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Measuring the Self-Efficacy of Students Participating in VEX Robotics Competitions

Joseph S. Furse
Utah State University

MEASURING THE SELF-EFFICACY OF STUDENTS PARTICIPATING IN

VEX ROBOTICS COMPETITIONS

by

Joseph S. Furse

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Approved:

Gary A. Stewardson, Ph.D. Major Professor	Edward Reeve, Ph.D. Committee Member
Trevor P. Robinson, Ph.D. Committee Member	Michael L. Pate, Ph.D. Committee Member
Wade Goodridge, Ph.D. Committee Member	Richard S. Inouye, Ph.D. Vice Provost for Graduate Studies

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ABSTRACT

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by

Joseph S. Furse, Doctor of Philosophy

Utah State University, 2019

Major Professor: Gary A. Stewardson, Ph.D.
Department: School of Teacher Education and Leadership

Robotic competitions have become an increasingly popular educational tool to increase students' interest and achievement in STEM. The largest and fastest growing of these is VEX Robotics Competitions (VRCs). Although millions of dollars of funding are allocated, and countless hours of effort are expended annually to provide students with the opportunity to compete in VRCs, little research has been done to investigate the educational impacts of participation in these competitions. One promising research framework in this area is to investigate the self-efficacy of students who participate in VRCs. Self-efficacy has been shown to have a strong influence on students' career and educational interests, choices, and attainment. The purpose of this study was to investigate two research questions: (1) What factors influence VEX Robotics Competition participants' self-efficacy? (2) What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors? A cross sectional study was conducted utilizing Robinson's Self-Confidence Survey for VEX Robotics

Participants (SCSVRP) to measure VRC participants' self-efficacy in three constructs: Mechanical & Design, Programming, and Teaming & Professional Traits. In addition, the Post-Secondary Choices Survey was utilized to gather data about the relationship between VRC participants' self-efficacy and their post-secondary educational choices. Study participants were recruited over a period of 3 years at state- and national-level VRCs, as well as through nationwide recruitment efforts assisted by the CREATE Foundation. A total of 390 students participated in the SCSVRP, while 28 students participated in the Post-Secondary Choices Survey. Correlation and regression analyses were conducted to investigate the relationship between several predictor variables and overall self-efficacy. Correlation analysis was conducted to investigate the relationship between VRC participants' self-efficacy and their choice of major upon enrolling in post-secondary educational programs. The results indicated that VRC participants' self-efficacy was primarily influenced by their biological sex and the number of seasons they had participated in VRCs. In addition, self-efficacy was correlated with students' interest in choosing engineering majors, but not STEM majors more generally. Finally, a statistically significant relationship was found between self-efficacy and VRC participants' actual choice of STEM majors, but not engineering majors specifically.

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PUBLIC ABSTRACT

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Robotic competitions have become an increasingly popular educational tool to increase students' interest and achievement in STEM. The largest and fastest growing of these is VEX Robotics Competitions (VRCs). Although millions of dollars of funding are allocated, and countless hours of effort are expended annually to provide students with the opportunity to compete in VRCs, little research has been done to investigate the educational impacts of participation in these competitions. One promising research framework in this area is to investigate the self-efficacy of students who participate in VRCs. Self-efficacy, or the beliefs one holds about one's own abilities in a given area, has been shown to have a strong influence on students' career and educational interests, choices, and attainment. The purpose of this study was to investigate two research questions: (1) What factors influence VEX Robotics Competition participants' self-efficacy? (2) What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors? A cross sectional study was conducted utilizing Robinson's Self-Confidence Survey for VEX Robotics Participants (SCSVRP) to measure VRC participants' self-efficacy. In addition, the Post-Secondary Choices Survey was utilized to gather data about the relationship between VRC participants' self-efficacy and their post-secondary educational choices. Study participants were recruited over a period of 3 years at state- and national-level VRCs, as well as through nationwide

recruitment efforts assisted by the CREATE Foundation. A total of 390 students participated in the SCSVRP, while 28 students participated in the Post-Secondary Choices Survey. Correlation and regression analyses were conducted to investigate the relationship between several predictor variables and overall self-efficacy. Correlation analysis was conducted to investigate the relationship between VRC participants' self-efficacy and their choice of major upon enrolling in post-secondary educational programs. The results indicated that VRC participants' self-efficacy was primarily influenced by their biological sex and the number of seasons they had participated in VRCs. In addition, self-efficacy was correlated with students' interest in choosing engineering majors, but not STEM majors more generally. Finally, a statistically significant relationship was found between self-efficacy and VRC participants' actual choice of STEM majors, but not engineering majors specifically.

DEDICATION

I would like to dedicate this project to my dear mother, Nani Lii Staheli Furse, who passed away as a result of a car accident just a few weeks prior to the beginning of my doctoral studies. In too many ways to list, she is responsible for the person I am today and the successes I have experienced throughout my education. The most trivial of these was teaching me at a very young age to read and write well—skills I have relied heavily upon to produce this work. I remember many (sometimes tearful) late-night hours spent sitting in front of a computer screen writing, revising, and rewriting essays and stories for grade-school classes until they were of sufficient quality for mom to allow me to turn them in, which usually meant that my writing was far above and beyond the teacher's expectations.

Thank you, mom, for all you have taught me and the many significant sacrifices you have made to help me be successful throughout the years. Getting through graduate school without your physical presence has been a challenge, and I have missed your wisdom and being able to have a conversation with you. Nevertheless, I have felt your presence and relied upon your guidance many times over the past 5 years, and I cannot wait to meet you again on the other side. It seems appropriate that the defense of this dissertation will take place within just a few days of the anniversary of your passing, because in so many ways it is you who have made it possible. I love you, Mom.

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always being there with a huge smile and big hug at the end of a long day. To my father, Todd and my late mother, Nani, thank you for your advice, encouragement, and example, and for laying the foundation upon which I stand.

Finally, I would like to thank my Creator for giving me the talents, abilities, energy, and strength to see this through. I owe to you every success and every failure, every trial and every blessing which has made the life I enjoy possible.

Joseph S. Furse

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CHAPTER I

INTRODUCTION

Since their inception in the early 1990s, the popularity of educational robotic competition leagues for school children has increased dramatically in the United States, yet relatively little research exists which shows whether participation in these robotic competitions accomplishes educational goals. Today, hundreds of thousands of students participate in a wide variety of educational robotic competition programs throughout the United States and internationally. For example, according to the Robotics Education & Competition Foundation (RECF), the 2018 VEX Robotics World Championship tournament alone attracted over 30,000 participants, coaches, and fans representing more than 1,600 teams hailing from 30 countries (RECF, 2018a). In 2018, more than 20,000 teams participated in VEX Robotics Competitions (VRCs) worldwide, an increase of more than 2,000 teams since 2013, making it both the largest and the fastest growing robotic competition in the world (RECF, 2018b; T. P. Robinson, 2014; Stewardson, Robinson, Furse, & Pate, 2018). In addition to VRCs, many other robotic competitions exist worldwide, including the For Inspiration and Recognition of Science and Technology (FIRST) Robotics Competition (along with its subsidiaries, FIRST Tech Challenge and FIRST Lego League), Boosting Engineering Science and Technology (BEST), SeaPerch, the National Robotics Challenge (NRC), Botball, and others. Given the consistent growth of robotic competitions within the last several years (T. P. Robinson, 2014), it appears that participation will likely continue to increase.

In consideration of the number of students participating in educational robotic

competitions, and specifically VRCs, it is reasonable to ask what educational impacts have occurred as a result of the investment of financial and other resources enabling student access to these programs. Since the 1970s, self-efficacy has been studied relative to its impact on many areas of human learning and development, including its effects on educational achievement, persistence, and other impacts. However, the study of self-efficacy in relation to students who participate in robotic competitions is a relatively new area of research (Stewardson, Robinson, Furse, & Pate, 2018). This study explored the development of self-efficacy among students who participate in VEX Robotics Competitions, and the relationship between self-efficacy in VRCs and students' educational choices.

Statement of the Purpose

The purpose of this study was to investigate the factors which contribute to the development of self-efficacy among VRC participants, and whether self-efficacy impacts students' educational choices as it relates to pursuing STEM careers, with particular focus on engineering. Two research questions were developed for this study, along with hypotheses addressing each research question.

Research Question 1: What factors influence VRC participants' self-efficacy?

- Hypothesis 1A – Self-efficacy increases over years of participation in VRCs.
- Hypothesis 1B – Males have higher self-efficacy in VRCs than females.
- Hypothesis 1C – Students who have participated in other robotic competitions in addition to VRCs have higher self-efficacy in VRCs.
- Hypothesis 1D – Students who participate in VRCs as part of a formal, graded class have higher self-efficacy than students who participate in a more

informal setting.

Research Question 2: What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors?

- Hypothesis 2A: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing a STEM major.
- Hypothesis 2B: Students with higher self-efficacy in VRCs are more likely to choose a STEM major upon enrollment in post-secondary education.
- Hypothesis 2C: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing an engineering major.
- Hypothesis 2D: Students with higher self-efficacy in VRCs are more likely to choose an engineering major upon enrollment in post-secondary education.

Statement of the Need for the Study

Participation in competitive robotic events entails significant costs to organizers, mentors, parents, and participants. For example, schools and other sponsoring organizations can spend well in excess of $10,000 to field a FIRST Robotics Competition (FRC) team (FIRST, 2014a). It is often significantly less expensive to field a team for other robotic competitions, such as VEX Robotics Competitions (VRCs). As a result of these savings, schools that sponsor VRC teams often support more than one team and participate in several events throughout the competition season, adding to their financial costs. Monetary support for these costs is often provided by schools, fundraising efforts, and donations and grants from public and private sector sponsors, in addition to out-of-pocket expenditure by participants and their families. In summary, millions of dollars are spent each year by various entities to support student participation in just one of the larger robotic competitions available, (e.g., VEX or FIRST), not to mention moneys spent

on participation in all the smaller competitions (e.g., SeaPerch or Botball) that are also available (Stewardson et al., 2018). Each individual robotic team also requires a significant investment of human resources in the form of time and effort on the part of mentors, educators, volunteers, and parents. Many educators involved with supporting VRC teams as coaches and mentors work extra, often uncompensated hours in order to provide that support. Coaches, mentors and parents often spend many hours away from their families and careers in order to provide support for a robotic team (Stewardson et al. 2018).

Large expenditures of resources are required for participation in competitive robotics, and the political and social pressures placed on schools to increase emphasis on STEM education by investing resources in STEM activities including robotic competitions are high. As a result, researchers must investigate the outcomes of these competitions, in terms of educational gains made by students who participate. Is there correlation between participation as a member of a robotic team and different measures of educational success? How does participation in competitive robotics affect students over time? How does it affect decisions made by students, such as whether to attend college and which college major to select? Relatively few researchers have pursued these and similar questions, and those who have tend to compare students who participate in robotic competitions to students who do not participate in robotic competitions. The results of these comparisons seem to support the conclusion that competitive robotics is effective at attracting and engaging students who have a high interest in STEM, and specifically in engineering. This type of information is valuable in that it demonstrates

that competitive robotics could provide an effective avenue to foster and validate student interest in engineering. Similarly, one might surmise that a MathCounts program would attract students who are interested in mathematics, or that an orchestra program might attract students interested in playing musical instruments. However, it should be expected to some degree that any given educational program is likely to attract students who already have interest and perhaps even some ability in that area, but it does not necessarily follow that students who engage in any such activity receive any marginal benefit because of participation in that program. A possible next step, then, is to conduct studies that seek to compare participants at different levels of experience in robotic competitions, and to observe whether students who have participated in these activities for longer periods of time demonstrate desirable outcomes such as higher self-efficacy, higher achievement in STEM subjects, and increased likelihood of choosing a STEM major and following through to pursue a STEM career. Studies approaching robotic competitions from this angle would be by providing needed baseline knowledge to begin more robust studies investigating the value of robotic competitions as a means to accomplish educational goals Students who participate may merely be confirming activity choices which align with their interest in STEM on their way to post-secondary education and careers in those fields.

Stewardson et al. (2018) utilized Social-Cognitive Theory (SCT) and its sub-framework, Social Cognitive Career Theory (SCCT) to provide one useful lens through which the question of whether VRCs result in improved educational impacts may be effectively addressed. A central component of both SCT and SCCT is the concept of self-

efficacy, or "beliefs in one's capabilities to organize and execute the courses of action required to manage prospective situations" (Bandura, 1995, p. 2). These self-efficacy beliefs can have meaningful impacts on students' choices relating to future careers and post-secondary education in STEM fields (Stewardson et al., 2018). T. P. Robinson (2014) has developed a valid and reliable instrument to measure the self-efficacy of students who participate in VRCs called the Self-Confidence Survey for VEX Robotics Participants. Since Robinson's instrument has been developed, it has not been implemented in a large-scale study. T. P. Robinson stated that

> The research conducted with this instrument will be able to provide the VEX community, financial supporters, and school administrators with valuable information related to student outcomes from participation in competitive VEX robotics. (p. 87)

The magnitude of financial and other resources being devoted to support student participation in VRCs, along with the relative lack of robust research about whether participation results in measurable student outcomes, indicate a strong need for additional study using Robinson's instrument to assess the outcomes of participation in VEX Robotics Competitions. This study builds upon Robinson's work and aligns with his call for additional research utilizing his instrument to investigate the educational impacts of students' participation in VRCs.

Limitations of the Study

The following limitations were inherent in this study.

1. The study is limited to VRC participants within the U.S.
2. The scope of the instrument used for the study is limited to VRCs.

3. The data were obtained only from a sample of the population of VRC participants.

Assumptions of the Study

The following assumptions were inherent in this study.

1. Survey responses accurately represent the actual feelings or condition of the respondent.
2. The sample of VRC participants used in this study is representative of the overall population of VRC participants in the United States.
3. Any sample of first year VRC participants is similar to any other sample of first-year VRC participants in terms of baseline self-efficacy.

Summary of the Study Procedure

This study was conducted using a cross sectional design to compare self-efficacy and other variables among students at different levels of experience in VRCs. The survey instrument was administered to study participants near the end of the VRC season. The survey was administered across multiple years in order to maximize the number of responses, and some participants submitted survey responses for multiple years. Study participants who graduated high school during the study period were given a separate survey approximately one year after graduation to assess their post-secondary educational choices and progress.

Definition of Acronyms and Terms

BEST (Boosting Engineering, Science, and Technology): “A middle and high

school robotic competition whose mission is to engage and excite students about engineering, science, and technology as well as inspire them to pursue careers in these fields" (BEST, 2014, para. 2).

Botball: A middle and high school robotic competition that "engages middle and high school aged students in a team-oriented robotic competition" (KISS Institute for Practical Robotics, 2014, para. 1).

