Word document through rev.com audio to text transcription services. The teacher's names on these files were converted to pseudonyms to protect their identities. These files were then entered into Hyper Research, with each teacher being a listed as a code. While analyzing the teacher generated data, the researcher recognized a number of descriptive codes. Some of these descriptive codes included critical thinking, motivation, females in STEM and self-efficacy. Just as with student data, the teacher centered codes were analyzed in an elaborative coding process the elaborative coding process was selected to allow the researcher to corroborate research by previous researchers (Saldaña, 2016). The coded data was used to illustrate the theoretical frameworks of 21st century job skills, female role models and self-efficacy.

Data and Analysis

Student Centered Codes

There are five student-centered codes related to students' attitudes towards entering STEM fields and the factors that influence these attitudes. Each code also has filters for the student sample as a whole, the study's GATE participants, the study's female participants and the single EL student.

21st Century Job Skills

During qualitative analysis, all student mentions of any of the "Four C" skills, or the application of these skills were coded as a 21st century job skills, and then coded again to fit into the job skill illustrated by the notes. However, the skill of communication was found to be more clearly observed by the teachers and was thus coded in the teacher centered codes. In addition, creativity was not a skill explicitly used during the program, and thus did not appear in any codes.

Collaboration. There were a number of students who expressed or demonstrated collaboration during the robotics education enrichment. An example of student collaboration is when Student 1 worked with Student 4 to problem solve why a motor was not running.

In this exchange Student 1 said, "Check your connections to the brick. Did it make a click sound like this?" Student 1 plugged the cable into the brick, making a click sound. "No? Then it was not clicked in all the way. Now try it. It works now? Good." Student 1 further expressed how much enjoyment was received through collaboration by stating, "The most important thing I learned would be working with others and how fun it can be experiencing more new things. I enjoyed helping others."

Another student realized that she benefitted from collaborating with her classmates. During a debriefing session at the end of class, Student 7 expressed, “I feel I got better [at robotics] because I did a lot of challenges and I got a lot of help from my class.” Student 7 also expressed, “I was trying to do a rectangle today and someone help(ed) me by showing their program to help me with my programming.”

At times, the teachers had to moderate the collaboration, with the students contributing in the chat. The following is a restatement of the collaboration that took place after Student 8 completed the fifth challenge, in which the robot was to touch a wall and stop. The researcher was restating the collaboration that took place, while the students were responding in the chat:

> Student 8, are you there? Actually, Student 2 helped him. What do you mean you need it to change from three to one? Can you tell them what you mean by that? The cables, so in other words, his cable was plugged into three and the computer was reading one. So he actually had to move his cable from three to one to make it work because when it was touching the wall, it just kept spinning and spinning. But by changing the cables, he was able to get it to work. So that was awesome to see and Student 2 actually troubleshot that for him and they were able to figure it out together.

Communication. The students’ method of communication evolved over the course of the enrichment program. During the first few meetings, students communicated almost exclusively through the chat feature of Zoom. Because these observations were made by the researcher and co-teachers, communication will be further examined in the teacher centered codes.

Critical Thinking. Critical thinking, otherwise known as problem solving, was a skill that students were aware they were developing. One student's reaction to problem solving illustrated how problem solving in the ZPD made critical thinking a skill that could be mastered. Challenge Two is one step past Challenge One. Challenge One has a student program the robot to travel one meter and stop, while the second challenge is to program the robot to travel one meter and return to the start, to which Student 5 said, "It made it easier because I just had to put the same code again but instead make it go backwards."

After completing the second challenge Student 1 asked the question, "I got it to go one meter and come back. Does it count if it goes backwards?"

Student 7 expressed the following about critical thinking:

> Somethings that were hard was finding the mistake in the programming and finding the bugs that will make the program work. I feel like I can be an engineer when I grow up and I think I might make money out of it. I think I have solved problems of the robots.

Creativity. Creativity was not tested in the S-STEM survey, nor were there any noted instances of creativity during the enrichment program. The nature of the survey did not allow students to create, or innovate, new designs for their robots.

Self-Efficacy (Student Perspective)

This study used self-efficacy as the theoretical framework in which students developed their intention to enter into STEM fields, whether it be short term pursuit of STEM classes in middle school, or long-term intentions of entering into a STEM career. Self-efficacy is defined as the belief that one can successfully complete tasks that are important to the individual or that certain behaviors will lead to certain outcomes (Bandura, 1997; Estrada et al., 2011).

During the debriefing sessions at the end of each meeting, 75% of students explicitly expressed positive self-efficacy in regards to both robotics and entering into the STEM fields. The lone omission was Student 6. In addition, Student 3 expressed that he would not like to enter into STEM fields in the future.

In one of the final debriefing sessions, Student 1 expressed the following about the robotics club:

> It has made me prepared and a better student by helping me work better with others, learning more new things, and being helpful when something either breaks of needs to be built. I feel more confident as a robotics engineer, I think I´ll be able to make money as an engineer.

Student 2 fairly succinctly expressed positive self-efficacy towards the STEM fields in the following statement, "I might enter a STEM field. Robotics helped me decide this because I want to see how robots work, how we can improve them and how we can fix them so, it might be a yes that I might enter a STEM field." This student further expressed, "What I feel like have gotten better at is engineering, math, technology, and computers."

Student 4 stated the belief that, "Now I am good at technology."

Student 5 was fairly definitive about his or her feelings towards STEM fields by stating:

> I think being in robotics has made me a better student because I've learned to program a robot and do hard challenges. I think it's prepared me for the future because every time I do harder and harder challenges. I found it easy moving and turning the robot and I kind of feel like an engineer now and I think I could be able to earn money as an engineer. I've gotten better at completing the challenges

> than when we first started. I have gotten better at STEM projects because in robotics club we do a lot of STEM projects.

Student 6, a female EL student, did not express anything about developing self-efficacy in the STEM fields. Overall, she demonstrated a lower overall S-STEM score on her post-treatment survey than on her pre-treatment survey.

Student 7, a female, SEI, RFEP student expressed her increased self-efficacy in the following statement:

> I think I have been getting better at programming because I did a lot of challenges and I got a lot of help from my class. I think robotics has made me better at science and technology so I think it will make a good future for me.

Student 8, a male, GATE, SEI, RFEP student demonstrated self-efficacy at various points throughout the program. For example, he expressed the determination to solve each problem as he stated, "I passed challenge 5 after 8 days of investigating." This perseverance was also reflected when he said, "I finally can connect the touch sensor." Finally, at the end of the class, when asked about how he felt about the challenges, he responded, "I feel like I have gotten better at them because I have been studying math and engineering and technology."

The most powerful in which students build self-efficacy is by having a sufficiently challenging task that an individual is able to complete successfully (Eccles & Wigfield, 2002; Fouad & Santana, 2016). This builds self-efficacy in that specific field and begins a feedback loop in which a student creates approach behaviors to that subject, in this case robotics specifically and STEM fields in general.

An example is when Student 2, upon completing a challenge exclaimed, "I am done with Challenge 4! More challenges for me!" It is worth noting that for the next class meeting, this

student had completed Challenges 5, 6, and 7 on his own after the class meeting. When reporting the completion of these challenges he stated, “I learned by doing the challenges is that programming is harder than you think, and it is pretty fun. And coding is fun.” Later in the course he expressed, “Some things I found easy was debugging programs and making the programs.”

Entering STEM Fields

Student 2 gave a fairly strong endorsement of how much the robotics education program affected his attitudes towards STEM by saying, “Robotics helped me prepare me for the future because I'm learning something that is probably going to be required to enter a STEM field and I will probably go to a STEM field.”

Student 3 had a higher average Post-Treatment mean score on the S-STEM Survey than on the Pre-Treatment Survey. However, when asked in a debriefing session about possibly entering STEM fields in the future, this student simply replied, “No.” This was not surprising, as the student attended less classes as the enrichment program progressed.