CREATE Foundation: The CREATE (Competitive Robotics Enhancing and Advancing Technology Education) Foundation is a "non-profit organization dedicated to aiding educational organizations, students, teachers and mentors in advancing the education of our youth in Science, Technology, Engineering and Math (STEM)" (CREATE, 2019, para. 1). The CREATE Foundation played an integral role in the recruitment of participants for this study. The CREATE Foundation also sponsors the CREATE Open robotic competition.

CREATE Open: An educational robotic competition founded and sponsored by the CREATE Foundation.

FIRST (For Inspiration and Recognition of Science and Technology): The mission of FIRST is "to inspire young people to be science and technology leaders, by engaging them in exciting mentor-based programs that build science, engineering and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership" (FIRST, 2014b, Mission section, para. 1). FIRST sponsors the FIRST Robotics Competition (FRC) and FIRST Tech Challenge (FTC), which are robotic competitions for high school and middle school students,

respectively.

MathCounts: “A non-profit organization that strives to engage middle school students of all ability and interest levels in fun, challenging math programs, in order to expand their academic and professional opportunities” (Mathcounts Foundation, 2014, para. 1).

NRC (National Robotics Challenge): An annual robotic challenge consisting of 12 individual robotic contests.

Outcome: A measurable result of participation in an educational activity.

ROAVcopters: “ROAV (remotely operated aerial vehicle) copters sponsors the ROAVcopter Challenge. ROAVcopters is an integrated STEM activity that blends the challenge of an engineering design problem with the excitement of a sporting event. The ROAVcopter Challenge engages students to program and fly ROAV quadcopters to compete in teams in a variety of skill challenges.” (ROAVcopters, 2019a).

SeaPerch: SeaPerch is an “underwater robotics program that equips teachers and students with the resources they need to build an underwater Remotely Operated Vehicle (ROV) in an in-school or out-of-school setting” (SeaPerch, 2013, para. 1).

Self-efficacy: A measure of a person’s confidence in his or her own ability to succeed at completing a particular task.

STEM (Science, Technology, Engineering, and Mathematics): A term which refers to fields, disciplines, or programs of study which integrate knowledge of science, technology, engineering, and mathematics. STEM education, also known as Integrative STEM (Wells & Ernst, as cited in International Technology and Engineering Education

Association [ITEEA], 2019), generally refers to educational curricula that focus on teaching of multiple areas of STEM together.

SCSVRP (Self-Confidence Survey for VEX Robotics Participants): The instrument developed by T. P. Robinson (2014) which was used in this study to measure the self-efficacy of students participating in VEX Robotics Competitions.

SWENext: An outreach program of the Society of Women Engineers for school-aged females interested in engineering.

VRC (VEX Robotics Competition): A robotic competition presented by the Robotics Education and Competition Foundation, in which "teams of students are tasked with designing and building a robot to play against other teams from around the world in a game-based engineering challenge. Classroom STEM concepts are put to the test on the playing field as students learn lifelong skills in teamwork, leadership, communications, and more. Tournaments are held year-round at the regional, state, and national levels; local champions go on to compete against the best in the world at the VEX Robotics World Championship each April" (VEX Robotics Incorporated, 2014, para. 1). It should be noted that the word "VEX" is not an acronym and has no established meaning in this context other than the name of the robotic competition.

CHAPTER II

REVIEW OF LITERATURE

Theoretical Framework

In order to adequately position this research in a theoretical framework, it was necessary to identify the underlying theoretical perspectives and assumptions guiding the research. Social Cognitive Theory (SCT) was identified as the overarching theory guiding the study. More narrowly, Social Cognitive Career Theory (SCCT) provided a robust framework for applying the self-efficacy mechanism in the context of investigating the impact of students' VEX Robotics Competition (VRC) participation as it relates to their education and career choices.

Social Cognitive Theory

Bandura's Social Cognitive Theory provides an anchoring perspective from which this study was conducted. According to Bandura (1991), self-regulation is a central lynchpin governing human actions and choices. While a person's actions are clearly influenced by external factors, the individual exercises a significant degree of control over thoughts, feelings, and courses of action based on his or her self-reflective and self-reactive capacities. Bandura theorized that "self-regulation operates through a set of psychological subfunctions that must be developed and mobilized for self-directed change" (p. 249) which include the self-monitoring of one's actions, judgement of those actions in light of environmental circumstances along with personal standards and goals, and affective self-reaction, or the satisfaction or dissatisfaction resulting from the

judgement of one's actions.

Central to the operation of these subfunctions is the mechanism of self-efficacy. Self-efficacy refers to the "beliefs in one's capabilities to organize and execute the courses of action required to manage prospective situations" (Bandura, 1995, p. 2). These self-efficacy beliefs "mediate the effect of skills or other self-beliefs on subsequent performance by influencing effort, persistence, and perseverance" (Pajares, 1996, p. 552). Bandura and Locke (2003) stated that, "among the mechanisms of human agency, none is more central or pervasive than beliefs of personal efficacy" (p. 87), and that self-efficacy has been found to be a strong influencer of human action in a variety of different contexts.

Self-efficacy, and its central role in self-regulating behaviors as described in the SCT literature provides the underpinning theoretical support for this study in its investigation of the self-efficacy beliefs of VRC participants, the development of these beliefs over time, and the effects of these beliefs on students' educational choices and success.

Social Cognitive Career Theory

A focusing lens which proved to be exceedingly useful in further specifying and operationalizing this study was provided by Social Cognitive Career Theory (SCCT). As the name suggests, SCCT draws upon the more general principles of SCT and applies those principles in the context of career development. According to Lent, Brown, and Hackett (2002),

> People help construct their own career outcomes…[and] their beliefs (for

> example, about themselves, their environments, and possible career paths) play key roles in this process. (p. 255)

Central to SCCT is the interplay between self-efficacy, outcome expectations, and personal goals, as they relate to the self-regulating behaviors leading to interest formation, career choice, and performance/persistence. It is important to note that educational or academic interests, choices, and performance are included within career interests, choices, and performance, as they are often nearly synonymous (Lent et al., 2002). According to SCCT, self-efficacy plays a significant role in mediating the relationship between internal or external influences (such as past experience, ability, gender, social pressures, economic factors, etc.) and career interests, choices, and performance (Lent et al., 2002). The evidence supporting the role of self-efficacy in interest development, vocational (and, by extension, educational) choices, and performance will be addressed in greater detail further on.

This study applies SCCT by investigating the relationship between students' self-efficacy beliefs in the context of the engineering challenges posed through participation in VRCs, and those students' chosen preferences for post-secondary study and career choices.

Self-Efficacy

The Nature of Self-Efficacy

Self-efficacy consists of one's beliefs about one's own ability to successfully organize and carry out a given course of action required to manage a prospective situation. These prospective situations often contain "many ambiguous, unpredictable,

and often stressful elements" (Bandura & Schunk, 1981, p. 587). These elements can result in one of two different views of the situation, based on whether the individual has a strong perception of his or her own capabilities to cope with the situation: either the situation is perceived as a threat to be avoided, or it becomes a challenge to be overcome (Bandura, 1977). Whether a person perceives a prospective situation as a threat or a challenge tends to determine the type of action that person will choose (i.e., whether to avoid the threat or to expend effort and persist in the face of obstacles; Bandura, 1977). According to Bandura, "the stronger the perceived self-efficacy, the more active the efforts" (p. 194). Furthermore, when a person successfully overcomes such a challenging situation, self-efficacy is reinforced, leading to increased likelihood that the person will continue to engage in similar challenging activities rather than pursuing a defensive course of action to avoid the perceived threat (Bandura, 1977). Of course, Bandura notes that successfully navigating a challenging situation is not solely dependent upon self-efficacy beliefs. A variety of other factors such as capability or external circumstances also influence the outcome. However, self-efficacy beliefs are a critical factor in determining whether a person will even attempt to put forth effort in the first place.

Self-efficacy expectations can vary on multiple scales. Bandura (1977) identifies three different variables upon which self-efficacy can be measured, including magnitude, generality, and strength. The magnitude of self-efficacy beliefs refers to the perceived difficulty of the tasks which individuals expect they can effectively address (Latham & Locke, 1991). The efficacy beliefs of a person who expects that they can accomplish a task they view as being very challenging are higher in magnitude than the efficacy beliefs

or a person who expects that they can only accomplish a task they perceive as being moderately or minimally difficult. Generality refers to the scope of the efficacy expectation (i.e., whether it applies only to a specifically circumscribed situation or whether it can be extended to a more general sense of efficacy that may apply in a wider variety of prospective situations). Finally, the strength of self-efficacy expectations refers to the impact of disconfirming experiences on the self-efficacy of the individual (Latham & Locke, 1991). A person who perseveres in the face of experiences which would tend to discount his or her efficacy beliefs can be said to have strong self-efficacy, while a person whose efficacy expectations are easily diminished by such experiences can be said to have weaker self-efficacy.

Developing Self-Efficacy

Self-efficacy beliefs can arise from several sources. Bandura's (1977) work identifies four sources of self-efficacy, including performance accomplishments, vicarious experience, verbal persuasion, and emotional arousal. Performance accomplishments include personal successes and failures which can increase or decrease the magnitude, generality, and/or strength of self-efficacy beliefs. Repeated success tends to lead to higher/stronger self-efficacy, while repeated failures tend to result in lower/weaker efficacy expectations. These effects can become generalized once efficacy expectations become well-established through repeated successes or failures. Performance accomplishments are likely the strongest source of self-efficacy beliefs, as it is difficult for other sources to overcome the effect of direct evidence obtained through personal experience. Although performance accomplishments occurring within personal

experiences are strong sources of self-efficacy, they are not the only source of self-efficacy.

Vicarious experiences, such as those gained by a child watching an older sibling climb a ladder at the playground, can also positively influence self-efficacy beliefs, provided that the observing individual (in this case, the younger child) already possesses the capabilities necessary to accomplish the task (e.g., if the child is tall enough to reach between the rungs of the ladder). The influence of vicarious experiences on self-efficacy are strengthened when the observed outcomes are clearly successful (or, conversely, unsuccessful).

Verbal persuasion represents a third source of self-efficacy, consisting of verbal attempts by another person to imbue certain outcome expectations in the individual "simply by telling them what to expect" (Bandura, 1977, p. 198). Although used often because of its ease of implementation, verbal persuasion is likely not a powerful means of instilling self-efficacy beliefs, according to Bandura, because the act of informing someone that they may expect a certain outcome does not necessarily mean the individual will believe in that outcome, especially if his or her personal experience suggests otherwise. This is not to say that verbal persuasion is never a source of self-efficacy beliefs, since, according to Bandura, "…people who are socially persuaded that they possess the capabilities to master difficult situations and are provided with provisional aids for effective action are likely to mobilize greater effort…" (1977, p. 198).

Finally, Bandura states that the emotional arousal which often accompanies stressful situations can also become a source for self-efficacy expectations. This can work

in favor of either higher or lower self-efficacy, depending on the nature of the emotions experienced. For example, the emotion of intense fear, such as might be experienced by a college student faced with a difficult final exam, might have a diminishing effect on self-efficacy. On the other hand, more positive types of emotional arousal, such as the feelings of pride and solidarity that might be evoked in the members of a sports team during a coach's pregame speech, might have a positive effect (Bandura, 1990; Vargas-Tonsing & Bartholomew, 2006). Weiner (as cited in Bandura, 1977) suggested that whether an emotional state will motivate and inform action depends upon the individual's cognitive appraisal of the emotional state.

Usher and Pajares (2008) also addressed these theoretical sources of self-efficacy in their review of literature focused on sources of self-efficacy in the school setting. Their work found strong support for mastery experience (the equivalent of Bandura's performance accomplishments) as a predictor of students' academic self-efficacy across a variety of academic disciplines. However, according to Usher and Pajares (2008), "findings for the other three sources have been less consistent" (p. 781), though they point out that methodological problems in the studies they evaluated may have contributed to these inconsistencies, rather than a failing of self-efficacy theory itself. Additionally, Usher and Pajares (2008) suggested that other sources of self-efficacy may yet exist, such as the self-messaging, or invitational messages, employed by students about their academic capabilities. There appears to be evidence that the invitational messages used by students about their capabilities may serve as sources of self-efficacy (Usher & Pajares, 2006; Zeldin & Pajares, 2000). Usher and Pajares (2008) as well as

Bandura (1998) in a later article, also identified transformative experiences known as chance events (though this may be a misleading term, as these events are typified by individuals having more control over them than they perceive) as potentially powerful sources of self-efficacy beliefs. These events can fundamentally alter “the furniture of our minds” (Usher & Pajares, 2008, p. 786), and, consequently, individuals’ beliefs about their own capabilities. An example of such an experience relevant to the context of this study could be students winning a major VEX Robotics tournament, such as a state/regional tournament in consequence of being picked as a member of the eventual winning alliance.

Environmental Factors Influencing Self-Efficacy

Environmental factors can also play a large role in the development of self-efficacy beliefs. Schunk and Pajares (2002) noted that the development of self-efficacy begins in infancy, and that “home influences that help children interact effectively with the environment positively affect self-efficacy” (p. 4). The sources of self-efficacy encountered in the home setting are varied and can work in the positive or negative direction. Children whose home environment is rich in mastery experiences that are challenging and interesting—but also attainable—tend to have higher self-efficacy (Schunk & Pajares, 2002). Schunk and Pajares (2002) also discuss the vital role parents play in providing modeling of perseverance and other efficacious behaviors which serve as vicarious experiences for children. Parents also serve as a persuasive influence by encouraging or discouraging children to try new things (Schunk & Pajares, 2002).

Peer groups, including both smaller groups and larger peer networks as strong

environmental influences on self-efficacy, primarily through the mechanism of vicarious experience (Schunk, 1987). The fact that peer groups tend to include individuals who are more similar to each other aids this effect (Schunk & Pajares, 2002). The effects of peer groups become more pronounced during adolescence (Schunk & Meece, 2006; Schunk & Pajares, 2002).

Another critical environment which has an impactful effect on self-efficacy is the school environment. Schunk and Pajares (2002) list a variety of potential factors occurring within the school context which impact self-efficacy, such as "greater competition, more norm-referenced grading, less teacher attention to individual student progress, …stresses associated with school transitions" (p. 7), rigidly sequenced instruction, ability grouping, and social comparison.

> Students' involvement and participation in school depend in part on how much the school environment contributes to their perceptions of autonomy and relatedness, which in turn influence self-efficacy and academic achievement. (p. 7)

Lent et al. (2002) also highlighted the importance of schooling in the development of efficacy beliefs when they stated that "methods for fostering reliable self-efficacy and outcome expectations and for maximizing development of abilities may be most useful during the school years, when students' self-percepts and occupational beliefs are likely to be relatively malleable" (p. 287).

Self-Efficacy and Interest

According to SCCT, self-efficacy is a critical component in the theoretical model of interest development. Researchers in career psychology have identified self-efficacy as

an important factor in determining vocational interests (Betsworth & Fouad, 1997). It is also reasonable to include educational interests as part and parcel with vocational interests, since SCCT acknowledges the close relationship between education and vocation, and since all vocations require some form of education. The model of interest development proposed by Lent et al. (2002) asserts "that self-efficacy and outcome expectations regarding activity involvement exert an important, direct effect on the formation of career interests" (p. 265). Lent et al. argue that an individual who is confident in their ability to perform some activity at a high level and who believes that they will benefit from the performance will develop an interest in that activity. In the broader context of career psychology, as well as in the narrower context of this study investigating the relationship between VRC participants' self-efficacy and post-secondary educational and career preferences, this is a critical question.

A database and Internet search was conducted for meta-analytic literature reviews investigating the relationship between self-efficacy and vocational and/or academic interest using the search terms "self-efficacy," "interest," and "meta-analysis." Narrowing terms such as "vocational" and "academic" were deliberately avoided in order to cast the widest possible net. Literature reviews which directly addressed the relationship between self-efficacy as an independent variable and either vocational or academic interests as a dependent variable were selected. Three relevant meta-analyses were found investigating the relationship between self-efficacy and interest as described in the SCCT literature, including Lent, Brown, and Hackett (1994), Rottinghaus, Larson, and Borgen (2003), and Sheu et al. (2010).

In their path analysis of 45 independent samples encompassing more than 11,000 participants, Sheu et al. (2010) found effect sizes ranging from .57 to .71 between self-efficacy and vocational interest across RIASEC (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional) occupational themes (Holland, 1997). Among their many other findings, Sheu et al. concluded that, "self-efficacy produced a direct path to outcome expectations, and both of these variables were predictive of interests" (p. 259). This finding would seem to support the model proposed by Lent et al. (2002), in which the formation of career interests is directly related to self-efficacy.

Rottinghaus et al. (2003) also conducted a meta-analysis of 60 samples representing over 37,000 individual participants and found a moderate correlation across all RIASEC domains between vocational interests and self-efficacy with an average weighted mean effect size of .59, which translates to approximately one third of the variance being shared between self-efficacy and vocational interests. In addition, Rottinghaus et al. also explored the efficacy-interest relationship in more depth, addressing domain-specific relationships as well as gender and age differences. They found that although variations between domains did exist, the linkage between self-efficacy and vocational interests was consistently strong across various domains. Sex differences were not substantial, although Rottinghaus et al. are quick to point out that more research is needed to "examine sex differences in specific instances where theory suggests the possibility of gender-role socialization" (p. 231). Finally, Rottinghaus et al. found that age group moderated the relationship between self-efficacy and interests, with the strongest relationship existing among working adults followed by college students.

The weakest relationship between self-efficacy and interests was found among adolescents, but the authors point out that the domains measured by samples including adolescents "examined traditionally female and/or male domains whose correlations were weaker" (p. 232) in comparison to more basic domains with stronger correlations for working adults. These findings seem consistent with those of Sheu et al. (2010), previously discussed.

Finally, in an earlier meta-analysis, Lent et al. (1994) evaluated the results of 13 different studies examining whether occupational or academic interests reflect self-efficacy beliefs and outcome expectations, as postulated in their interest development model. They found that "self-efficacy expectations and outcome expectations each appear to account for approximately 27% of the variance in vocational interests" (p. 110). In a related question, Lent et al. also investigated whether the relationship between occupational interests and concomitant abilities were mediated by self-efficacy. Their results indicated that "the relation of aptitudes to interests is eliminated when self-efficacy is controlled, thereby suggesting that the ability-interest relation is fully mediated by self-efficacy" (p. 110). Finally, (although the results that follow were not meta-analytic due to a low number of relevant studies) Lent et al. found that self-efficacy and outcome expectations in combination were the best predictor of interest in academic courses, exceeding the predictiveness of either variable in isolation.

Although all three of the reviews just discussed pointed out the need for more rigorous longitudinal studies to establish causality, all three were largely consistent in their findings, which in all cases appear to support the existence of an important

relationship between self-efficacy and interests in the interest development model proposed by Lent et al. (2002). Thus, it seems reasonable to argue, based on available evidence, that an individual's self-efficacy bears a strong relationship to whether that person will show interest in a particular field of vocation, along with the accompanying educational path. The importance of this conclusion is evident when considered in light of this study, which sought to examine the relationship between participation in VRCs and self-efficacy, and the educational and career choices preferred by students who participate in VRCs. A strong relationship between self-efficacy and career interests begs investigation into whether VRC participation results in higher self-efficacy, which in turn might lead to more interest in STEM careers and post-secondary education.

Self-Efficacy and Career/Educational Choice

In addition to the relationship between self-efficacy and vocational interests, Lent et al. (2002) also postulated that self-efficacy has a direct impact on vocational choice goals and choice actions in their career choice model, identifying "self-efficacy and outcome expectations as shapers of interest patterns and as co-determinants of choice" (p. 274). This choice model simultaneously incorporates and expands upon the model of basic interest-development discussed in the preceding section. According to Lent et al., "the relationship of these two models reflects the developmental continuity between the evolution of basic vocational interests and their eventual translation into career-relevant choices" (p. 272).

It should be noted here that Lent et al. indicate that the primary effect of self-efficacy on career choice is through the development of basic interests (i.e., self-

efficacy's effect on career choice is largely indirect), however, they also note that a direct effect on choice goals and choice actions must exist, since, "for many persons, career choices are not made under 'optimal conditions'" (p. 274) in which interests lead directly to career choice. Other external factors such as economic conditions, personal finances, family responsibilities, etc. also play a role (Astin, 1984; Krumboltz, Mitchell, & Jones 1976), and in these situations self-efficacy and outcome expectations act directly on choice goals and actions within the constraints imposed by these other factors. Following the same pattern as in the previous section, a database and Internet search was conducted to locate evidence pursuant to the relationships between self-efficacy and choice goals or choice actions in the career choice model.

Sheu et al. (2010), conducted a meta-analytic path-analysis of the choice model across Holland themes. Their findings supported the proposed relationship between self-efficacy and choice goals proposed by Lent et al. They stated that "the current meta-analysis suggests that outcome expectations and self-efficacy each contribute usefully to the prediction of interests, and, along with interests, help to explain variation in choice goals…" (p. 262). Their findings also agreed with the supposition of Lent et al. that much of the effect of self-efficacy was indirect, but that direct effects do exist and are important. Sheu et al. stated that:

> In some cases, our meta-analytic findings showed that outcome expectations produced larger direct path coefficients than did self-efficacy, although it should be noted that the total effect of self-efficacy includes its indirect path through outcome expectations. That is, self-efficacy is assumed to function both as an antecedent of outcome expectations (and interests) as well as a direct contributor to goals. (p. 262)

In summation, Sheu et al. found that the choice model proposed by Lent et al. accurately

predicted that self-efficacy would have an appreciable effect on choice goals, both indirectly through outcome expectations and interests, as well as directly.

Lent et al. (1994) also found support for the relationship between self-efficacy and vocational choice in their meta-analysis. They found a statistically significant, positive correlation between self-efficacy and choice goals with a small-to-medium effect size ($r = .40$, $p < .01$). In addition, they also found a significant and positive correlation between interests and choice goals ($r = .60$, $p < .001$). Interpreting these results, Lent et al. stated that:

> The data are largely consistent with expectations that much (but not all) of the influence of self-efficacy and outcome beliefs on goals is mediated by interests: the correlations of self-efficacy and outcome expectations to choice goals are substantially reduced but not eliminated when the influence of interests is partialled out. Thus, it appears that the effects of self-efficacy and outcome beliefs on goals are largely channeled through interests, but that both sets of cognitions also assert a small direct effect on goals, independent of interests. (p. 111)

Given the results of these two meta-analyses, it is reasonable to proceed under the assumption that self-efficacy has an important relationship with vocational choice goals; thus, a change in self-efficacy will likely have impact on these goals and subsequent career choices. As it relates to this study, if participation in VRCs increases a student's confidence in their ability to participate successfully in this engineering competition, the likelihood that the student will express a preference for a future career in engineering (or, perhaps in STEM more broadly) should increase as well.

Self-Efficacy and Performance

The third model of the SCCT triumvirate postulated by Lent et al. (2002) is the task performance model. This model "is concerned with the level (or quality) of people's

accomplishments, as well as with the persistence of their behavior in career-related pursuits" (Lent et al., 2002, p. 277), including academic pursuits. According to Brown et al., "…work and academic performance is a function of five conceptually distinct but interrelated (in a reciprocal manner) cognitive and behavioral variables" (p. 299). These variables are general cognitive ability, past performance, outcome expectations, self-efficacy, and performance goals. The role of self-efficacy is central to career-related performance (which includes academic performance) and mediates the effects of ability and past performance on performance attainment levels directly as well as indirectly via its impact on outcome expectations and performance goals (not to be confused with the choice goals referenced in the preceding section) which in turn impact performance attainment. According to Lent et al., while it is important to recognize that self-efficacy does not override objectively assessed ability, it is still important to consider how people view their own abilities in a given performance domain, and how effectively they are able to marshal those abilities to accomplish a given task. In other words, when a person is presented with a challenging task, their performance depends both on their capabilities and on their sense of personal efficacy in deploying those capabilities resulting in a positive outcome. This sense of self-efficacy has direct impacts on performance attainment, as well acting indirectly by influencing the kind of performance goals people set. An individual with high self-efficacy in the performance domain would therefore tend to set more challenging goals and simultaneously be more likely to achieve those goals, provided that their sense of self-efficacy was aligned with their performance capabilities (Lent et al., 2002). Thus, according to the model of task performance put

forth by Lent et al., self-efficacy represents an indispensable factor in determining whether an individual will be successful in establishing and attaining career-related performance goals.

To evaluate whether the predictions of the performance model held true as they relate to self-efficacy, a search was made for reviews of literature addressing the relationship between self-efficacy and career-related performance attainment. Since this study is primarily concerned with academic performance as it relates to career development, as opposed to career-related performance more broadly (which would include other career-related performance such as job performance), and because the body of literature on this relationship appeared to be very large, an effort was made to narrow the search by utilizing the following search terms: "self-efficacy," "academic performance," "career," and "meta-analysis." Meta-analytic reviews which addressed the relationship between self-efficacy and academic performance as it relates to career development were selected for inclusion in this review of literature. Five reviews were located and are addressed here, beginning with the most recent.

Sheu and Borden (2017) found only inconclusive evidence for the performance model in their meta-analysis of international SCCT research. However, they noted that the performance model has received far less scholarly attention internationally than the choice model, and that only a few studies had addressed the performance model. In addition, Sheu and Borden acknowledged that their international approach generated questions about the cultural applicability and operationalization of the SCCT models which warrant further study in order to understand how self-efficacy and performance are

related in diverse cultural settings.

Brown et al. (2008) found strong evidence supporting the impact of self-efficacy on two indicators of academic performance: college GPA (representing performance attainment) and retention (representing persistence). Their meta-analysis focused on validating findings from an earlier analysis (see discussion of Robbins, Lauver, Le, Davis, & Langley, 2004, below) of bivariate relationships found within the SCCT performance model in a multivariate approach with the goal of estimating “the fit of the model to the data when all relevant variables are included” (Brown et al., 2008, p. 300).

When investigating the strength of the performance model in predicting college GPA, Brown et al. (2008) used high school SAT/ACT scores as a measure of prior attainment, college completion as the performance goal, and college GPA as the performance outcome. In this test, the model predicted that the effect of self-efficacy on GPA would primarily be mediated by performance goals. Surprisingly, the results indicated that the indirect effect of self-efficacy on GPA as mediated via performance goals was nearly zero, but instead the effect of self-efficacy on GPA was primarily a direct effect on GPA. Brown et al. suggested that this could either be a result of a methodological breakdown caused by a mismatch between the performance goals (intentions to complete college) and performance outcomes (college GPA), or it could be the result of the importance of self-efficacy exceeding that of goals in terms of increasing performance attainment. Brown et al. seem to believe that the former explanation is more likely, though the implications of the latter explanation, if true, would be interesting. In any case, Brown et al. show that self-efficacy is directly linked to performance attainment

(in the form of college GPA) and may be indirectly linked via its influence on performance goal setting (in the form of intention to complete college).

Brown et al. (2008) also addressed the performance model in terms of persistence. Persistence, defined essentially as perseverance in the face of difficulty, has a profound influence academic success, including in STEM disciplines (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Marra, Rodgers, Shen, & Bogue, 2009; Mateo, 2014). Brown et al.'s findings were based on the SCCT performance model where persistence was the measure of academic success as represented by retention. In their analysis, the data indicated that neither ability nor past performance had a direct relationship to persistence, but that these effects were mediated via self-efficacy beliefs and goals. Brown et al. asserted that "academically able students are no more likely to finish college than are less able ones unless they develop strong confidence in their college academic capabilities…" (p. 306).

The analysis conducted by Brown et al. (2008) provides robust support for the assumption that self-efficacy plays an indispensable role in mediating the relationship between past experience and success when it comes to a student's ability to succeed academically in a college setting, both in terms of performance attainment and persistence. Since, as was discussed earlier, self-efficacy beliefs primarily arise from prior experiences (e.g., past performance experience), the study by Brown et al. seems to support the assumption that success at the college level is in large part determined by the experiences, including STEM experiences (Bottia, Stearns, Mickelson, Moller, & Parker, 2015) that happen prior to college entrance during high school and earlier years. In light

of this study, it seems reasonable to predict that participation in an engineering experience such as VEX Robotics should bolster students' self-efficacy that they can be successful in engineering programs at the college level.

Robbins, Lauver, Le, Davis, and Langley (2004) conducted a meta-analysis of 109 studies which investigated the relationship between psychosocial and study skill factors (PSFs) college performance (represented by college GPA) and educational persistence (represented by college retention). The PSFs were categorized into 9 constructs, including: achievement motivation, academic goals, institutional commitment, perceived social support, social involvement, academic self-efficacy, general self-concept, academic-related skills, and contextual influences. While Robbins et al. were not specifically focusing on SCCT's performance model, their study investigated multiple bivariate relationships found within the SCCT performance model, thus making their findings very relevant to the present discussion.

With respect to educational persistence, results of this analysis indicated that academic self-efficacy was comparable to traditional predictors of retention (e.g., socioeconomic status, high school GPA, ACT/SAT scores) in its predictive power. Additionally, academic self-efficacy was found to be one of the strongest predictors of college retention out of the PSFs included in the analysis. According to Robbins et al. (2004), "educational persistence models may underestimate the importance of academic engagement, as evidenced by academic goals, academic-related skills, and academic self-efficacy constructs, in college students' retention behavior" (p. 275). With respect to academic performance, Robbins et al. found that academic self-efficacy was among the

strongest predictors of college GPA, along with achievement motivation, high school GPA, and ACT/SAT scores. Robbins et al. noted that when considering both retention and achievement, academic self-efficacy was the best single predictor for both outcomes. Robbins et al. stated that, “the real question then may be not whether improved study skills alone raise academic performance, but how study skills combine with social and motivational factors to ensure positive student action” (p. 276).