Students 4, 5, and 8 all expressed a desire to enter the STEM fields. Student 4 simply stated, “I do want to get into a STEM career.” Student 5 saw himself as kind of feeling “like an engineer now.” and that “I could be able to earn money as an engineer.” Student 8 began to see himself as a college student when he said, “I actually do want to get in a college with STEM because that will give me a pass to be an important person.”

Teacher Centered Codes

There are four teacher centered codes regarding students’ potential to enter into STEM fields. These include self-efficacy, female teachers as role models, cultural barriers and attitudes towards the STEM fields. The teacher-centered codes include the findings of the researcher and

the three teachers involved in the study. Each teacher, and the researcher, have been assigned a case number in Hyper Research to allow the code to be assigned to individuals.

Self-Efficacy (Teacher Perspective)

From a teaching standpoint, allowing students to complete work in their Zone of Proximal Development (ZPD) is one of the fastest ways to build student self-efficacy. This is because tasks in the ZPD are within the student's ability to solve with sufficient support, but sufficiently challenging to allow for a feeling of accomplishment (Eun, 2019; Vasile, 2011). To this end, challenges were designed to build on one another. For example, in Challenge 1 students were to program their robot to travel one meter and then stop. Challenge 2 built on this program by having students program the robot to traverse 1 meter, turn around and return.

Working in the ZPD was essential to the success of this program. Teacher 1 recognized this in a number of ways during the final COP meeting.

> It was just the way that you did the programs and the challenges that they all built on themselves, and they all had to explore something they didn't know, or they hadn't experienced before. So that was definitely there. And then I feel that it just worked on that growth mindset. And then you always hear the word grit, but just {difficult] enough for them to have a goal that was above their knowledge, but it was a definite reachable goal.
>
> It also kind of lends itself to GATE students, like working on your own, like giving them choices. I think, actually, that's where I need help giving them choices on what to do, or what to do to learn main menu or something like that. Do you want to do this project, or do you want to be sorry?

I think the way that you structured the club was really good with the challenges. That way all the kids were able to complete their challenge at their own pace. And then also they knew who to ask for help too. Not just us. They said, "Hey, Student 2 already did this. How did you do this?”

Teacher 2 further expressed the idea of working in the ZPD in the COP meeting during the second week of instruction by saying, “The students seem very engaged, very interested in having some kind of interactive learning experience. They seem very excited to complete the challenges and move on to something that's a little bit more challenging for them, to move.. And they're doing it independently, and they're self-motivated. I think just completing those challenges, motivates them to keep moving on.”

Teacher 2 added

The format was great for the students because they built on, on the previous challenge. So, if the student had already mastered the first one, all they had to do was just a little more to master the second one and so on. So, it was like a little step ladder. They were really great at that. I think that facilitated their learning. That “I don't know this” changed to that whole idea of “I don't know this yet,” and setting again those unanswered questions for further exploration, further growth, self-pacing, self-motivating, self-driven. It required a lot of independence, discipline, discipline to continue exploring that challenge, and then, "Okay, so I completed this one. Now, if I did this one, then I can surely move on to the next one." So, there's that building the knowledge or the process, building on their prior knowledge from the previous challenge.

Furthermore, Teacher 3 also recognized that, “the format was great for the students because they built on, on the previous challenge. So, if the student had already mastered the first one, all they

had to do was just a little more to master the second one and so on. So, it was like a little step ladder. They were really great at that. I think that facilitated their learning."

Female Teachers as Role Models

Another way in which students can develop self-efficacy is when they see others of similar backgrounds and ethnicities being successful in the field, thus allowing students to vicariously compare their successes with those who they see as successful in that field (Bandura, 1997). In the context of this study, there were three female teachers. All three are Latinx, with the remaining male teacher being Filipino. This allowed each student in the study to see someone of the same ethnic background as themselves. In addition, two of the female teachers graduated from the subject school's school district, with one of them actually being a student who attended the subject school. This gave the advisors unique perspectives on how best to reach the students. Teachers were also very intentional about pointing out that each teacher came to the program with their own strengths; hopefully highlighting that all students are also unique and that they may see their own strengths within themselves. An example is the following in which the researcher describes working with Teacher 1 to understand better how to troubleshoot one of the robots.

> See, boys and girls, I go to Teacher 1 because she's an expert on a lot of this stuff and it's her strength. We're both really smart but she's really good at not quitting. She'll work and work and work and figure it out, which makes her better at perseverance.

This also led to the following revelations from Teacher 1 about being a role model for the female students in the program.

> The fact that me, Teacher 4, Teacher 2 here, I feel like they feel like, hey, it's normal for me to be doing this. I'm not the only female here. I can do this. It's not weird. I can join in, and I can also solve all of these things. It's not just for males. So, it's completely normal for me to also want to do math and to also want to do science and do engineering." As opposed to let's say maybe when I was younger, there was mostly just male. I'm trying to think if I had any female math or science teachers. And I don't think I did, even when I went to college, they were all males.

While discussing the idea of being a role model for females entering into STEM fields at a COP meeting, Teacher 2 also expressed that times had changed, and females now had more role models to inspire them to go into STEM fields.

> It was more of a gender specific subject or general area where it was more male predominant, whereas that's shifting. So, it's currently shifting over and now you see more of the females within that's area sciences, your math. And so, I think having females, as part of the robotics, to be the instructors opens up, like you said, miss Teacher 1, opens up that door or opens up their thinking to, "Hey, it's not only for males, or it's not what maybe I had heard or what not."

Teacher 3 explained that she believed the female students at the subject school already saw themselves as equal to the male students in the STEM fields. To her, this was due to the fact that so many female teachers had already taken the lead in STEM fields, and that other female students had already participated in activities such as past Robotics Clubs and Math Field Day events. This was expressed during a COP when she said the following:

> I think at our school, there have always been a good number of girls that joined these clubs. So, I don't think it has ever been an issue where it's like, "Oh, this is just a boy

dominant club." The girls have taken on lead roles whenever we've had these. Maybe it is because we are their teachers, but I don't think so. I think like Teacher 2 said, things are changing. We are seeing more science and math teachers that are women take the lead. So maybe for our students, they don't really see that difference. Their belief is that they started at the same level as the other students in the class, the males. They were just learning what everybody else was learning. They were learning those skills. They were comfortable with the program. And they didn't feel like just because they were girls, they would not do very well. I think it helped that there were female coaches for that. And they have already seen that throughout the years of school having this program there.

Cultural Barriers

While having several female teachers to serve as role models to the female students was one of the original designs of the study, the researcher was able to recruit two teachers who grew up locally to the subject school. Teacher 1 graduated from the subject school's school district, while Teacher 2 actually attended the subject school as a child. Teacher 2 also admits that she "could have gone to school with maybe some of [the students'] parents if their parents are in their late thirties. If there're about ten, eleven years old, I mean, they could have had them in their late twenties, early thirties. And yeah, I could have gone to school with their parents."

In addition, the researcher and Teacher 3 both have had a fairly long relationship with the subject school. The researcher has been a teacher there since 2001, and previously coached basketball at the local high school for three years. Teacher 4 did her student teaching, as well as her first five years of teaching, at the subject school. The intimate knowledge of the area allowed the teachers in the program to identify and attempt to remediate any cultural barriers for the participants to engage in this program.

One of the biggest barriers, especially for the females in the group, was lack of recognition by parents that this program had potential long-term academic benefits, or that they had high expectations to help around the house. The literature suggests that this is especially true of parents who are immigrants or first-generation Americans (Gándara, 2018). Teacher 1 highlighted this concern while agreeing with Teacher 2 at a COP in the following:

> Yeah. Well, sometimes for us, I'm thinking my kid or robotics, that's freaking amazing, right? But just like Teacher 2 said, some parents don't value that at all. They think that it's a waste of time, and that their kids should be doing something else, whether it be cleaning the house or cooking or whatever it is that they think is valuable. They think that any extra stuff is a waste of time. They're like, "If you want to go out, clean the whole house."