Lent et al. (1994) posited that self-efficacy beliefs would influence career and academic performance both directly, and indirectly via performance goals. They hypothesized that positive correlations would exist between self-efficacy beliefs and academic performance, and that this relationship would be reduced when controlled for performance goals. Lent et al. conducted a meta-analysis to determine whether these hypotheses turned out to be accurate and found that self-efficacy was indeed correlated with academic and vocational performance with a moderate effect size. Although Lent et al. did not test whether this correlation was attenuated when controlled for performance goal setting, other researchers have supported this reasoning (e.g., Latham & Locke, 1991). In addition, Lent et al. hypothesized that self-efficacy was a partial mediator of the effect of ability on performance. Their findings indicated the expected reduction in the effect of ability on performance when self-efficacy was partialled out.

Multon, Brown, and Lent (1991), conducted two meta-analyses investigating the relationship between self-efficacy and academic performance, and between self-efficacy and persistence, respectively. The analysis for academic performance utilized 38 independent samples, comprising 36 studies representing 4,998 participants. These 38

samples utilized 19 separate indicators of academic performance for students ranging in age from elementary to college, which were grouped into three categories of performance, including standardized achievement tests, classroom-related measures (e.g., GPA), and basic skill tasks. The data indicated that approximately 14% of the variance in academic performance was accounted for by self-efficacy beliefs. In their analysis of the relationship between self-efficacy and persistence, Multon et al. utilized 18 samples from 18 studies representing 1,194 participants. Persistence was categorized as time spent on task, number of items/tasks completed, or the number of academic terms completed (e.g., college semesters). The results of this analysis indicated that approximately 12% of the variance in persistence across the board was explained by self-efficacy beliefs. Multon et al. do note that there was a large amount of variability between effect size estimates for both performance and persistence when these were covaried with subject and study characteristics. For example, effect sizes for self-efficacy and academic performance in different age groups ranged from r =.21 for elementary-age students to r = .41 for high school students, with college students falling between at r = .35. Also of interest, Multon et al. found that the strongest effect sizes for self-efficacy on performance were found when the "level of measurement involves discrete, specific, proximal tasks, as opposed to more complex, multifaceted, or distal behaviors" (p. 35). Thus, studies which measured the effect of self-efficacy on performance in basic, domain-specific skills tended to produce higher effect sizes on performance compared to studies which measured more broad performance measures such as standardized achievement tests.

Aside from Sheu and Borden (2017), whose inconclusive results were hampered

by a lack of available research, the five meta-analytic reviews discussed in this section provide robust support for the SCCT performance model. Regardless of methodological approach (e.g., bivariate, multivariate, path analysis, etc.), the positive relationship between self-efficacy and academic performance, as measured by either achievement or persistence appears to hold. Since this study seeks to investigate whether self-efficacy beliefs of VRC participants improve over time, and whether these beliefs have an impact on their educational choices and performance (especially persistence in engineering programs at the college level), the relationship between self-efficacy and performance becomes of critical importance.

Self-Efficacy in STEM

Support in the literature for the relevance of self-efficacy in STEM education generally and engineering education specifically is robust. Many studies and reviews of literature have been conducted investigating self-efficacy and its effect on various outcomes in the context of STEM disciplines. Rittmayer and Beier (2009) suggested that STEM educators “should pay as much attention to students’ self-efficacy—their perceptions of capability—as they do to students’ actual capability” (p. 8). Based on this assertion, self-efficacy should be considered as it relates to post-secondary and secondary STEM education, along with extracurricular STEM experiences.

Self-efficacy in post-secondary STEM education. Olson and Riordan (2012) noted in their President’s Council of Advisors on Science and Technology (PCAST) Report to the President that the majority of students who begin STEM majors in college do not persist to completion, and that increasing students’ confidence in their abilities

increases persistence in STEM majors. Graham et al. (2013) also identified self-efficacy as an essential requirement for persistence and stated that “it is imperative that persistence efforts address motivation and confidence” (p. 1455). A longitudinal study of the academic persistence model among 350 Latino/a and white engineering students found that self-efficacy had an indirect effect on persistence mediated via engineering persistence goals (Lee, Flores, Navarro, & Kanagui-Muñoz, M., 2015). Lent et al. (2016) conducted a longitudinal study investigating the effect of social cognitive predictors including self-efficacy on the academic persistence and performance of 908 engineering undergraduates and found that self-efficacy predicted students’ persistence in engineering over four academic semesters.

In addition to academic persistence in STEM majors, self-efficacy has also been identified as an important predictor of student interest in and choice of STEM majors generally and engineering more specifically. In a study investigating the academic goal-setting of African American, Latino/a, Southeast Asian, and Native American (ALANA) undergraduate students majoring in biology and engineering, Byars-Winston, Estrada, Howard, Davis, and Zalapa (2010) concluded that “it is likely that bolstering self-efficacy beliefs will have a positive, dual effect on strengthening the academic interests and goals of ALANA students in STEM majors” (p. 215). Lent et al. (2008) investigated the longitudinal relationship between self-efficacy, outcome expectations, and major choice goals in 209 beginning engineering students. Their results indicated that self-efficacy was correlated with and temporally antecedent to students’ outcome expectations, interests, and goals. Conversely, a relationship in the opposite direction (i.e., interests, goals, etc.

being temporally antecedent to self-efficacy) was not supported, which would be consistent with a causal role played by self-efficacy in predicting these outcomes.

Self-efficacy in secondary STEM education. The relevance of self-efficacy in STEM education is not limited to post-secondary students. Pajares and Graham (1999) conducted a study of 273 first-year middle school mathematics students and found that task-specific self-efficacy was the only variable which independently predicted mathematics performance. Additionally, Pajares and Graham found that high-performing students tended to have a more accurate sense of mathematics self-efficacy and were thus less overconfident in their abilities. Britner and Pajares (2006) investigated the impact of self-efficacy sources on science self-efficacy, and the relationship between science self-efficacy and science achievement. They found that their results confirmed and extended earlier findings among high school students (e.g., Kupermintz, 2002; Lau & Roeser, 2002) that science achievement was an important predictor of science achievement, and that a decrease in science self-efficacy during secondary years can have a negative impact on high school and college science achievement. Brown, Concannon, Marx, Donaldson, and Black (2016) conducted a study investigating the relationship between middle school students' self-efficacy in STEM and their interest in and perceptions of STEM. The results of their study showed that self-efficacy and students' perception of STEM were the best indicators of students' intention to persist in STEM education before the students had engaged in STEM instruction. Interestingly, Brown et al. concluded that interest in STEM became the best predictor of intention to persist in STEM after students had engaged in STEM instruction. However, Brown et al. did not partial out the effect of

interest that was independent of self-efficacy, thus, given the effect of self-efficacy on interest in the SCCT interest model, it seems likely that self-efficacy still exerted an influence on intent to persist via its influence on students' interest in STEM. In a mixed-methods study involving 1,066 middle school students, Degenhart, Wingenbach, Dooley, Lindner, Mowen, and Johnson (2007) found that students' beliefs about their ability in a particular subject area (e.g., science, mathematics, engineering, technology) predicted whether they would respond positively to the prospect of pursuing a career within that discipline. Furthermore, "students who indicated subject area as a determinant of future STEM career pursuit indicated that changes in their own perceived ability in that subject influenced their like or dislike of the subject" (p. 57).

Extracurricular STEM experiences. In addition to traditional in-school curricula, extracurricular STEM activities have been identified as a means of increasing secondary students' self-efficacy in STEM. According to Fantz, Siller, and DeMiranda (2011), pre-collegiate participation in extra-curricular engineering activities or hobbies outside of school (e.g., robotic competitions, Science Olympiad, model rocketry, etc.) resulted in statistically significant increases in engineering self-efficacy among 332 first-year engineering undergraduates, as did participation in formal technology education and pre-engineering classes during high school and middle school. However, individual extracurricular programs (e.g., FRC, Science Olympiad, etc.) did not produce statistically significant results although moderate effect sizes were achieved. This was likely due to lack of statistical power when parsing out to individual programs, thus it seems that studies with larger sample sizes investigating individual programs are necessary to

determine whether these effects exist. Skorinko and Doyle (2012) found that students reported higher academic self-efficacy at the end of a season of participation in FRCs, and that this effect was more pronounced among females than among males.
Mason and Cooper (2013) found that female students had higher computer programming self-efficacy after participating in an information technology workshop which was centered around programming Lego Mindstorms robots. Nugent, Barker, Grandegenett, and Adamchuk (2010) found statistically significant pre-to-post increases in robotics self-efficacy with a large effect size ($r = .72$) for students who participated in an intensive summer program focusing on robotics, geographic information systems (GIS), and global positioning systems (GPS).

Interestingly, Sahin, Ekmekci, and Waxman (2017) found that participation in out-of-school STEM activities (e.g., STEM club, STEM projects, science fair, etc.) did not predict whether students would choose a STEM major in college, but that students with higher math and science self-efficacy were more likely to do so. Conversely, although they did not address self-efficacy directly, other studies have found that participation in STEM activities outside of school is related to students' choice of STEM majors in college (e.g., Bottia et al., 2015; Dabney et al., 2012; Hendricks, Alemdar, & Ogletree, 2012; Melchior, Cohen, Cutter, & Leavitt, 2005). Although, again, these studies did not directly address self-efficacy, they addressed interest and career choice, which, according to SCCT, are both influenced by self-efficacy, as has been discussed above. Of particular relevance to this study, Melchior et al. found impressive correlations between students participating in FRCs and choice of STEM majors, and engineering majors in

particular. However, Melchior et al. did not control for prior interest in those career paths, thus raising questions about whether the high rate of students' choice of engineering majors was a result of participation in FRCs or merely the result of prior interest in engineering. Similarly, Hendricks et al. found exceptionally high interest in further pursuit of STEM education and careers among VRC participants, but also failed to account for prior interest. Clearly, more research on this topic is needed to parse the relationships between students' participation in extracurricular STEM activities, their self-efficacy, and their educational choices and success.

VEX Robotics Competitions

Comparison to Other Robotic Competitions

In 1992, the first competitive event of the For Inspiration and Recognition of Science and Technology robotic competition took place in Manchester, NH (FIRST, 2019). This would prove to be a watershed moment in secondary STEM education. Although other robotic competitions had existed since the late 1970s (A. L. Robinson, 1978), they were mainly geared toward adult hobbyists and professionals. FRC pioneered the concept of educational robotic competitions that mimicked a team-based sporting environment designed to appeal to students (T. P. Robinson, 2014). Since that first FRC event, educational robotic competitions have exploded in popularity, with a variety of different competitions in every imaginable flavor taking place all over the world. Examples of robotic competitions include but are in no way limited to FIRST Lego League (FLL), FIRST Tech Challenge (FTC), VEX Robotics Competition, VEX IQ

(VIQ), CREATE Open, ROAVcopters Quadcopter Competition (RQC), Botball, SeaPerch, and others. Each of these examples represents a unique variation in competition format, cost, restrictions on mechanisms/materials, type of robots used, participation, and the timing and number of individual events taking place.

This study addresses the VEX Robotics Competition, which is a robotic competition that utilizes a team-based ‘alliance’ format in which pairs of teams compete against one another in timed matches that mimic many aspects of a sporting event or game. Points are scored by placing objects in goals or accomplishing a variety of other tasks, such as positioning the robot or a special scoring object in a certain location at the end of the match. Matches consist of an autonomous period in which the robot may only operate without operator input, followed by a “driver-control” period in which the robot is operated remotely by the driver (although semi-autonomous programming is often used during the driver-control period as well). Match winners are determined by the alliance scoring the most points. A VRC event consists of preliminary rounds in which teams are selected for alliances at random, and each team competes in several matches. Following preliminary rounds, teams move on to elimination rounds. Top-ranked teams select two additional teams as alliance partners, and all three teams compete as an alliance for the remainder of the event. Alliances are seeded based on the ranking of the highest-ranked team on the alliance and compete in best-of-three elimination rounds in which each team on each alliance must compete in at least one match for each round. After all elimination rounds are complete, the teams on the winning alliance are the tournament champions. In addition to the tournament championship, VRC events distribute special awards based on

judging, overall performance, and performance in a certain aspect of the competition (e.g., programming, operator control, etc.). The highest honor of a VRC event is the Excellence Award which is awarded to the best overall team in all phases of the event. This information, along with more on the specifics of VRCs can be found by accessing the current VRC game manual (e.g., VEX Robotics Inc., 2019).

VRCs represent a unique combination of characteristics compared to other robotic competitions, although VRCs are most similar in many aspects to FRCs, given their shared history in the early days of VRCs (T. P. Robinson & Stewardson, 2012; T. P. Robinson, 2014). Unlike FRC and some other robotic competitions (e.g., Botball), the VEX Robotics Competition consists of a ‘season’ featuring multiple ‘qualifier’ events spanning several months and culminating in state/regional, national (in some countries), and world championships, not unlike the format of sporting events such as basketball or football in which teams play multiple games against local competition before advancing to championship events. This format allows many engineering design iterations over a prolonged period of testing and redesign (Bartholomew & Furse, 2015; T. P. Robinson, 2014). Other robotic competitions (e.g., FIRST, FTC, Botball, etc.) utilize the approach of a limited-time build period, followed by a one-time event in which the winners qualify to advance to the next level of competition (Bartholomew & Furse, 2015).

Another key difference between VRCs and other robotic competitions is cost. VRCs fall on the upper end of the cost scale compared to other robotic competitions but maintain a relatively achievable cost compared to the most expensive competitions such as FRCs, which cost $5,000 in entry fees alone for a single event. This does not include

additional costs for materials/parts, travel, etc., which can exceed $10,000 for a typical FRC team (T. P. Robinson & Stewardson, 2012; Johnson & Londt, 2010). Typical entry fees for a VRC event range from less than $40 for a small regional/state qualifier event (RECF, 2019a) to $975 for the VRC World Championship (RECF, 2019b). Since teams typically compete in multiple events over the course of a season, these costs add up along with travel and other expenses. Parts and material costs for a typical VRC robot run in the neighborhood of $1,500, which is a significant reduction compared to the most expensive competitions (T. P. Robinson, 2014). VRC participants can select only proprietary parts or their exact equivalent from an approved list which may be re-used year after year; however, due to the proprietary nature of the approved parts this results in increased expenses compared to other competitions such as SeaPerch and ROAVcopters which reduce costs by limiting competitors to a pre-defined parts kit and/or imposing cost limits (ROAVcopters, 2019b; SeaPerch, 2019).

Educational Impact of VRCs

Studies assessing the educational impacts of participation in VRCs are few in number and even fewer addressed self-efficacy. A database and internet search for studies addressing this topic netted only a handful of individual articles. The majority of articles located through this method were focused on curriculum development, (e.g., T. P. Robinson & Stewardson, 2012) or were informational in nature (e.g., Caron, 2010) rather than research assessing the educational impact of VRCs. Only a few studies sought to address the educational impact of participation in VRCs.

Hendricks et al. (2012) conducted a mixed-methods program evaluation of VEX

Robotics Competitions at the request of the RECF, which administers VRC events to "determine whether VRC was meeting its goal of inspiring students to pursue STEM education and career paths" (p. 2). Online surveys were taken by 341 middle and high school VRC participants and 345 VRC team leaders. These online surveys were designed to assess impacts of VRC participation on students' interest in STEM education and careers as perceived by the students and by their team leaders. A few VRC participants and team leaders were also selected to participate in semi-structured focus groups and/or individual interviews. Interestingly, Hendricks et al. noted that their evaluation results did address self-efficacy, but these data were not published in their paper and unfortunately do not appear to be publicly available. According to the results of this study, 92.4% of VRC participants reported wanting to learn more about robotics as a result of participation in VRCs, while 89.8% of participants reported that VRC participation made them want to learn more about engineering design. 87.4% of students reported more interest in pursuing a STEM career as a result of their VRC participation. Although these results are encouraging, the reliance on participants' recollection of whether VRC participation increased their interest in STEM after the fact is a concerning methodological weakness. This study would have been strengthened by utilizing a design which allowed for comparison of interest levels at different time periods to assess whether interest actually increased in conjunction with VRC participation.

A dissertation study conducted by T. P. Robinson (2014) developed an instrument for measuring self-efficacy of VRC participants. According to Robinson,

> The research possibilities that can come from the application of this survey instrument will benefit the VEX community by providing valuable information

> related to the outcomes of the student population in competitive VEX robotics. (p. 82)

Though his work was focused on instrument development rather than reporting on the self-efficacy of VRC participants directly, his work is invaluable to this study in providing a robust measuring tool to collect participant data. According to Robinson, overall instrument reliability as measured by Cronbach's alpha was .916. Robinson's instrument also measured self-efficacy within three constructs related to VRC participation, including Mechanical & Design Self-efficacy ($\alpha = .934$), Programming ($\alpha = .957$), and Teaming & Professional Traits ($\alpha = .834$). Robinson recommended that this instrument be utilized to study how VRC participants' self-efficacy changes over time and to compare self-efficacy based on participant characteristics such as gender. In addition, Robinson recommended that the relationship between self-efficacy of VRC participants and their choice of college major and completion rates of STEM majors should be investigated.

Stewardson et al. (2018) utilized Robinson's self-efficacy instrument to conduct preliminary research on VRC participant self-efficacy and its relationship to several potential variables including the number of seasons of VRC participation, gender, college major preference, prior robotics experience, and whether students participated in VRCs as part of a graded class or a more informal setting. The primary purpose of this study was to provide exploratory data to inform further research. The study included a sample of 166 students who participated in VRCs over the course of one year. The results of this study indicated that higher overall self-efficacy, along with higher self-efficacy in Mechanical & Design and Programming were correlated with longer participation in

VRCs as measured by the number of seasons students had participated. Stewardson et al. also found that self-efficacy for females was lower than self-efficacy for males in Mechanical & Design, as well as in Programming and overall; however, they were careful to note that these findings should be interpreted with caution since they were based on a very small and highly variable sample of female participants. Interestingly, females did show slightly higher self-efficacy in Teaming & Professional Traits, but this result was non-significant, although the small sample size of female students could have resulted in a Type II error. Students' self-efficacy in all areas except Mechanical & Design were correlated with prior experience in other robotic competitions. Higher self-efficacy overall and in Mechanical & Design specifically were also correlated with choosing a STEM major and with choosing an Engineering major specifically, as was prior experience in other robotic competitions. Stewardson et al. also recalculated the reliability of T. P. Robinson's (2014) instrument and found similarly high reliability compared to Robinson's findings. Stewardson et al. (2018) were hampered in some of their analyses by the relatively small sample size, which, when split into various subgroups (e.g., female vs. male), restricted the depth of analysis that could be accomplished and perhaps resulted in an underpowered study, opening the possibility for Type II errors. Stewardson et al. describe their study as a work in progress, and strongly recommended that their findings be tested through additional research, particularly as it relates to the relationship between self-efficacy and gender, educational choices, and success at the college level. This study is a continuation of the work begun by Stewardson et al.

Sullivan and Bers (2019) investigated gender differences in students' attitudes and experiences in VRCs to explore female underrepresentation in VRCs. Their mixed-methods study included 675 research participants comprised of 47 students and 628 mentors. Sullivan and Bers found significant differences in students' confidence between males and females in being "good at technical things" and "good at putting things together" (p. 105) with males being more confident than females. Sullivan and Bers also found that mentors reported female students entering VRC programs with less experience in technical and building skills than males. These findings tracked closely with the earlier finding by Stewardson et al. (2018). No other statistically significant differences in confidence levels between males and females were reported. Other findings included that both male and female students reported having positive experiences on VRC teams, that students were satisfied with their mentors, and that females were indeed underrepresented both in the ranks of student participants and mentors. The results of this research indicate the importance of gender in considering the self-efficacy and other characteristics of VRC participants.

Conclusion

Self-efficacy is an essential factor influencing students' interests, academic and vocational choice, and academic performance/persistence. Multiple meta-analytic reviews representing numerous studies and thousands of individual participants have consistently shown that self-efficacy is indeed an integral component of interest formation, the educational/vocational choices that result from those interests, and the

success that individuals have in pursuing those choices. Self-efficacy is formed most effectively through experiences which give individuals an opportunity to experience success in challenging situations, observe others like themselves achieve success, and to do so in an environment which evokes positive emotions and support from others. Self-efficacy has been shown to be relevant to STEM education in that students with higher self-efficacy are more likely to develop interest in and pursue STEM education and careers, and to persist when challenges arise. Robotic competitions and other extra-curricular STEM activities can potentially improve students' self-efficacy in STEM disciplines such as engineering by providing real-world situations in which students can be challenged and experience success in a positive environment leading to the development of strong self-efficacy beliefs. Several robotic competitions exist, but the largest and fastest growing of these is the VEX Robotics Competition, "with more than 20,000 teams from 50 countries playing in over 1,700 competitions worldwide" (RECF, 2019c). Although the body of literature is growing, few studies have addressed the educational impacts of robotic competitions, including the impacts on students' self-efficacy, in a rigorous way. Of these studies, only a small number have addressed VRCs specifically, although some preliminary research has been done and a highly reliable instrument to measure the self-efficacy of VRC participants has been developed. Researchers who have published studies in this area have repeatedly acknowledged the need for more and better studies to be conducted to examine how VRC participants' self-efficacy changes over time, and its relationship to important variables such as gender, educational choice, and success in STEM disciplines at the college level. As a result of

this need, this study was conducted in order to add to the scholarly conversation addressing these important issues.

CHAPTER III

METHODOLOGY

Introduction

The purpose of this study was to investigate the factors that contribute to the development of self-efficacy among VRC participants, and whether self-efficacy impacts students' educational choices as it relates to pursuing STEM careers, with particular focus on engineering. Two overarching questions were investigated in this study:

- What factors influence VRC participants' self-efficacy?
- What is the relationship between VRC participants' self-efficacy and their interest in and choice of STEM majors?

The following discussion identifies the rationale for investigating these questions, the hypotheses tested, and the study design, procedures, and statistical methods used.

Research Questions

The review of literature identified only a few studies addressing the educational impacts of VRCs, especially as it relates to self-efficacy. Although a handful of studies have investigated this topic, these were preliminary in nature and the authors issued recommendations for further, more rigorous research. In the literature review, several important variables were identified, especially by Stewardson et al. (2018) for further study. Based on the results of the literature review, two research questions were developed for this study, along with testable hypotheses. These questions, hypotheses, and a rationale for each hypothesis are given below.

Research Question 1: What factors influence VRC participants' self-efficacy?

- Hypothesis 1A – Self-efficacy increases over years of participation in VRCs. As shown in the literature review, self-efficacy can be increased through experiences in which individuals experience success at accomplishing a given task. (Conversely, it can be decreased by experiencing failure.) Self-efficacy is also influenced by witnessing others succeed (or fail). If VRCs provide an opportunity for participants to experience success in overcoming VRC-related challenges such as the design, construction, and programming of robots, being a team player, and acting in a professional manner, and/or to observe others like them experiencing similar success, then participants' self-efficacy in accomplishing these tasks should increase over time. Stewardson et al. (2018) found that self-efficacy was higher among students who had participated in VRCs for more seasons and used this finding to support the conclusion that self-efficacy in tasks related to VRC participation increases over time. Stewardson et al. (2018) based this conclusion on the assumption that any representative sample of first-year VRC participants will have similar self-efficacy on average to any similar sample of first-year VRC participants. Thus, if self-efficacy in a sample of second-year participants is higher than that of first-year participants, self-efficacy can be said to have increased for the second-year participants. Since Stewardson et al. conducted their study with only a small sample of participants, this question needs to be addressed using a larger sample.

- Hypothesis 1B –Males have higher self-efficacy in VRCs than females. Without exception, studies which have investigated the educational impacts of VRCs, including self-efficacy, have found significant differences between males and females (e.g., Sullivan & Bers, 2019; Stewardson et al., 2018), with females generally being at a perceived disadvantage. Stewardson et al. identified this as a critical question, especially in light of the disparity between males and females within the STEM workforce. Stewardson et al. particularly pointed to this as an area in which their analysis was weak due to insufficient sample size, thus it is important to address this important issue with a larger-scale study.

- Hypothesis 1C – Students who have participated in other robotic competitions in addition to VRCs have higher self-efficacy in VRCs. Stewardson et al. (2018) found that participation in other robotics competitions in addition to VRCs was associated with higher overall self-efficacy in VRC tasks, as well as in the Programming and Teaming & Professional Traits Constructs. Addressing this finding with a larger sample may provide insight to inform the discussion on how self-efficacy beliefs are formed in the context of educational robotic competitions and may also provide direction in using the self-efficacy framework to evaluate the educational impacts of other robotic competitions.

- Hypothesis 1D – Students who participate in VRCs as part of a formal, graded class have higher self-efficacy than students who participate in a more informal setting. A constant issue within education programs is the allocation of funding and time to various curricula, including robotics curricula in a school setting. Although Stewardson et al. (2018) found no evidence that there is any difference in the self-efficacy of students who participate in VRCs as part of a graded class versus those who participate in non-graded settings, this question is important to administrators and other stakeholders making decisions about resource allocation and class offerings. Individuals entrusted with making these decisions must have access to additional data which would inform their decisions about whether and how to include robotic competitions as part of the curriculum offered in their schools, whether previous findings are supported or otherwise.

Research Question 2: What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors?

- Hypothesis 2A: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing a STEM major. Major classification (i.e., STEM versus non-STEM) was guided by the STEM Designated Degree Program List (Department of Homeland Security, 2016). As shown in the literature review, self-efficacy mediates the effects of prior experience on educational interests. An individual with high self-efficacy in a given field will be more likely to show interest in a career (and corresponding education) which aligns with his or her perceived strengths. VRCs are primarily formatted as an engineering design challenge which also incorporates strong elements of science, technology, and mathematics. One could assume that the tasks a VRC participant is expected to accomplish as a member of a VRC team (e.g., designing a lift mechanism, working effectively with team members, or using a particular programming technique such as a while loop) closely mirror tasks that might be expected in a real-world STEM career. If this assumption is correct, and a student develops high self-efficacy in accomplishing tasks related to VRC participation, then one might expect that the student may be more likely to show higher levels of interest in a career path which aligns with those type of tasks. Thus, since VRCs are modeled as an engineering design challenge with strong elements of science, technology, and math, higher self-efficacy among VRC participants should result in higher interest in and choice of STEM careers and associated educational pathways.

- Hypothesis 2B: Students with higher self-efficacy in VRCs are more likely to choose a STEM major upon enrollment in post-secondary education. In addition to influencing career and educational interests, self-efficacy has been shown to greatly impact actual choices with respect to careers and education.

Since VRCs incorporate strong elements of STEM in the process of preparing for and participating in competitions, it is reasonable to expect that students with high self-efficacy in VRCs are more likely to ultimately choose a STEM major upon enrolling in post-secondary education.

- Hypothesis 2C: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing an engineering major. Although VRCs incorporate elements of science, technology, and mathematics, they are primarily structured as engineering design challenges, and heavy emphasis is given to the design process and solving engineering problems. As a result, it is reasonable to expect that students who develop higher self-efficacy in VRCs will be more likely to develop interest in pursuing an engineering degree.
- Hypothesis 2D: Students with higher self-efficacy in VRCs are more likely to choose an engineering major upon enrollment in post-secondary education. Considering that self-efficacy impacts educational and career choices, and that VRCs are structured primarily as an engineering design challenge, it seems reasonable to expect that students with higher self-efficacy in VRCs will be more likely to choose an engineering major.

Study Design

This study utilizes a cross sectional design by comparing different sub-groups of students to each other, as opposed to a longitudinal design which would involve comparing the same students to themselves across multiple time points. Although data was collected over a period of multiple years and included 52 participants who provided survey responses in more than one year, this study was cross sectional in its methodology because there was no attempt to analyze changes in individual students across multiple time points. A major goal of this study was to compare students with different levels of VRC experience to each other in order to determine what changes to self-efficacy may be occurring among students over time. This investigation depends on the reasonable assumption that any given group of first-year VRC participants is substantially similar to any other earlier or later group of first-year VRC participants in terms of self-efficacy.

The validity of this assumption was tested by comparing the self-efficacy of first-year VRC participants from each season to determine whether there were any differences between first-year VRC participants in successive seasons in this study. Under this assumption, the comparison between students with different levels of experience in VRCs can be used to support conclusions about how VRC participants' self-efficacy changes over time. It is also worth mentioning at this point that maturation over time does not necessarily translate to increased self-efficacy. As discussed in the literature review, self-efficacy is most strongly influenced by successes and failures experienced by an individual. Self-efficacy is also influenced by observing other individuals experience success or failure. Depending on whether individuals are experiencing successes or failures in a given activity, self-efficacy may increase or decrease over time. Simply participating in VRCs does not necessarily guarantee that a person's self-efficacy will increase over time. Rather, if an individual participates in VRCs and finds that they are experiencing success in challenging situations, their self-efficacy can be expected to be increased. If the same individual finds the situation too challenging and does not experience success, their self-efficacy can be expected to decrease over time. In addition to investigating differences in self-efficacy among students with different levels of VRC experience, this study also investigated the effect of other variables on self-efficacy, such as biological sex, participation in other robotics competitions, etc. This study also investigated the relationship between self-efficacy and students' interest in and choice of a college major.