Teacher 2 went on to elaborate:

> It is true, it is true. And especially if you have parents and you are the first generation born in the United States, that cultural things get passed on. And if your parents aren't open-minded, and still have that small-town mentality, it's also harder. Or they don't put that emphasis on education or don't see the value of being exposed to robotics. I don't know that they see the value, and hopefully not associated with it being playtime, or just a toy.

Attitudes Towards STEM Fields

At the final COP meeting, the researcher expressed previous successes with the robotics club. The other teachers were interested in hearing about this, as the researcher was the only one who had previously registered students for middle school. It was stated that:

> I know that, not this year, obviously, because we haven’t registered for middle school yet, but I know that some of our students in the club in the past have looked for the robotics

club at the middle school. And they've looked for the STEM class at the middle school. So, they're actually looking for continuity. So, we don't know what these kids will do at middle school yet, because they haven't left. But historically, we've had these kids go on to engineering club or robotics clubs looking and entering into the higher maths, or the prerequisites to higher maths, going into middle school. So, it's pretty nice that they are doing that sort of thing.

During this same meeting, Teacher 1 expressed that the enrichment program was impactful, if for no other reason than, "the mere fact that they were exposed to it. I think that okay, now it becomes an option. Okay, if I want to do this when I grew up, I can. Just because it's there, they know that it's there."

Teacher 2 had a few more observations about how the robotics club enrichment activities may have impacted student entry into the STEM fields.

> I've seen from the students, now they're starting to realize that in terms like engineering, and the fact that we're making it a point to call them robotics engineers, rather than the same students does something for them. I think having them be part of this Robotics Club and exploring the STEM fields that this area also lends itself to other areas of exploration. Like, how is science tied to this? How is math tied to this? How will my ELA skills? How can I apply them? It gave the other areas value as well, because to have proper communication or whatnot, they need to have those good ELA skills, good reading skills, math application, the different sciences. So, exploring across the different disciplines, and looking to see like, okay, so it's not just robotic, it involves other areas.

Finally, Teacher 3, who has been a long-time robotics club sponsor and co-coached that robotics team at the previous 2019 Vex Robotics Competition had the following to say about the impact of robotics on students' entry into the STEM fields:

> I think that after going through this, if we can do it online, I think they can definitely go on because some of them are fifth graders. So, they would go to that middle school and hopefully our robotics program would be offered for them. I think many of them would want to seek something like that out. They really enjoyed working with the robots.

Summary

In summary, this inferential, non-experimental, problem based qualitative case study was to examine the impact, if any, that a robotics enrichment program had on students' attitudes towards STEM fields had at a predominantly Latinx inner-city elementary school. The null hypothesis was that students participating in the robotics enrichment program would show no significant difference in their attitudes towards the STEM careers and majors. This hypothesis was retained (see Table 4). For the qualitative data, key findings were that three fourths (75%) of students expressed that they had built self-efficacy in the STEM fields, five eighths (62.5%) of students explicitly stated that they wanted to enter into STEM fields, and that all of the female teachers in the program felt that their presence gave credibility to females entering into STEM fields. In the final chapter, these findings will be compared to the literature, conclusions and implications will be drawn, and a series of recommendations will be suggested.

Chapter 5: Conclusions, Implications & Recommendations

The purpose of this inferential, problem based case study was to determine if a robotics education enrichment program would be an effective intervention in getting more minority and female students to develop self-efficacy, and thus develop approach behaviors, towards the STEM fields. This chapter includes discussions of the major findings of this study and how they relate to the literature on entering the STEM workforce and self-efficacy, and implications for practice. The chapter concludes with a discussion of the limitations of this study, suggestions for future research, and a brief conclusion.

The following research questions and findings are discussed below.

- RQ1: What impact, if any, does a robotics enrichment program have on elementary school students' attitudes towards STEM at a predominantly Latinx inner-city elementary school located in Orange County, California?
- RQ2: What 21st century job skills, if any, do students develop in a robotics education program?
- RQ3: What impact, if any, does a robotics education program have on female, English Learners and GATE students?

The following question was considered: What impact, if any, does a robotics enrichment program have on an Orange County, California elementary school students' attitudes towards STEM fields in a predominantly Latinx inner-city elementary school? The null hypothesis was that students participating in the robotics enrichment program would show no significant difference in their attitudes towards STEM careers and majors. The alternative hypothesis was that students participating in a robotics enrichment program would show a significantly more positive view regarding STEM careers and majors.

To answer this question, Table 4 displays the Wilcoxon matched pairs tests for the five scale scores. As stated in Chapter 4, Wilcoxon tests were used instead of the more common paired *t* test due to the sample size ($N = 8$). One can see that there are no significant changes ($p < .05$) in any of the subtests, nor in the overall results (see Table 4), and the null hypothesis was supported.

The theoretical framework used to frame this study was self-efficacy theory. When self-efficacy is strong, an individual believes that he or she can complete certain tasks with success (Ng & Lovinond, 2020). Building self-efficacy in students can be accomplished when students successfully complete specific and challenging tasks (Eccles & Wigfield, 2002; Fouad & Santana, 2016). It can also be built through verbal praise and encouragement (Lent, 2007). In this study, the specific and challenging tasks were built by scaffolding robotics challenges in a specific order that built on the previous challenge's results. This was specifically noted by Teacher 1 during a COP meeting when it was stated "that the programs and challenges built on themselves. . . but it was a reachable goal." This scaffolding of challenges allowed the work to be in the students' ZPD and gave them the opportunity to complete mastery experiences that allowed them to have a positive view of their achievements, further building their self-efficacy towards robotics (Bandura, 1997).

Interpretations of the Findings

The main purpose of this study was to find a way to get more Latinx, female and GATE students interested in entering the STEM fields. Results of this study were mixed. While the S-STEM survey supported the null hypothesis, and there was no significant effect on attitudes towards STEM fields, these results do not tell the whole story of the subject school's robotics education program. For the qualitative data, key findings were that three fourths (75%) of

students expressed that they had built self-efficacy in the STEM fields, five eighths (62.5%) of students explicitly stated that they wanted to enter into STEM fields, and that all of the female teachers in the program felt that their presence gave credibility to females entering into STEM fields.

Zone of Proximal Development

The student ZPD was facilitated through scaffolded challenges, with each successive challenge being built on completing the previous challenge. Implementing new challenges for each student allowed them to work at their own pace. Both the teachers and students saw success in this model. Students expressed that they were excited to move on to more challenges, and teachers noted that students were usually able to problem solve on their own. As students progressed through the challenges, they developed more capacity in robotics. This allowed them to have a higher base of knowledge from which to build new knowledge (Eun, 2019). As each challenge became more difficult students would be able to build on their previous knowledge so that each challenge would not be in the students' frustration level. This would allow students to build self-efficacy in robotics education (Bandura, 1997).

Self-Efficacy Theory

Students were able to complete challenges within their ZPD. However, these challenges were seen as meaningful and challenging. At the end of each daily session, students often looked forward to working on new challenges. They also enjoyed the challenge of debugging and fixing their programs. Because the challenges were engaging and challenging, students expressed excitement at completing challenges. This allowed students to build their self-efficacy in the STEM fields (Eccles & Wigfield, 2002; Fouad & Santana, 2016).

In addition to students having success in these robotics challenges, students were encouraged to see themselves as robotics engineers. The teachers called the students robotics engineers throughout the course. For example, during the daily introduction, it was common practice for the teachers to say, “Good afternoon, robotics engineers. How are you doing today and what challenges are you problem solving for?” This helped students identify themselves as part of the engineering community, allowing them to build more self-efficacy in the engineering fields (Estrada et al., 2011).