Study Procedure

Recruitment of Participants

In order to recruit study participants, students were approached directly at competition events and indirectly through team coaches. Students were recruited at state and national-level competitions over a three-year period, including two annual Utah State Championship events and three annual CREATE U.S. Open Robotics Championship events. The Utah State Championship events attracted approximately 30 teams each year (along with their coaches) from around the state of Utah, while the U.S. Open events attracted approximately 200 teams (along with coaches) each year, representing more than 40 U.S. states. In addition, the CREATE Foundation assisted in recruiting additional students by sending out information to its network of VRC coaches and mentors asking them to encourage their students to volunteer for the study. A total of approximately 900 individual students over the three-year period volunteered to participate in the study by providing all of the requested contact information, including a valid email address for themselves and a parent or guardian. Contact was maintained with study participants via email, and/or through contacts with coaches in order to increase retention. Once study participants graduated from high school, they were asked to provide an email address which would remain active for at least one year, as well as a phone number for texting. 73 students graduated high school during the study and were given the opportunity to continue participating in the post-secondary portion of the study. All participants were given an opportunity to update their contact information during each annual survey. This information was used to help retain study participants for the remainder of their

participation in the study.

Study Ethics and Protection of Participants

Since this study involved the collection of personally identifiable information, including names, email addresses, and some indicators of academic preparation (e.g., the level of mathematics completed in high school), precautions were taken to ensure the security of this data, as required by the Utah State University Institutional Review Board. All personal identifiers such as names were replaced with a study identifier, and all individual data were stored on a password protected computer in a locked room. Only the primary investigator and the graduate researcher had access to the required key to associate personal identifiers with individual participant data. Once a participant concluded his or her participation in the study for any reason, the name and contact information were permanently destroyed.

The IRB protocol also required that each participant be given a Letter of Information explaining their rights as research participants in the study before they were allowed to participate in the study. A video (Furse, 2015) explaining the Letter of Information was also included at the beginning of the survey. Letters of Information explaining these rights were also required to be sent to a parent or guardian of each participant, followed by a waiting period of at least 10 calendar days in order to grant an opportunity for the parent or guardian to withdraw their consent to have their child participate in the study. Following this waiting period, the participant was sent a link to the survey instrument via email and allowed to participate in the study if their parent or guardian did not opt them out. Only one participant was opted out by a parent or guardian

during the entire study. Copies of the parent and student Letters of Information can be found in Appendices A and B.

Target Sample Size

A minimum of approximately 500 survey responses to a maximum of 2,000 responses was identified as the target sample size. This number was obtained based on the assumption that at least 20% of VRC participants would be female, which was consistent with the findings of previous studies (e.g., Hendricks et al., 2012; Sullivan & Bers, 2019), which all found that at least 20% or more of VRC participants were female. It was assumed that 500 valid survey responses would yield enough responses from females to enable a more robust analysis of differences between males and females, which was identified as an issue in need of further investigation by Stewardson et al. (2018). Since approximately 900 VRC participants volunteered to take part in this study by providing all of the necessary contact information, the researchers were confident in obtaining a large enough sample of completed survey responses.

Survey Instruments

The study utilized T. P. Robinson's (2014) Self-Confidence Survey for VEX Robotics Participants to measure the self-efficacy of students participating in VRCs. Robinson's instrument measures self-efficacy within three constructs relating to tasks students are asked to complete during the normal course of participating in VRCs as well as overall self-efficacy. These constructs are (1) Mechanical & Design, (2) Programming, and (3) Teaming & Professional Traits. Self-efficacy in each construct was measured by

participants' responses to eight to ten individual items which asked students to rate their level of agreement or disagreement with statements about their confidence in accomplishing certain tasks on the following Likert scale:

- Strongly Disagree (1)
- Disagree (2)
- Neither Agree nor Disagree (3)
- Agree (4)
- Strongly Agree (5)

Table 1 shows examples of the statements to which participants were asked to respond on the aforementioned Likert scale. A complete copy of the Self-Confidence Survey for VEX Robotics Participants used in this study can be found in Appendix C.

Table 1

Examples of Self-Efficacy Items in Self-Confidence Survey for VEX Robotics Participants

Item ID	Statement
MD1	I feel confident that I can design and construct a structurally sound and stable robot—chassis, lift, end-effectors
MD2	I feel confident that I can explain the design tradeoffs between various lift systems—linear, single arm, parallel arm (4-bar), or 6-bar
PR1	I feel confident that I can program conditional statements (for example, if statements and while loops)
PR2	I feel confident that I can update the master code (firmware) on the Cortex microcontroller and joystick
TP1	I feel confident that I can collaborate with other team members to accomplish tasks
TP2	I feel confident that I can resolve conflicts among team members

Note. The Item ID column displays the construct category and a numeric identifier for each item, where MD refers to the Mechanical & Design construct, PR refers to the Programming construct, and TP refers to the Teaming & Professional Traits construct.

To obtain self-efficacy scores within each construct for each participant, Likert scale responses were averaged across all items within that construct to obtain a mean score for that construct. To obtain overall self-efficacy scores, Likert scale responses

were averaged across all three construct categories.

Robinson’s instrument has been shown to be a highly reliable and valid means of measuring the self-efficacy of VRC participants both overall and within each of the three constructs (T. P. Robinson, 2014; Stewardson et al., 2018). One of the reasons for the high reliability in Robinson’s instrument is the use of “focus questions.” Within the self-efficacy survey items for each construct was embedded a question which directed the student to click a particular answer (e.g., “strongly agree”) if they were still paying attention to the survey. A student who proceeded through the survey clicking answers at random or in a particular pattern that was not necessarily reflective of his or her actual thoughts or feelings was likely to answer at least one of the three focus questions incorrectly. This allowed the reliability of the data within a particular response to be judged with a greater degree of accuracy in order to discard responses which were unreliable. In addition to the self-efficacy instrument items and focus questions, additional demographic questions were added for the purpose of this study (e.g., sex, grade level, team affiliation, etc.). For a complete copy of the Self-Confidence Survey for VEX Robotics Participants used in this study, see Appendix C. Actual sample characteristics (number of survey responses, number of incomplete/invalid responses, etc.) will be discussed in the next section.

A second component of the study was conducted using the Post-Secondary Choices Survey, which gathered data about students’ educational choices after high school graduation, their level of preparation for engineering programs upon entering college, and their progress toward completing an engineering degree (for those choosing

to pursue engineering). The survey questions for this part of the study were developed by a team of three experts who were experienced in VRCs and familiar with the goals of this study. Since this survey asked only objective questions about students' academic choices and progress, it was determined that statistical tests of reliability and validity were not necessary. A copy of the Post-Secondary Choices Survey can be found in Appendix D.

The survey instruments were administered to study participants via an emailed web link using Qualtrics Online Survey Solutions. Study participants who were in their first year of participation in VRCs were asked to complete the Self-Confidence Survey for VEX Robotics Participants at the beginning of their VEX experience in order to establish a baseline measure. All participants, including those who were in their first year of participation in VRCs, were asked to complete the same survey annually sometime between the participants' state-level VRC and shortly after the VEX Robotics World Championship competition. After participants graduated from high school, they were asked to complete the Post-Secondary Progress Survey, on an annual basis until they: (a) completed an engineering degree, (b) changed to a non-engineering program of study, (c) left school, or (d) the study was completed. This survey was also delivered online via Qualtrics.

Data Collection

Data was collected for three years (corresponding with three VRC seasons), resulting in a total of 550 responses to the Self-Confidence Survey for VEX Robotics Participants, along with 34 responses to the Post-Secondary Choices Survey. After eliminating incomplete or invalid responses (e.g., those with incorrectly answered focus

questions) 390 responses to the Self-Confidence Survey for VEX Robotics Participants were retained for data analysis, along with 28 validated responses to the Post-Secondary Choices Survey.

Data Analysis

In order to facilitate data analysis, variables were identified and coded as shown in Table 2.

In order to answer the research questions posed in this study, each hypothesis for each research question was tested using the following statistical methods (actual results are discussed in Chapter IV).

Research Question 1: What factors influence VRC participants' self-efficacy? The goal of the statistical analysis relating to Research Question 1 was to develop regression models for predicting Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E, respectively, in order to identify what factors are important to the development of self-efficacy in VRCs. For each of the hypotheses addressed below, variables with a statistically significant correlation to one or more of the self-efficacy variables were incorporated as possible predictor variables in the subsequent regression analysis.

- Hypothesis 1A – Self-efficacy increases over years of participation in VRCs. Pearson's R was calculated to determine whether a statistically significant correlation existed between Seasons and Overall S/E. Similarly, Pearson's R was calculated to determine the correlation between Seasons and Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E, respectively. Statistically significant relationships suggest an association between years of participation and self-efficacy.

Table 2

List of Variables and Coding Information

Variable	Description	Coding
Overall SE[a]	Overall self-efficacy score	Numeric value from 1-5 corresponding to Likert scale where 1 corresponds to "strongly disagree"
Mechanical & design SE[a]	Mechanical and design self-efficacy score	See above
Programming S/E	Programming self-efficacy score	See above
Teaming & professional traits SE[a]	Teaming and Professional Traits self-efficacy score	See above
Sex[a]	Self-reported sex of participant	0 = Male, 1 = Female
Seasons[a]	Number of VRC seasons participated in so far	1 season = 1, 2 seasons = 2, etc.
Other robotics[a]	Whether the respondent has participated in other robotics competitions	0 = No, 1 = Yes
Graded[a]	Whether the respondent participated in VRCs as part of a formal, graded class	0 = No, 1 = Yes
STEM preference[a]	Classification of current major preference with respect to all STEM majors	0 = non-STEM, 1 = STEM[c]
Engineering preference[a]	Classification of current major preference with respect to Engineering majors	0 = non-Engineering, 1 = Engineering[c]
STEM choice[b]	Classification of actual major choice upon enrollment in post-secondary education with respect to all STEM majors	0 = non-STEM, 1 = STEM[c]
Engineering choice[b]	Classification of actual major choice upon enrollment in post-secondary education with respect to Engineering majors	0 = non-Engineering, 1 = Engineering[c]
Advanced STEM attainment[b]	The number of AP/Honors STEM courses taken during high school	

(*table continues*)

Variable	Description	Coding
Engineering coursework[b]	Whether the student took at least one engineering course during high school	0 = No, 1 = Yes
Math attainment[b]	Represents the highest-level math course taken during high school	1 = Pre-Algebra 2 = Algebra 3 = Pre-Calculus or Trigonometry 4 = Calculus or Statistics 5 = AP/Honors Calculus or AP/Honors Statistics
Calculus ready[b]	Whether the student met the minimum standard to enroll in a calculus class during their first semester of college, either by default or by passing a test.	0 = No, 1 = Yes

[a] Data collected from the Self-Confidence Survey for VEX Robotics Participants ($N = 390$)

[b] Data collected from the Post-Secondary Choices Survey ($N = 28$)

[c] Major classification was guided by the STEM Designated Degree Program List (Department of Homeland Security, 2016). Preferred and actual college majors as self-reported by the participant were compared to the list to determine whether they aligned with one of the listed degree programs.

- Hypothesis 1B – Males have higher self-efficacy in VRCs than females. Point biserial correlations were calculated between Sex and Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E, respectively in order to determine whether any statistically significant associations existed between Sex and self-efficacy.

- Hypothesis 1C – Students who have participated in other robotic competitions in addition to VRCs have higher self-efficacy in VRCs. Point biserial correlations were calculated between Other Robotics and Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E, respectively, in order to identify any statistically significant relationships (if any) between participation in other robotic competitions and students' self-efficacy in VRCs.

- Hypothesis 1D – Students who participate in VRCs as part of a formal, graded class have higher self-efficacy than students who participate in a more informal setting. Point biserial correlations were calculated between Graded and Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E, respectively, in order to identify any statistically significant relationships (if any) between the context in which students participated and their self-efficacy.

Research Question 2: What is the relationship between self-efficacy in VRCs and

students' interest in and choice of STEM majors? The primary goal of the statistical analysis relating to Research Question 2 was to develop regression models for VRC participants' interest in pursuing STEM majors, and for participants' interest in pursuing engineering majors in particular. For each of the hypotheses addressed below, variables with a statistically significant correlation to one or more of the self-efficacy variables were incorporated as possible predictor variables in the subsequent regression analysis. A secondary goal was to explore the association between students' self-efficacy and actual choice of STEM majors, particularly engineering. Regression models were not attempted for the secondary goal since only a small number of participants ($N = 28$) responded to the Post-Secondary Choices survey after graduating high school, thus imposing limitations on the depth of analysis that could be achieved. Maxwell (2000) suggests a minimum sample size of at least n = 40 for regression analysis, depending on the number of predictor variables, statistical power desired, etc.

- Hypothesis 2A: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing a STEM major. The point biserial correlations between STEM Preference and Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E, respectively, were calculated to determine whether any statistically significant relationships existed between self-efficacy and VRC participants' interest in STEM majors.

- Hypothesis 2B: Students with higher self-efficacy in VRCs are more likely to choose a STEM major upon enrollment in post-secondary education. Chi square tests for independence were calculated between STEM Choice and Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits, S/E, respectively. The purpose of these tests was to determine whether any statistically significant relationships existed between STEM Choice and self-efficacy in any of the three constructs or overall.

- Hypothesis 2C: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing an engineering major. The point biserial correlations between Engineering Preference and Overall S/E,

Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E, respectively, were calculated to determine whether any statistically significant relationships existed between self-efficacy and VRC participants' interest in engineering majors.

- Hypothesis 2D: Students with higher self-efficacy in VRCs are more likely to choose an engineering major upon enrollment in post-secondary education. Chi square tests for independence were calculated between Engineering Choice and Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits, S/E, respectively. The purpose of these tests was to determine whether any statistically significant relationships existed between Engineering Choice and self-efficacy in any of the three constructs or overall.

In the interest of thoroughness, additional correlation and chi-square tests were conducted to examine all possible relationships between the variables listed in Table 2. Statistically significant results which were meaningful to the research questions posed in this study, or which were relevant to areas for further inquiry were investigated in further depth as appropriate.

Conclusion

The methodology presented in this chapter was used to gather and analyze data during this study. This study utilized a cross-sectional design and investigated the relationships between several variables, ultimately leading to the development of regression models for predicting VRC participant self-efficacy, and predicting participants' preference for STEM majors, and participants' preference for engineering majors in particular. In addition, this study explored the relationship between these variables and students' choice of STEM majors (and students' choice of engineering majors in particular).

CHAPTER IV

FINDINGS

Introduction

The purpose of this study was to investigate the factors which contribute to the development of self-efficacy among VRC participants, and whether self-efficacy impacts students' educational choices as it relates to pursuing STEM careers, with particular focus on engineering. Two research questions were developed for this study, along with hypotheses addressing each research question.

Research Question 1: What factors influence VRC participants' self-efficacy?

- Hypothesis 1A – Self-efficacy increases over years of participation in VRCs.
- Hypothesis 1B – Males have higher self-efficacy in VRCs than females.
- Hypothesis 1C – Students who have participated in other robotic competitions in addition to VRCs have higher self-efficacy in VRCs.
- Hypothesis 1D – Students who participate in VRCs as part of a formal, graded class have higher self-efficacy than students who participate in a more informal setting.

Research Question 2: What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors?

- Hypothesis 2A: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing a STEM major.
- Hypothesis 2B: Students with higher self-efficacy in VRCs are more likely to choose a STEM major upon enrollment in post-secondary education.
- Hypothesis 2C: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing an engineering major.
- Hypothesis 2D: Students with higher self-efficacy in VRCs are more likely to

choose an engineering major upon enrollment in post-secondary education.

In order to test these hypotheses and answer these research questions, correlation tests were conducted to determine whether any statistically significant relationships existed between the different variables. Once these relationships were identified, the first goal was to create regression models which could be used to predict students' self-efficacy, both overall and in each of the three construct areas (Mechanical & Design, Programming, and Teaming & Professional Traits) based on contributing factors such as biological sex, participation in other robotic competitions, years of experience, etc. The second goal of this study was to create regression models which could be used to predict students' interest in STEM majors, and students' interest in engineering majors specifically, based on self-efficacy (overall and/or in specific constructs) and other contributing factors. In addition, this study sought to offer a preliminary investigation into the relationship between variables such as self-efficacy and students' actual choice of major upon enrolling in post-secondary educational programs. This chapter discusses the findings of this study as outlined above.

Results

Sample Description

After three years of data collection (corresponding to three VRC seasons), 550 responses to the Self-Confidence Survey for VEX Robotics Participants (SCSVRP) were collected. Of the 550 responses to the SCSVRP, 160 were incomplete or invalid because of incorrectly answered focus questions, leaving 390 valid responses. As was discussed earlier, the focus questions were incorporated in the survey instrument in order to

improve the reliability and validity of the instrument by identifying responses where the participant likely marked items haphazardly or in a pattern. The number of incomplete/invalid responses was viewed as being characteristic of the age group of the participants, rather than being indicative of a problem with the length or difficulty of the survey (the average time to complete the survey was approximately 15 minutes, with most participants completing the survey in 10 minutes or less). Descriptive statistics for the data collected from the SCSVRP is shown in Table 3.

Table 3

Descriptive Statistics for Data Collected from the Self-Confidence Survey for VEX Robotics Participants (*N* = 390)

Variable	*M*	*SD*	Notes
Sex			28% female, 72% male
Grade level	9.930	1.657	Range from 5th - 12th grade
Seasons	2.510	1.395	Range from 1-7 seasons
Graded			20% graded class, 80% non-graded setting
Other robotics			42% participated in non-VRC competitions, 58% did not
STEM preference			76% indicated preference for STEM major
Engineering preference			50% indicated preference for engineering major
Mechanical & Design S/E	4.167	.709	Mean out of 5
Programming S/E	3.422	1.177	Mean out of 5
Teaming & professional traits S/E	4.483	.468	Mean out of 5
Overall S/E	4.036	.569	Mean out of 5

During the same 3-year period, 63 students who submitted a valid response to the SCSVRP also graduated from high school and had an opportunity to participate in the Post-Secondary Choices Survey. Of those 63 participants, 28 submitted completed

responses to the Post-Secondary Choices Survey (34 total responses were submitted, 6 of which were incomplete and discarded). Table 4 shows descriptive statistics for this sample.

Table 4

Descriptive Statistics for Data Collected from the Post-Secondary Choices Survey ($N = 28$)

Variable	*M*	*SD*	Notes
STEM choice			79% of participants chose a STEM major upon post-secondary enrollment
Engineering choice			46% of participants chose an engineering major upon post-secondary enrollment
Advanced STEM attainment	2.45	1.660	Participants took an average of 2.45 AP/Honors STEM courses during high school
Engineering coursework			55% of participants took at least one engineering course during high school
Calculus ready			83% of participants were calculus ready upon post-secondary enrollment
Math attainment	4.48	.785	Out of 5, higher numbers associated with higher math attainment

One of the major goals of this study was to establish whether VRC participants' self-efficacy increases over time. In order to investigate this question, it was necessary to determine whether the self-efficacy of different groups of first-year VRC participants from different years was the same, so that the self-efficacy of students with different levels of experience in VRCs could be compared. In order to test this assumption, ANOVA tests were conducted to determine whether any statistically significant differences in self-efficacy (overall or in any of the three constructs) existed between the different cohorts of first-year VRC participants. A non-statistically significant result was

considered to indicate that there were no differences between cohorts, thus indicating that first-year VRC participants start from a similar baseline self-efficacy and that the self-efficacy of different groups at different levels of experience in VRCs could be compared. Analysis of variance showed that there was no statistically significant difference in overall self-efficacy between any of the three cohorts of first-year VRC participants, $F(2, 94) = .464$, $p = .630$. Analysis of variance also showed that there was no statistically significant difference in Mechanical & Design self-efficacy between any of the three cohorts of first-year VRC participants, $F(2, 94) = .588$, $p = .558$. Analysis of variance also showed no statistically significant difference in Programming self-efficacy between any of the three cohorts of first-year VRC participants, $F(2, 94) = .075$, $p = .928$. Analysis of variance also showed that there was no statistically significant difference in Teaming & Professional Traits self-efficacy between any of the three cohorts of first-year VRC participants, $F(2, 94) = .394$, $p = .676$. These results supported the assumption that different groups of first-year VRC participants from different years were statistically similar in their baseline level of self-efficacy, both overall and in all three construct areas. Thus, comparisons of self-efficacy between students of different levels of experience could be made, and conclusions could be drawn from those comparisons about whether VRC participants' self-efficacy increases over time.

Results of Correlation Tests

Results prior to high school graduation. In order to identify statistically significant relationships between variable, correlation tests and chi square tests for independence were conducted between all of the variables listed in Table 2. Results

including participants who completed the SCSVRP are shown in Tables 5-7 (each will be discussed separately below followed by the table). These data represent participants before they graduated from high school.

Table 5

Pearson's R Correlation Results for Secondary Participants (N = 390)

Variable	1	2	3	4	5
1. Seasons		.242***	.322***	.151**	.064
2. Overall S/E					
3. Mechanical & Design S/E				.346***	.378***
4. Programming S/E					.081
5. Teaming & Professional Traits S/E					
Mean	2.51	4.036	4.167	3.422	4.483
SD	1.395	.569	.709	1.177	.468

***$p < .001$, **$p < .01$.

As shown in Table 5 above, statistically significant relationships were found between Overall S/E and Seasons ($r = .242$, $p < .001$), Mechanical & Design S/E and Seasons ($r = .322$, $p < .001$), and Programming S/E and Seasons (r = .151, $p = .003$). (Self-efficacy is abbreviated S/E.) These results indicate a statistically significant positive association between overall self-efficacy scores and the number of seasons a student participated in VRCs. The relationship between the number of seasons and self-efficacy scores in the Mechanical & Design construct was also positive, with a medium effect size. The correlation between the number of seasons and self-efficacy scores in the Programming construct was also positive.

In addition, statistically significant relationships were identified between self-

efficacy scores in the Mechanical & Design and Programming constructs (*r* = .346, *p* < .001), and the Mechanical & Design and Teaming & Professional Traits constructs (*r* = .378, *p* < .001). These indicate a positive association between self-efficacy scores in the Mechanical & Design construct and the Programming and Teaming & Professional Traits constructs, respectively.

As shown in Table 6, statistically significant relationships were identified between Sex and Seasons (*r* = -.114, *p* = .024), Sex and Overall S/E (*r* = -.298, *p* < .001), Sex and Mechanical & Design S/E (*r* = -.370, *p* < .001), and Sex and Programming S/E (*r* = -.245, *p* < .001). These results indicate that the biological sex indicated by the participant was negatively correlated with the number of seasons they participated in VRCs. In other words, females who responded to the survey tended to have participated in slightly fewer VRC seasons than males. Biological sex was also negatively correlated with overall self-efficacy scores, as well as self-efficacy scores in the Mechanical & Design and Programming constructs. These results indicate that female respondents had

Table 6

Point Biserial Correlation Test Results for Secondary Participants (*N* = 390)

Variable	Sex	Graded	Other Robotics	STEM preference	Engineering preference
Seasons	-.114*	-.070	.186***	.087	.074
Teaming & Professional Traits S/E	.026	.077	.071	.050	.115*
Programming S/E	-.245***	.046	.114*	.065	.014
Mechanical & Design S/E	-.370***	-.016	.039	.138**	.293**
Overall S/E	-.298***	.049	.115*	.111*	.153**
Mean	.28	.20	.42	.76	.50

* *p* < .05.
** *p* < .01.
*** *p* < .001.

lower self-efficacy scores than males overall and within the Mechanical & Design and Programming constructs.

The results shown in Table 6 also indicate statistically significant, positive relationships between Other Robotics and Seasons (r = .186, p < .001), Other Robotics and Programming S/E (r = .114, p = .024), and Other Robotics and Overall S/E (r = .115, p = .024). These results suggest that students who had participated in other types of robotics competitions had also participated in VRCs for longer and had higher overall and programming self-efficacy scores.

STEM Preference was positively correlated with overall self-efficacy scores (r = .111, p = .028) with a small effect size, as well as self-efficacy scores in the Mechanical & Design construct (r = .138, p = .006). These results suggest that students' interest in pursuing a STEM major in college was positively correlated with their overall self-efficacy score and with their self-efficacy score within the Mechanical & Design construct.

Engineering Preference was positively correlated with Overall S/E (r = .153, p = .002), Mechanical & Design S/E (r = .293, p < .001), and Teaming & Professional Traits S/E (r = .115, p = .024). These results suggest that students' interest in pursuing an engineering major in college was positively associated with their overall self-efficacy score and with their self-efficacy scores in the Mechanical & Design and Teaming & Professional Traits constructs, respectively.

Table 7 shows a statistically significant relationship between Sex and STEM Preference, X^2 (1, 390) = 7.945, p = .006, φ_C = .143. Female participants were less likely

to show an interest in pursuing a STEM major than males. The relationship between STEM Preference and Engineering Preference-was not considered meaningful as it merely indicated that students with an interest in pursuing an engineering major were also interested in pursuing a STEM major, which is true by definition.

Table 7

Chi-Square Test Results for Secondary Participants (N = 390)

Variable	1	2	3	4	5
1. Sex		7.945**	2.510	.892	.183
2. STEM preference				.271	3.190
3. Engineering preference				2.735	3.421
4. Graded					.000
5. Other robotics					
Mean	.28	.76	.50	.20	.42

**p < .01.

Post-secondary results. In order to identify statistically significant relationships between variables, correlation tests and chi square tests for independence were conducted between all of the variables listed in Table 2. Results including participants who participated in both the SCSVRP and the Post-Secondary Choices Survey are shown in Tables 8-10. This represents only participants who graduated from high school during the study.

As shown in Table 8, a statistically significant positive correlation was identified between Advanced STEM Attainment and Math Attainment (r = .596, p = .001). This result suggests that students who took higher level mathematics coursework during high school also were more likely to take advanced STEM courses during high school.

Table 8

Pearson's R Correlations for Post-Secondary Participants (N = 28)

Variable	Advanced STEM attainment	Math attainment
Seasons	-.006	-.123
Overall SE[a]	.165	-.150
Mechanical & Design SE[a]	.158	-.038
Programming SE[a]	.093	-.155
Teaming & Professional Traits SE[a]	.223	-.141
Advanced STEM Attainment		.596**
Mean	2.51	4.036
SD	1.395	.569

[a]These data were obtained from the post-secondary students' responses to the Self-Confidence Survey for VEX Robotics Participants, submitted during their 12th Grade year.

** $p < .01$.

As shown in Table 9, a statistically significant negative correlation was identified between Math Attainment and Engineering Choice (r = -.463, p = .013). These results suggest that students who took higher level mathematics courses during high school were less likely to choose an engineering major. Statistically significant correlations were also identified between STEM Choice and Programming S/E (r = .432, p = .022), and STEM Choice and Overall S/E (r = .435, p = .021). These results indicate that higher overall self-efficacy as well as higher self-efficacy in the Programming construct are both associated with choosing a STEM major upon enrollment in post-secondary studies. Finally, as shown in Table 9, a statistically significant relationship was identified between Engineering Coursework and Teaming & Professional Traits S/E (r = -.434, p = .019), suggesting that students who had taken an engineering course during high school tended to have lower self-efficacy in the Teaming & Professional Traits construct.

Table 9

Point Biserial Correlations for Post-Secondary Participants (N = 28)

Variable	STEM Choice	Engineering Choice	Calculus Ready	Engineering Coursework
Advanced STEM Attainment	.094	-.347	-.210	-.347
Math Attainment	-.136	-.463*	-.069	-.065
Mechanical & Design SE[a]	.348	.233	.082	-.240
Programming SE[a]	.432*	.134	-.022	-.095
Teaming & Professional Traits SE[a]	.188	.207	-.335	-.434*
Overall SE[a]	.435*	.211	-.076	-.245

[a]These data were obtained from the post-secondary students' responses to the Self-Confidence Survey for VEX Robotics Participants, submitted during their 12th Grade year.

*$p < .05$.

As shown in Table 10, a statistically significant relationship existed between STEM Preference and STEM Choice X^2 (1, 28) = 5.739, p = .050, φ_C = .438. Students who had expressed a preference for choosing a STEM major prior to graduating from high school were more likely to choose a STEM major upon enrollment in post-secondary education programs. A statistically significant relationship also existed between STEM Preference and Engineering Choice X^2 (1, 28) = 5.275, p = .044, φ_C = .434. Participants who expressed a preference for choosing a STEM major prior to graduating from high school were more likely to choose an engineering major upon enrolling in post-secondary education programs. A third statistically significant relationship was found between Engineering Preference and Engineering Choice X^2 (1, 28) = 21.031, p < .001, φ_C = .867. Participants who expressed a preference for choosing an engineering major prior to graduating high school were more likely to choose engineering upon enrollment in post-secondary education programs.

Table 10

Chi-Square Test Results for Post-Secondary Participants ($N = 28$)

Variable	STEM choice	Engineering choice	Calculus ready
Sex[a]	.159	1.197	.005
Graded[a]	.005	.021	2.368
Other Robotics[a]	3.394	.144	1.934
STEM preference[a]	5.379*	5.275*	.032
Engineering preference[a]	4.182	21.031***	2.435
Engineering coursework	-.137	.149	-.044
Calculus Ready	.035	.862	
Mean	.28	.76	.83

[a]These data were obtained from the post-secondary students' responses to the Self-Confidence Survey for VEX Robotics Participants, submitted during their 12th Grade year.