Furthermore, the fact that one of the teachers attended the subject school, and another had graduated from the subject school’s district, allowed the students to vicariously compare these teachers’ successes with their own circumstances. This is another manner in which self-efficacy is built in a particular area (Bandura, 1997). The fact all of the students had a teacher who represented their ethnic background and spoke the same languages that they speak allowed students to have a deeper belief that they could be successful in engineering (Byars-Winston & Rogers, 2019).

All of these factors contributed to five-eights (62.5%) of the student participants explicitly stating that they would like to enter into the STEM fields. This was expressed as while answering a debriefing question about entering the STEM fields with a simple, “I do want to go into a STEM career,” for one student, all the way to an enthusiastic, “I could be able to earn money as an engineer.”

The results of this study were mixed. The quantitative data showed no significance in differences in attitudes towards the STEM fields. However, in the qualitative data, the students and teachers believed that there was a change in attitude. While there are examples of previous robotics studies having a positive impact on students (Kazakoff et al., 2012; Nabeel et al, 2017;

Ortiz, 2015; Sheehy, 2017) the literature contains examples of studies with minimal, no, or mixed impact of robotics education (Huang et al., 2013; Mac Iver & Mac Iver, 2019; Williams et al, 2007). This study differed from the others in that this study was specifically looking at how robotics education impacted student attitudes towards STEM fields. The previously mentioned studies focused on specific subject matter or job skills. There was one study that found robotics education boosted student self-efficacy in STEM, but it did not take the next step to find the impact on student attitudes towards entering STEM fields (Nugent et al., 2016).

21st Century Job Skills

According to analysis of the S-STEM survey 21st century skills subsection there was no statistical significance to difference between Pre-Treatment and Post-Treatment surveys (p = .16) (see Table 5). The 21st century job skills examined in the S-STEM survey more closely align with the skills of interpersonal skills and self-regulatory skills. While these skills are seen as important to the 21st Century workforce (Lund et al., 2019), they are not the focus of this study as the subject school focuses on the Four C's model of 21st century job skills.

While observing students for the Four Cs skills of communication, collaboration, critical thinking and creativity the program's teachers did notice a change in how students used 21st Century job skills, especially in the areas of communication and collaboration. This was especially true over the course of the study.

Table 5

Wilcoxon Matched Pairs Tests for Selected Scale Scores

Scale Score	Time	*n*	*M*	*SD*	*z*	*p*
21st Century Skills					1.41	.16
	Pretest	8	3.91	0.54		
	Posttest	8	4.08	0.88		

Note. N = 8

Communication

At the start of the robotics education program, students rarely had their microphones on, and never had their cameras on in the Zoom meetings. However, over the course of the program, students sought each other out during the introduction to work together. Students also expressed that they were able to solve problems with each other and were able to successfully debug their own problems. This was a marked change from pre-COVID-19 robotics programs in which students freely communicated with each other, as well as the teachers.

The difference between the pre-pandemic program and the program during COVID-19 protocols underscore how much students benefit from intention, and unintentional, communication with others. Students working in a face-to-face setting will overhear other students working on their programs, and either help the other student, or receive help, without ever having to actively seek help. In addition, students working in a face-to-face setting would have a defined group from which to gain insights.

It is possible that the improvement communication was related to the three main pillars of Latinx families, which are respect, education and family (Aldoney & Cabrera, 2016), rather than as a direct result of the robotics program. It is theorized that these beliefs feed the 21st century skill of teamwork, effective communication and collaboration (Gándara, 2018).

Collaboration

Collaboration was another area in which students would have had defined groups to work with in a face-to-face setting. However, similar to communication, students did learn to collaborate over time. Students asked to work with one another in breakout rooms. They learned to listen during the daily meeting introductions to find students who could be the more knowledgeable other with whom to work.

The three pillars of Latinx family values are respect, education, and family (Aldoney & Cabrera, 2016; Cox et al., 1999). This explains why students were willing to help each other in breakout rooms to help one another trouble shoot and problem solve their programs. It is theorized that these three pillars may have played a role in focusing collaboration skills (Gándara, 2018)

Critical Thinking

Throughout the study students expressed that they were able to problem solve, or debug, their robotics codes. This not only allowed them to see themselves as having a mastery experience when working with code, thus building self-efficacy (Eccles, & Wigfield, 2002; Fouad & Santana., 2016;), but it also allowed them to build capacity in debugging their programs, The building of self-efficacy towards programming would lead students to have approach behaviors towards the STEM fields (Ng & Lovibond, 2020).

Creativity

A traditional, face-to-face, robotics education program would have allowed students to show more creativity. Working in person would have allowed students to go through the entire EDP. The first two steps of the EDP, identifying a problem and designing a potential solution, all while allowing the students full access to the Lego EV3 kit, would best allow the students to demonstrate and develop creativity. The 21st century job skill definition of creativity is to use existing information in a way (van Laar et al, 2020). Designing robots to fill a purpose would fill this definition perfectly

The results of developing 21st century job skills is in line with a 2014 study in which the most observed student behavior in robotics education was engaging in collaboration and discussion, with the least observed behavior being programming, engineering and debugging the

robots (Yuen et al., 2014). The results are also supported by other, previous studies. These studies suggested that interacting with educational robots enhanced critical thinking skills, teamwork, computational thinking and collaboration. In addition, they had the further benefit of increasing student interest in the STEM fields. (Casey et al., 2017; Nabeel et al., 2017).

Females

Two thirds (66.7%) of the females in this study finished with a positive attitude towards the STEM fields, according to qualitative data. However, there was insufficient sample size to run a meaningful quantitative statistics test in this population. The one female student whose attitude towards STEM fields went down did have a decrease in attendance rate over the course of the class. She was also the only EL student in the program. When asked about her declining attendance rate, she replied that she had "a lot to do around the house." This is in line with a study that stated the barrier of Latinx females is extremely burdensome, as they are expected to do more chores around the house (Jabber et al., 2017). This also came out in a COP meeting in which the female teachers recounted having to do chores like "cleaning the whole house" before being allowed to go out, or that their parents just saw extra-curricular programs as just playing.

While the first female had a negative view of the STEM fields, the remaining two had a positive outlook. The teachers believed that this is part of the overall effect of having female teachers involved in robotics education, as well as math field day, over the past six years. The female teachers believed that sponsoring these programs has opened STEM fields to female students. They also believed that it was important to establish positive attitudes towards STEM in younger students as all of their science and math teachers from middle school through college were males.

English Learners

The population size of EL students in this study was too small to run significant statistical tests. In addition, the lone EL student in this study had a lesser attitude towards the STEM fields post-treatment than pre-treatment. This student's attitudes towards STEM studies were recounted in the section above.

However, while there was only one EL student in the sample, it is important to look at her results closely as part of the deviant-case analysis, especially since she was the only student with a lower post-treatment S-STEM score than pre-treatment score. This helps to establish internal reliability of the study (Gibbert & Ruigrok, 2010).

In order to explain the change in S-STEM survey scores, as well as the fact that she did not report any positive feelings towards the STEM fields one must look at the possible explanations surrounding her case (Hancock & Algozzine, 2017; Yin, 2018). The student in question started with perfect attendance the first week and a half. However, her attendance deteriorated to the point that she only had one day of attendance in the last week of school. She explained this by stating that she "had a lot to do and couldn't come." This potential explanation for her lack of interest in STEM fields is supported by the fact that Latinx females traditionally have more household responsibilities than other students in the class (Gándara, 2018).

In addition to having a lower level of English fluency than the other students in the class, her standardized test scores were lower than the rest of the class. This had the potential to lead to lower self-efficacy in robotics and STEM. By vicariously comparing her accomplishments in the program to other students, she would develop lower self-efficacy than the other students, leading to avoidance behaviors towards robotics and STEM fields (Betz & Hackett, 2006; Ng & Lovibond, 2020).

GATE Students

All of the GATE students involved in this study had positive attitudes towards the STEM fields at the end of the study. However, one fourth (25%) of the GATE students expressed that he would not like enter the STEM fields in the future. The remaining three fourths (75%) had positive attitudes towards the STEM fields. It is possible that the GATE students developed more self-efficacy in STEM as they were frequently sought out by their peers to be the “more knowledgeable other” with whom to collaborate. This gave them an effective positive feedback loop that reinforced their self-efficacy in STEM and led to more approach behaviors towards these fields (Senge, 2006). This feedback loop was illustrated in Figure 1.

Implications for Practice

Robotics education programs are engaging for students and are useful for building self-efficacy in the STEM fields and promoting student interest in entering these fields. It is important when designing a robotics education program that one develops a curriculum that is scaffolded in such a way as to have students work in their ZPD. A successful robotics curriculum is both challenging enough to be worthwhile, yet attainable enough to not lead to frustration. This has the added benefit of producing a growth mindset and grit within the students. In addition, it is helpful for the adults in the group to create an atmosphere in which students can visualize themselves entering into STEM fields in the future. In our study, we consistently referred to the students as “robotics engineers” and asked them what their next step in the engineering cycle they would be working in next.

Moreover, it is desirable to have diversity within the adults in the program. As noted by the teachers in the program, the diversity allows the students to see minorities and women normalized within the STEM fields. It is especially helpful to have teachers who resemble the

backgrounds of the students. Seeing people of similar backgrounds working in a desired field can build self-efficacy within the students, as they are able to vicariously see their future success through their mentors (Bandura, 1997).

A further implication for practice is that students should work on robotics, in teams, in a face-to-face setting. In addition, they should be working on problem-based projects that allow them to go through the entire engineering process. These projects should incorporate all aspects of STEM, as it has been noted in previous studies that systematic instruction in the STEM fields impact student attitudes towards these fields (Guzey & Aranda, 2017; Mooney & Laubach, 2002).

Limitations and Suggestions for Further Research

Limitations

There were a number of limitations to this study, the most obvious of which were related to the COVID-19 pandemic. Due to distance learning, and the district mandate to follow Center for Disease Control (CDC) guidelines, enrollment in the class was extremely limited. Traditionally, the subject school's robotics club has around 20 participants. Due to only having nine robots, the study only had eight students and this small sample size limited deep analysis of the S-STEM survey. It is possible that one student having an unusually bad, or an exceptionally good day, could disproportionately skew the results. The small sample size precluded a robust quantitative study of the data and led to much of the quantitative results being statistically insignificant. In addition, the small sample size fundamentally altered the nature of the study from being a traditional mixed-methods study to a case study.

A second limitation of this study, again related to the small sample size, is the overrepresentation of GATE students and the underrepresentation of EL and female students in

the study population. In this study, there was only one EL student, making up 12.5% of the study population while the subject school is nearly 50% EL. In addition, although determining the impact of a robotics education program on female students' attitudes towards STEM was a goal of this study, only 37.5% of the study population was female; however, the subject school has a female population nearly equal to the male population in fifth grade. While the 37.5% female participation may be trending in the right direction for participation in the STEM fields, it does not match the subject school's demographics.

A third limitation is that the population self-selected into the robotics club. Students enrolled in this program on a first-come, first-served basis following announcements by fifth-grade teachers in their individual classrooms. This possibly skewed results towards students who were already predisposed to have interest in the STEM fields. Also, this is potentially reflected in the high number of "agree" and "strongly agree" responses to the traditionally coded Pre-Treatment S-STEM survey statements. In addition, these students were willing to participate in an after-school club, and probably had a more positive attitude towards school in general. Furthermore, three of the students had participated in the robotics club the previous year in a face-to-face situation at the subject school. These students may have already had a high self-efficacy in the STEM fields, thus leaving little room for their attitudes to change in the positive direction.

Finally, a potential limitation deriving from the small sample size was the large proportion of GATE students. Of the eight participants, 37.5% were identified as GATE students. The GATE population at the subject school was less than 5% of students' Grades 3-5. In the subject school, Grades 3-5 are the only grade levels in which students are placed in the GATE program. With such a high percentage of GATE students in this program, in relation to

the student population at large, it is possible that challenges were written to challenge the GATE students and thus be beyond the ZPD of some of the other students, leading to frustration. The vicarious comparison of one's accomplishments to others is one of the ways in which individuals can develop self-efficacy in a particular field. This may explain how the general education students' self-efficacy towards STEM fields decreased due to comparing themselves to the relative ease at which some other students completed the challenges (Bandura, 1997).

Suggestions for Future Research

Searching for and developing ways in which to engage underrepresented minorities and female students in the STEM fields will help fix the leaky STEM pipeline in which Caucasian and Asian males are overrepresented in STEM fields and Latinx, African-American and females are underrepresented in STEM fields in the United States. Inspiring a more diverse population to fill STEM related jobs will create a more representative workforce, allowing American companies to be more competitive in the 21st century marketplace. To this end, there are several suggestions for further research.

The first recommendation is to recruit a larger student population. This may be alleviated by performing this study while the subject school is open to in-person classes. The lack of in-person classes limited student participation. Because CDC recommendations limited in person contact between students and between students and teachers, we had to limit the student participants to the number of available robots. Further complicating the issue, district policy during the COVID-19 pandemic did not allow students to share robots without cleaning, effectively limiting us to one student per robot. During in-person instruction, we are able to host up to 24 students. In order to follow district protocols and maximize student safety, we delivered eight robots to eight individual students. The small sample size in this study did not closely

mirror the general student population at the subject school. It would be advisable to have a larger sample size that better mimicked the demographics of the subject school. Furthermore, a larger sample population will likely allow the quantitative study to have more meaningful and significant results.

The COVID-19 pandemic forced this study to be held virtually. This leads to the second recommendation. Performing a study with traditional, face-to-face education would possibly yield better results. During the COPs, the researcher often found that the teachers believed that they were not as effective teaching robotics in a virtual setting. They believed that they were not able to easily make observations of student interactions, and unable to easily identify students who needed help. Additionally, hardware problems with the robots were difficult to identify and remedy. Finally, the teachers in the COP often mentioned that the spontaneous conversations and actions of students in real time were missed, especially early in the study when the students were less likely to have their cameras and microphones on.

The third recommendation is to study the impact of robotics competitions on STEM interest. This would be a different study than the one completed in that this study was set up for students to develop their robotics skills in isolation, while a competition would allow students to have a common goal together. Unfortunately, the competition scheduled for the Orange County Robotics Organization is scheduled to be virtual this year, so the subject school opted out of participation because many of the same challenges faced in the study would also be faced in this competition. Traditional robotics competitions have teams of students working together, using each member’s individual strengths to successfully navigate the competition. The roles for each student include positions such as designer, coder, spokesperson and driver. Students must work

together to be successful, thus mirroring the 21st century skills for which many employers are looking.

A fourth recommendation is to organize a study in which the students themselves are interviewed. One of the purposes of a case study is to give a voice to traditionally underrepresented populations and to influence the policy that may affect said populations (Hancock & Algozzine, 2017; Yin, 2018). Unfortunately, this study relied on indirect student input and was not designed to directly hear student opinions about how they felt about STEM fields, or how to better get them interested in those fields. While the daily introductions and debriefing sessions were useful, students' voices would be much more effective in informing policy on STEM education.

Conclusion

The STEM pipeline in the United States has failed to adequately attract and retain underrepresented minorities and females into the STEM fields for some time. Fixing this pipeline is key to filling the future STEM careers that are so important to the U.S. economy moving forward. Moreover, a STEM workforce that more closely mirrors diversity in the U.S. is one step closer to social justice for all races in this country. In addition, companies who have a more diverse workforce have been shown to have higher profitability (Ellison & Mullin, 2014; Hewlett et al., 2013; Mayer et al., 2018).

The results of this study suggested that the elementary school students have improved attitudes towards the STEM fields following a robotics education program. In fact, seven of the eight (87.5%) students in this study have signed up for a spring semester robotics club. The hope is that positive attitudes towards STEM fields in elementary school will continue to lead students to seek STEM gateway classes, such as pre-algebra and exploratory science, in middle school. In

addition, it is hoped that students will seek out extra-curricular activities in the STEM fields, such as continuing in robotics clubs, entering model rocketry club or studying computer aided design in the middle schools to which the subject school feeds. This serves the dual purpose of allowing students to continue to develop self-efficacy, and build capacity in, the STEM fields. This will create more approach behaviors towards the STEM fields, and thus help to close the leaky STEM pipeline.

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APPENDIX A

Application to do Research

Santa Ana Unified School District

RESEARCH AND EVALUATION
Emily Wolk, Ph.D., Executive Director

Jerry Almendarez
Superintendent of Schools

APPLICATION TO CONDUCT EDUCATIONAL RESEARCH IN THE SANTA ANA UNIFIED SCHOOL DISTRICT

As the District's decision will be based on information provided in this application, it is the researcher's responsibility to provide all requested information on this form. If more space is needed to answer any question, please attach additional sheets. Supplementary materials may be attached, as appropriate.

Name of Researcher: [redacted] **Date:** 1/14/2020

Mailing Address: [redacted]

Office Phone: [redacted] **Home Phone:** [redacted]

Position: 5th Grade teacher, [redacted]

Are you a Santa Ana Unified School District Employee? Yes x **No:**

Project Title: Improving Attitudes Towards STEM by Building Self-Efficacy Through Robotics Education (working title)

Study Design: Mixed-Methods Explanatory Sequential design

1. **What questions does your study seek to answer?**
What impact, if any, does a robotics enrichment program have on an Orange County, California elementary school students' attitudes towards STEM fields in a predominantly Latinx inner-city elementary school?

2. **Please describe the ways in which the Santa Ana Schools would directly benefit from your study.**
SAUSD students who participate in this study will participate in robotics education in an after-school enrichment setting. Students will learn how to build, code and operate robots. The robot to be used will be from the Lego Mindstorms for Education Kit. Alternatively, Ozobot Classroom Pack robots may be used.

3. **Is this study legally mandated?** No

   If so, by what agency or authority?

4. **Approximate dates of data collection – From: February 2020-April 2020**

5. **Expected completion date of final report:** June 2020

6. **Please list school(s) in which the study, if approved, will be conducted.**
Lowell Elementary School
The Lowell Elementary School Principal, Miriam Gonzalez-Perez, is in support of this project.

7. **Please explain your selection of these schools.**

I am a fifth-grade teacher at Lowell Elementary School and have run both an after-school robotics program and a summer enrichment robotics program at Lowell for the past five years.

8. **Please indicate the number of participants and the approximate amount of time that would be required of each participant.**
I will recruit approximately 20 students for 20 hours of instruction over a 4-week period.
The research will be conducted within an existing after-school robotics program.
STUDENTS WILL NOT MISS REGULAR INSTRUCTION.

9. **What funding do you possess to cover costs to the school or District?**
All materials needed for instruction already exist at Lowell.
THERE WILL BE NO COST TO THE DISTRICT

10. **Describe the specific procedure to be used to select participants.**
Participants have, and will, self-select into the robotics program based on their interest. Informed consent forms will be sent home with robotics club members. Students who return informed consent forms indicating a desire to participate will be selected for the study. Informed consent forms will be translated into Spanish using the Expert Committee Method.

11. **Please describe school records that you wish to examine and indicate how they relate to your study.**
I will need access to demographic information regarding my study population in order to provide context for survey results.

12. **Please describe and attach the instruments, forms, questionnaires, or tests to be used to collect data and explain how those instruments relate to the study.**

In the first, quantitative phase of the study, data regarding student STEM attitudes will be collected from 20 participants at a public elementary school, using the S-STEM survey prior to their participation in the robotics-enrichment program. In the second phase, following student participation in the enrichment program, the researcher will re-administer the S-STEM survey to compare pre- and post-quantitative data and randomly select 3-5 students with whom to conduct interviews. These interviews will be semi-structured and seek to determine why, and how, students formed their attitudes towards the STEM field. The S-stem survey has also been used successfully in studies by Ke and Carfano (2016), Kwon and Hyuksoo (2016), Babarullah and Hussain (2019), and Navarro, et. al. (2016). It is a 37-item survey that measures both attitude towards STEM fields and career interest in STEM. The attitude section measures items on a 5-point Likert-type response scale, ranging from strongly disagree to strongly agree. Items measuring career interest are measured on a 4-point scale, ranging from not at all interested to very interested.

13. **Teacher Questionnaire/Survey:** n/a

14. **Who will be responsible for administering tests or questionnaires and how they will be administered?**

The researcher will be responsible for administering the questionnaire through the use of Google Forms.

15. **List the facilities at each school that you will need.**

Maker Space (room 106)

16. **How will the data be physically tabulated?**
Data will be entered into SPSS to analyze data pre- and post-treatment for descriptive analysis to determine any impact on attitudes.

17. **What analytical tools will you use in your design?** SPSS

18. **Will you request use of the district computer in either data collection and/or data analysis?** Yes

If yes, explain: Students will use the Chromebooks to answer the S-STEM survey.

19. **Do you plan to send parent permission forms? Yes**

20. **How will you report the results of the study, and to whom? (If approved, the researcher will provide the results of the study to the District)**
The results of the study will be presented to Pepperdine University as partial fulfillment of the requirements for the Doctorate of Education in Organizational Leadership program. The results will be sent to SAUSD research and evaluation to be archived to inform best practices.

21. **<u>To the copies of this application, the following is attached</u>:**

1) **Parent Informed Consent Forms**
2) **S-STEM Survey**
3)

Santa Ana Unified School District

RESEARCH AND EVALUATION
Emily Wolk, Ph.D., Executive Director

Jerry Almendarez
Superintendent of Schools

Statement of Researcher:

In submitting this application, I assure the Santa Ana Unified School District that I will conduct the research in all respects according to the conditions under which this application may be approved, including the Guidelines for Research Projects in the Santa Ana Unified School District. In compliance with the Education Rights and Privacy Act of 1974, I assure the Santa Ana Unified School District that identifiable data collected for this study will be kept confidential. Upon completion of this research, I will present to the department of Research and Evaluation of the Santa Ana Unified School District a copy of the findings and an abstract of my final report on June **of** 2020
.

(month) **(year)**

Principal Researcher: Kevin Obillo

Approval of supervisor or Study Advisor: Dr. Kfir Mordechay, Ph. D., Pepperdine University

I have reviewed this research request, the description of the research study and the attached instruments, and give my approval to this study.

Name: Kfir Mordechay

Position: Professor

School Instruction: Pepperdine University

Department: Graduate School of Education and Psychology

Phone:

see position above

Signature

January 31, 2020

Miriam Gonzalez-Perez

[redacted]

Dear Miriam,

Thank you for your support of my research proposal. At this point, it would be helpful to have you sign below to acknowledge our discussion and your approval. I will submit both my proposal and this letter to Emily Wolk in Research and Evaluation.

As per our discussion, I will provide you with a copy of the research results.

Thank you again for your support.

Sincerely,

Kevin Obillo
5th Grade Teacher

______________________________ 1/31/2020 I, Miriam Gonzalez-Perez, Principal at [redacted] Elementary School, am in agreement to allow Kevin Obillo to do his dissertation research at our school site as described in the Application to Conduct Research in the Santa Ana Unified School District.

Pepperdine University
Kevin Obillo, Researcher
Improving Attitudes towards STEM Fields

Parental Permission for Children Participation in Research

Title: Improving Attitudes Towards STEM by Building Self-Efficacy Through Robotics Education

Introduction

The purpose of this form is to provide you (as the parent of a prospective research study participant) information that may affect your decision as to whether or not to let your child participate in this research study. The person performing the research will describe the study to you and answer all your questions. Read the information below and ask any questions you might have before deciding whether or not to give your permission for your child to take part. If you decide to let your child be involved in this study, this form will be used to record your permission.

Purpose of the Study

The purpose of this study is to better understand what impact, if any, student attitudes towards STEM are affected by robotics education

What is my child going to be asked to do?

If you allow your child to participate in this study, they will be asked to
Take a pre- and post-treatment survey about their attitudes towards STEM
Participate in a 20-hour robotics education class
Potentially take part in an interview about their experiences

This study will take **a total of 20 hours, and will meet after school 2:30-3:30 three days a week, and four hours on two different Saturdays** and there will 20 participants people in this study.

What are the risks involved in this study?

There are no foreseeable risks to participating in this study.

What are the possible benefits of this study?

The possible benefits of participation are **increased understanding of coding and robotics, problem solving and other 21st-Century skills**

Does my child have to participate?

No, your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusing to participate will not affect their relationship with Lowell Elementary School in anyway. You can agree to allow your child to be in the study now and change your mind later without any penalty.

What if my child does not want to participate?

In addition to your permission, your child must agree to participate in the study. If you child does not want to participate they will not be included in the study and there will be no penalty. If your child initially agrees to be in the study they can change their mind later without any penalty.

Will there be any compensation?

Neither you nor your child will receive any type of payment participating in this study.

Your child will receive a raffle ticket for each hour of the program completed. 10 (ten) $15 gift cards will be raffled upon completion of the program

How will your child's privacy and confidentiality be protected if s/he participates in this research study?

Your child's privacy and the confidentiality of his/her data will be protected by collecting data through the use of identification numbers. They key to the identification numbers will be stored separately from the data and will be destroyed after data analysis. The data will be stored on a flash drive that will be kept in the researchers home in a locked file box.

If it becomes necessary for the Institutional Review Board to review the study records, information that can be linked to your child will be protected to the extent permitted by law. Your child's research records will not be released without your consent unless required by law or a court order. The data resulting from your child's participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with your child, or with your child's participation in any study.

NOTE: If audio/video recordings will be made include the following statements:

If you choose to participate in this study, your child **[will be/may choose to be] [audio and/or video]** recorded. Any **[audio and/or video]** recordings will be stored securely and only the research team will have access to the recordings. Recordings will be kept for **[insert length of time]** and then erased.

Whom to contact with questions about the study?

Prior, during or after your participation you can contact the Kevin Obillo at [redacted] or send an email to [redacted] for any questions or if you feel that you have been harmed.

Whom to contact with questions concerning your rights as a research participant?

For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at [redacted] or email at [redacted]

Signature

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow them to participate in the study. If you later decide that you wish to withdraw your permission for your child to participate in the study you may discontinue his or her participation at any time. You will be given a copy of this document.

Pepperdine University
Kevin Obillo, Researcher
Improving Attitudes towards STEM Fields
PLEASE RETURN THIS DOCUMENT BY ______

______ My child MAY be **audio** recorded.
______ My child MAY NOT be **audio** recorded.

____
Printed Name of Child

____________________________ ______________
Signature of Parent(s) or Legal Guardian Date

____________________________ ______________
Signature of Investigator Date

PsycTESTS®

Measure of Student Attitudes Toward Science, Technology, Engineering, and Math
Version Attached: Full Test

PsycTESTS Citation:
Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). Measure of Student Attitudes Toward Science, Technology, Engineering, and Math [Database record]. Retrieved from PsycTESTS. doi: http://dx.doi.org/10.1037/t50151-000

Instrument Type:
Survey

Test Format:
The measure has 2 versions with 37 items each. Attitude items were measured on a 5-point Likert-type response scale (strongly disagree to strongly agree), while career interest items were measured on a 4-point Likert-type response scale (not at all interested to very interested).

Source:
Unfried, Alana, Faber, Malinda, Stanhope, Daniel S., & Wiebe, Eric. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). Journal of Psychoeducational Assessment, Vol 33(7), 622-639. doi: 10.1177/0734282915571160, © 2015 by SAGE Publications. Reproduced by Permission of SAGE Publications.

PsycTESTS®

doi: http://dx.doi.org/10.1037/t50151-000

Measure of Student Attitudes Toward Science, Technology, Engineering, and Math
S-STEM

Items

Math
- (D) Math is an important life skill
- (-) Math has been my worst subject
- When I am older, I might choose a job that uses math
- (-) Math is hard for me
- (D) When I am older, I will need to understand math for my job
- I am the type of student who does well in math
- (-) I can understand most subjects easily, but math is difficult for me
- In the future, I could do harder math problems
- I can get good grades in math
- I am good at math

Science
- I feel good about myself when I do science
- I might choose a career in science
- After I finish high school, I will use science often
- When I am older, knowing science will help me earn money
- When I am older, I will need to understand science for my job
- I know I can do well in science
- Science will be important to me in my future career
- (-) I can understand most subjects easily, but science is hard for me to understand
- In the future, I could do harder science work

Engineering/technology
- I like to imagine making new products
- If I learn engineering, then I can improve things that people use every day
- I am good at building or fixing things
- (D) Understanding engineering will help me earn money
- I am interested in what makes machines work
- Designing products or structures will be important in my future jobs
- I am curious about how electronics work
- (D) I would choose a job that involves buidling things
- I want to be creative in my future jobs
- Knowing how to use math and science together will help me to invent useful things
- I believe I can be successful in engineering

doi: http://dx.doi.org/10.1037/t50151-000

Measure of Student Attitudes Toward Science, Technology, Engineering, and Math
S-STEM

Items

21st century skills

I can lead others to reach a goal
I like to help others do their best
(D) I usually know how to do the right thing
In school and at ahome, I can do things well
(D) I can and usually do act responsibly
I respect all children my age even if they are different from me
I try to help other children my age
When I make decisions, I think about what is good for other people
When things do not go how I want, I can change my actions for the better
I can maky my own goals for learning
I can use time wisely when working on my own
When I have a lot of homework, I can choose what needs to be done first
I can work well with all students, even if they are different from me

Note . (D) indicates that the item was deleted after EFA; (-) indicates that the item was reverse-coded during analysis.

APPENDIX B

Parental Consent (English)

Parental Permission for Children Participation in Research

Title: Improving Attitudes Towards STEM by Building Self-Efficacy Through Robotics Education

Introduction

The purpose of this form is to provide you (as the parent of a prospective research study participant) information that may affect your decision as to whether or not to let your child participate in this research study. The person performing the research will describe the study to you and answer all your questions. Read the information below and ask any questions you might have before deciding whether or not to give your permission for your child to take part. If you decide to let your child be involved in this study, this form will be used to record your permission.

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The purpose of this study is to better understand what impact, if any, student attitudes towards STEM are affected by robotics education

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What if my child does not want to participate?

In addition to your permission, your child must agree to participate in the study. If you child does not want to participate they will not be included in the study and there will be no penalty. If your child initially agrees to be in the study they can change their mind later without any penalty.

Will there be any compensation?

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Your child will receive a raffle ticket for each hour of the program completed. 10 (ten) $15 gift cards will be raffled upon completion of the program

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NOTE: If audio/video recordings will be made include the following statements:

If you choose to participate in this study, your child **[will be/may choose to be] [audio and/or video]** recorded. Any **[audio and/or video]** recordings will be stored securely and only the research team will have access to the recordings. Recordings will be kept for **[insert length of time]** and then erased.

Whom to contact with questions about the study?

Prior, during or after your participation you can contact the Kevin Obillo at [redacted] or send an email to [redacted] for any questions or if you feel that you have been harmed.

Whom to contact with questions concerning your rights as a research participant?

For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at [redacted] or email at [redacted]@pepperdine.edu.

Signature

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow them to participate in the study. If you later decide that you wish to withdraw your permission for your child to participate in the study you may discontinue his or her participation at any time. You will be given a copy of this document.

PLEASE RETURN THIS DOCUMENT BY ______

______ My child MAY be **audio** recorded.

______ My child MAY NOT be **audio** recorded.

____

Printed Name of Child

________________________________ ________________

Signature of Parent(s) or Legal Guardian Date

________________________________ ________________

Signature of Investigator Date

APPENDIX C

Parental Consent (Spanish)

Permiso de padres para participación de niños/as en el estudio

Título: Mejorando las actitudes hacia Ciencia, Tecnología, Ingenieria y Matemáticas (STEM) mediante creando la autoeficacia a través de la educación robótica.

Introducción
El propósito de este forma es para proporcionarle a usted (como padre una posible participación del estudio STEM) información que pueda resultar en su decisión sobre si deja que su hijo/a participe o no en este estudio de STEM. La persona que realizara la estudio le describirá el estudio y responderá todas sus preguntas. Lea la información a continuación y haga cualquier pregunta que pueda tener antes de decidir si autoriza o no a su hijo/a a participar en el estudio. Si decide dejar que su hijo/a participe en este estudio, este formulario se utilizará para registrar su permiso.

Propósito del estudio
El propósito de este estudio es comprender mejor qué impacto, si alguno, las actitudes de los estudiantes hacia STEM se ven afectadas por la educación en robótica.

¿Qué se le va a pedir a mi hijo/a que haga?
Si permite que su hijo/a participe en este estudio, se le pedirá que:
Toma una encuesta previa y posterior a la instruccion sobre sus actitudes hacia STEM
Participe en una clase de educación robótica de 20 horas.
Participe potencialmente en una entrevista sobre sus experiencias.

Este estudio tomará **un total de 20 horas, y se reunirá después de la escuela 2:30-3:30 tres días a la semana, y cuatro horas en dos sábados diferentes** y habrá 20 personas participantes en este estudio.

¿Cuáles son los riesgos involucrados en este estudio?
No hay riesgos previsibles para participar en este estudio.

¿Cuáles son los posibles beneficios de este estudio?
Los posibles beneficios de la participación son una mayor comprensión de la codificación y la robótica, la resolución de problemas y otras habilidades del siglo 21.

¿Tiene que participar mi hijo/a?
No, la participación de su hijo/a en este estudio es voluntaria. Su hijo/a puede negarse a participar o retirarse de la participación en cualquier momento. Retirarse o negarse a participar no afectará su relación con Lowell Elementary School de ninguna manera. Puede permitir que su hijo/a participe en el estudio ahora y cambiar de opinión más adelante sin penalización.

¿Qué pasa si mi hijo/a no quiere participar?
Además de su permiso, su hijo/a debe aceptar participar en el estudio. Si su hijo/a no quiere participar, no se incluirá en el estudio y no habrá penalidad. Si su hijo/a inicialmente acepta participar en el estudio, puede cambiar de opinión más adelante sin penalización alguna.

¿Habrá alguna compensación?
Ni usted ni su hijo/a recibirán ningún tipo de pago por participar en este estudio. Su hijo/a recibirá un boleto de rifa por cada hora del programa completado. Se sortearán 10 (diez) tarjetas de regalo de $ 15 al finalizar el programa

¿Cómo se protegerá la privacidad y la confidencialidad de su hijo/a si participa en este estudio de investigación?
La privacidad de su hijo/a y la confidencialidad de sus datos estarán protegidos mediante la recopilación de datos mediante con uso de números de identificación. La clave para los números de identificación se almacenará por separado de los datos y se destruirá después del análisis de datos. Los datos se almacenarán en una unidad flash que se guardará en la casa de los investigadores en un cuadro de archivo bloqueado. Si es necesario que la Junta de Revisión Institucional revise los registros del estudio, la información que puede vincularse con su hijo/a estará protegida en la medida permitida por la ley. Los registros de investigación de su hijo/a no se divulgarán sin su consentimiento, a menos que lo exija la ley o una orden judicial. Los datos resultantes de la participación de su hijo/a pueden ponerse a disposición de otros investigadores en el futuro para fines de investigación no detallados en este formulario de consentimiento. En estos casos, los datos no contendrán información de identificación que pueda asociarlo con su hijo/a o con la participación de su hijo/a en cualquier estudio.

NOTA: Si se harán grabaciones de audio/video, incluya las siguientes declaraciones:
Si elige participar en este estudio, su hijo/a [será / podrá optar por ser] [audio y / o video] grabado. Cualquier grabación [de audio y / o video] se almacenará de forma segura y solo el equipo del estudio tendrá acceso a las grabaciones. Las grabaciones se guardarán durante [insertar tiempo] y luego se borrarán.

¿A quién contactar con preguntas sobre el estudio?
Antes, durante o después de su participación, puede comunicarse con Kevin Obillo al [redacted] o enviar un correo electrónico a [redacted] para cualquier pregunta o si siente que ha sido perjudicado.

¿A quién contactar con preguntas sobre sus derechos como participante del estudio?
Para preguntas sobre sus derechos o cualquier insatisfacción con cualquier parte de este estudio, puede comunicarse, anónimamente si lo desea, con la Junta de Revisión Institucional por teléfono al [redacted] o por correo electrónico a [redacted]@pepperdine.edu.

Firma
Está tomando la decisión de permitir que su hijo/a participe en este estudio. Su firma a continuación indica que ha leído la información provista anteriormente y ha decidido permitirle participar en el estudio. Si luego decide que desea retirar su permiso para que su hijo/a participe en el estudio, puede suspender su participación en cualquier momento. Recibirá una copia de esta forma.

POR FAVOR DEVUELVA ESTE FORMA ANTES DE ___________________.

______ Mi hijo/a PUEDE tener audio grabado.
______ Mi hijo/a NO PUEDE tener audio grabado.

____
Nombre impreso del niño/a

_________________________________ _________________
Firma del padre (s) o tutor legal   Fecha

_________________________________ _________________
Firma del estudio   Fecha

APPENDIX D

IRB Approval Letter

PEPPERDINE

Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263
TEL: 310-506-4000

NOTICE OF APPROVAL FOR HUMAN RESEARCH

Date: July 31, 2020

Protocol Investigator Name: Kevin Obillo

Protocol #: 20-05-1367

Project Title: What impact does robotics education have on student attitudes towards STEM fields?

School: Graduate School of Education and Psychology

Dear Kevin Obillo:

Thank you for submitting your application for expedited review to Pepperdine University's Institutional Review Board (IRB). We appreciate the work you have done on your proposal. The IRB has reviewed your submitted IRB application and all ancillary materials. As the nature of the research met the requirements for expedited review under provision Title 45 CFR 46.110 of the federal Protection of Human Subjects Act, the IRB conducted a formal, but expedited, review of your application materials.

Based upon review, your IRB application has been approved. The IRB approval begins today July 31, 2020, and expires on July 30, 2021.

The consent form included in this protocol is considered final and has been approved by the IRB. You can only use copies of the consent that have been approved by the IRB to obtain consent from your participants.

Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit an amendment to the IRB. Please be aware that changes to your protocol may prevent the research from qualifying for expedited review and will require a submission of a new IRB application or other materials to the IRB. If contact with subjects will extend beyond July 30, 2021, a continuing review must be submitted at least one month prior to the expiration date of study approval to avoid a lapse in approval.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite the best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the IRB as soon as possible. We will ask for a complete written explanation of the event and your written response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the IRB and documenting the adverse event can be found in the *Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual* at community.pepperdine.edu/irb.

Please refer to the protocol number denoted above in all communication or correspondence related to your application and this approval. Should you have additional questions or require clarification of the contents of this letter, please contact the IRB Office. On behalf of the IRB, I wish you success in this scholarly pursuit.

Sincerely,

Judy Ho, Ph.D., IRB Chair

cc: Mrs. Katy Carr, Assistant Provost for Research