* $p \leq .05$.

*** $p < .001$.

Results of Regression Analysis

In addition to correlation analyses, multiple linear regression models and binary logistic regression models were calculated in order to answer the research questions/ hypotheses presented at the beginning of this chapter. First, regression coefficients were calculated predict Overall S/E, Mechanical & Design S/E, Programming S/E, and Teaming & Professional Traits S/E. Second, regression coefficients were calculated to predict STEM Preference and Engineering Preference.

Predicting Self-Efficacy

The first major goal of this study was to investigate what factors influence VRC participants' self-efficacy. In order to accomplish this task, it was necessary to develop predictive models for overall self-efficacy and for self-efficacy within each of the three

constructs. The development of these models provided evidence about which factors contribute to the development of VRC participants' self-efficacy and the relative importance of each of these factors.

In order to calculate regression coefficients for independent variables predicting Overall S/E, a multiple linear regression analysis was performed utilizing Seasons, Sex, Other Robotics, Engineering Preference, and STEM Preference as predictor variables. These five variables were shown to be statistically significant correlates of Overall S/E during correlation analysis. The results of the regression analysis are shown in Table 11.

The results of the multiple regression analysis for predicting Overall self-efficacy summarized in Table 11 indicated that 15% of the variance in overall self-efficacy was predicted by the five variables, $F(5, 384) = 13.549$, $p < .001$, $R^2 = .150$. Only Seasons, Sex, and Engineering Preference added statistically significantly to the prediction.

Table 11

Multiple Linear Regression Analysis Summary for Independent Variables Predicting Overall Self-Efficacy ($N = 390$)

Variable	B	*SE B*	β	*t*	*F*(5,384)	R^2	Adj. R^2	Intercept
Model					13.549***	.150	.139	3.852
Seasons	.079	.020	.193	3.989***				
Sex	-.339	.061	-.267	-5.590***				
Other Robotics	.073	.055	.063	1.316				
Engineering Preference	.138	.065	.122	.034*				
STEM Preference	-.024	.076	-.018	.750				

*$p < .05$.
***$p < .001$.

In order to calculate regression coefficients for independent variables predicting Mechanical & Design S/E, a multiple linear regression analysis was performed utilizing Seasons, Programming S/E, Teaming & Professional Traits S/E, Sex, STEM Preference,

and Engineering Preference as predictor variables. These six variables were shown to be statistically significant correlates of Mechanical & Design S/E during correlation analysis. The results of the regression analysis are shown in Table 12.

The results of the multiple linear regression analysis for predicting Mechanical & Design self-efficacy summarized in Table 12 indicated that 44.6% of the variance in Mechanical & Design self-efficacy was predicted by the six independent variables, $F(6, 383) = 51.298$, $p < .001$, $R^2 = .446$. All six variables added statistically significantly to the prediction.

Table 12

Multiple Linear Regression Analysis Summary for Variables Predicting Mechanical & Design Self-Efficacy ($N = 390$)

Variable	B	*SE B*	β	*t*	$F(6,383)$	R^2	Adj. R^2	Intercept
Model					51.298***	.446	.437	1.278
Seasons	.114	.020	.224	5.780***				
Programming S/E	.131	.024	.217	5.469***				
Teaming & prof. traits S/E	.497	.058	.328	8.516***				
Sex	-.464	.063	-.294	-7.389***				
STEM preference	-.181	.077	-.110	-2.351*				
Engineering preference	.388	.066	.274	5.890***				

* $p < .05$.
*** $p < .001$.

In order to calculate regression coefficients for independent variables predicting Programming S/E, a multiple linear regression analysis was performed with Seasons, Mechanical & Design S/E, Sex, and Other Robotics as predictor variables. These four variables were shown to be statistically significant correlates of Programming S/E during correlation analysis. The results of the regression analysis are shown in Table 13.

Table 13

Multiple Linear Regression Analysis Summary for Variables Predicting Programming Self-Efficacy (N = 390)

Variable	B	$SE\ B$	β	t	F(4,385)	R^2	Adj. R^2	Intercept
Model					16.491***	.146	.137	1.400
Seasons	.022	.372	.026	.515				
Mechanical & Design S/E	.473	.088	.285	5.347***				
Sex	-.353	.133	-.134	-2.651**				
Other Robotics	.227	.114	.095	1.987*				

* $p < .05$.
** $p < .01$.
*** $p < .001$.

The results of the multiple linear regression analysis for predicting Programming self-efficacy summarized in Table 13 indicated that 14.6% of the variance in Programming self-efficacy was predicted by the four independent variables, $F(4, 385)$ = 16.491, $p < .001$, $R^2 = .146$. Only Mechanical & Design S/E, Sex, and Other Robotics added significantly to the prediction.

In order to calculate regression coefficients for independent variables predicting Teaming & Professional Traits S/E, a multiple linear regression analysis was performed with Mechanical & Design S/E and Engineering Preference as predictor variables. The results of the regression analysis are shown in Table 14.

The results of the multiple linear regression analysis for predicting Teaming & Professional Traits self-efficacy summarized in Table 14 indicated that 14.3% of the variance in Teaming & Professional Traits self-efficacy was predicted by the two independent variables, $F(2, 387) = 32.358$, $p < .001$, $R^2 = .143$. Only Mechanical & Design S/E added significantly to the prediction.

Table 14

Multiple Linear Regression Analysis Summary for Variables Predicting Teaming & Professional Traits Self-Efficacy (N = 390)

Variable	B	*SE B*	β	*t*	F(2,387)	R^2	Adj. R^2	Intercept
Model					32.358***	.143	.139	3.443
Mechanical & Design S/E	.249	.033	.377	7.667***				
Engineering Preference	.004	.046	.004	.086				

***p < .001.

College Major Interest and Choice

The second major goal of this study was to investigate the relationship between self-efficacy and students' interest in and choice of STEM majors, with a specific focus on engineering majors. In order to accomplish this goal, regression analysis was conducted in order to develop regression models for predicting participants' preference for choosing a STEM major and for engineering majors specifically. Unfortunately, the sample of students who had graduated from high school and enrolled in post-secondary programs was too small to develop a reliable regression model for predicting actual choice of major. However, the sample size of students participating in the SCSVRP was sufficient to continue with regression analysis for students' major preference prior to high school graduation.

In order to calculate regression coefficients for independent variables predicting STEM Preference, a binomial logistic regression analysis was performed utilizing Mechanical & Design S/E and Overall S/E as covariates. These two variables were shown to be statistically significant correlates of Overall S/E during correlation analysis. The results of the regression analysis are shown in Table 15.

Table 15

Binary Logistic Regression Analysis Summary for Variables Predicting Preference for a STEM Major (N = 390)

Variable	B	*SE B*	Odds ratio	X^2 (3)	Cox & Snell R^2	Nagelkerke R^2	Overall %	Intercept
Model				7.195*	.018	.027	75.6	-.802
Mechanical & Design S/E	.365	.233	1.440					
Overall S/E	.109	.300	1.115					

*$p < .05$.

The logistic regression model was statistically significant X^2 (3) = 7.195, p = .027. The model explained 2.7% (Nagelkerke R^2) of the variance in STEM major preference and correctly classified 75.6% of cases. However, neither Mechanical & Design S/E nor Overall S/E were statistically significant predictors in this model although correlation analysis indicated a positive association for both variables.

In order to calculate regression coefficients for independent variables predicting Engineering Preference, a binomial logistic regression analysis was performed utilizing Teaming & Professional Traits S/E, Mechanical & Design S/E, and Overall S/E as covariates. These three variables were shown to be statistically significant correlates of Overall S/E during correlation analysis. The results of the regression analysis are shown in Table 16.

The logistic regression model was statistically significant X^2 (3) = 40.046, p < .001. The model explained 13% (Nagelkerke R^2) of the variance in STEM major preference and correctly classified 64.4% of cases. Mechanical & Design S/E and Overall S/E were statistically significant predictors in this model.

Table 16

Binary Logistic Regression Analysis Summary for Variables Predicting Preference for an Engineering Major (N = 390)

Variable	B	*SE B*	Odds ratio	X^2 (3)	Cox & Snell R^2	Nagelkerke R^2	Overall %	Intercept
Model				40.046***	.098	.130	64.4	-3.893
Teaming & Prof. Traits S/E	.221	.276	1.247					
Mechanical & Design S/E	1.274	.253	3.577***					
Overall S/E	-.603	.301	.547*					

* $p < .05$.
*** $p > .001$.

Summary

Correlation and regression analyses were used to analyze data collected during this study to investigate two research questions.

Research Question 1: What factors influence VRC participants' self-efficacy?

- Hypothesis 1A – Self-efficacy increases over years of participation in VRCs.
- Hypothesis 1B – Males have higher self-efficacy in VRCs than females.
- Hypothesis 1C – Students who have participated in other robotic competitions in addition to VRCs have higher self-efficacy in VRCs.
- Hypothesis 1D – Students who participate in VRCs as part of a formal, graded class have higher self-efficacy than students who participate in a more informal setting.

Research Question 2: What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors?

- Hypothesis 2A: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing a STEM major.
- Hypothesis 2B: Students with higher self-efficacy in VRCs are more likely to

choose a STEM major upon enrollment in post-secondary education.

- Hypothesis 2C: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing an engineering major.
- Hypothesis 2D: Students with higher self-efficacy in VRCs are more likely to choose an engineering major upon enrollment in post-secondary education.

Research Question 1

Using the results from the SCSVRP instrument, regression models were developed predicting overall self-efficacy, Mechanical & Design self-efficacy, Programming self-efficacy, and Teaming & Professional Traits self-efficacy. These models are summarized as follows.

- Overall self-efficacy was predicted by the number of seasons a student had participated in VRCs, their self-reported biological sex, and whether they indicated a preference for an engineering major. Students with higher overall levels of self-efficacy tended to have more seasons of experience in VRCs, identify themselves as biological males and indicate a preference for pursuing an engineering degree.
- Mechanical & Design self-efficacy was predicted by the number of seasons a student had participated in VRCs, their level of Programming self-efficacy, their level of Teaming & Professional Traits self-efficacy, their self-reported biological sex, whether they indicated a preference for a STEM major, and whether they indicated a preference for an engineering major. Students with higher levels of Mechanical & Design self-efficacy tended to have more seasons of experience in VRCs and show higher levels of self-efficacy in Programming and Teaming & Professional Traits. Students with higher Mechanical & Design self-efficacy also tended to identify themselves as biological males and indicate a preference for studying engineering in college. When combined with the effects of the other variables, students who indicated a preference for pursuing a STEM major tended to have lower Mechanical & Design self-efficacy, despite the fact that the Pearson correlation indicated a positive association between STEM major preference and Mechanical & Design self-efficacy.
- Programming self-efficacy was statistically significantly predicted by students' Mechanical & Design self-efficacy, self-reported biological sex, and whether they had participated in another type of robotics competition in

addition to VRCs. Students with higher Programming self-efficacy tended to have higher levels of Mechanical & Design self-efficacy, to identify themselves as biological males, and have experience with other types of robotics competitions other than VRCs.

- Teaming & Professional Traits self-efficacy was statistically significantly predicted by Mechanical & Design self-efficacy. Students with higher levels of Teaming & Professional Traits self-efficacy also tended to have higher levels of Mechanical & Design self-efficacy.

Research Question 2

Using the results from the SCSVRP instrument, regression models were developed to predict students' preference for pursuing STEM majors and students' preference for pursuing engineering majors specifically. The results of the regression analyses of secondary participants' preferences for college major and correlation analysis of post-secondary participants' college major choices are summarized as follows.

- The model for predicting secondary students' preference for pursuing a STEM major was very weak and no statistically significant predictors were found, although statistical significance was achieved for the overall model, which incorporated overall self-efficacy and Mechanical & Design self-efficacy as predictors.

- Secondary students' preference for pursuing an engineering major was statistically significantly predicted by Mechanical & Design self-efficacy and overall self-efficacy. Students who indicated a preference for pursuing an engineering major tended to have higher overall self-efficacy and Mechanical & Design self-efficacy specifically.

Although regression analysis for students' post-secondary choice of major was not possible due to insufficient sample size, correlation analysis was conducted to investigate these choices utilizing results from both the SCSVRP and the Post-Secondary Choices survey for students who had submitted valid responses for both instruments.

- Students' choice of a STEM major upon enrolling in post-secondary studies was significantly correlated with indicating a preference to pursue a STEM

major prior to high school graduation, Programming self-efficacy, and overall self-efficacy. Students who chose a STEM major tended to have higher self-efficacy overall and in programming, and to have indicated a preference for a STEM major while still in high school.

- Students' choice of an engineering major upon enrolling in post-secondary studies was significantly correlated with the level of math coursework taken during high school, as well as indicating preference for pursuing an engineering major while still in high school. Students who had taken higher level math courses were significantly less likely to major in engineering. Students who had indicated a preference for pursuing an engineering degree while they were in high school were significantly more likely to major in engineering.

The conclusions that can be drawn from these findings and their overall implications for this study as well as for the broader context of robotics education research will be discussed in Chapter V along with recommendations for further study.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Introduction

Since the early 1990s, educational robotic competitions have become an increasingly popular means of promoting student engagement in STEM learning. Providing opportunities for students to participate in these competitions has come at a substantial cost to stakeholders, both in terms of financial resources and in terms of human resources such as time and effort. Despite the popularity of these competitions, little research has been conducted to investigate the educational impacts of participation in robotic competitions on students. One area in which only a small handful of preliminary studies have been conducted is the impact of participation in robotic competitions on students' self-efficacy. According to the literature review conducted in this study, self-efficacy has been shown to be an important factor influencing students' career and educational interests, choices, and attainment. The purpose of this study was to investigate two research questions relating to the self-efficacy of VEX Robotics Competition (VRC) participants. Several hypotheses relating to each research question were developed based on the findings of the literature review.

Research Question 1: What factors influence VRC participants' self-efficacy?

- Hypothesis 1A – Self-efficacy increases over years of participation in VRCs.
- Hypothesis 1B – Males have higher self-efficacy in VRCs than females.
- Hypothesis 1C – Students who have participated in other robotic competitions in addition to VRCs have higher self-efficacy in VRCs.

- Hypothesis 1D – Students who participate in VRCs as part of a formal, graded class have higher self-efficacy than students who participate in a more informal setting.

Research Question 2: What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors?

- Hypothesis 2A: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing a STEM major.
- Hypothesis 2B: Students with higher self-efficacy in VRCs are more likely to choose a STEM major upon enrollment in post-secondary education.
- Hypothesis 2C: Secondary students with higher self-efficacy in VRCs are more likely to express interest in choosing an engineering major.
- Hypothesis 2D: Students with higher self-efficacy in VRCs are more likely to choose an engineering major upon enrollment in post-secondary education.

Study Overview

In order to investigate these research questions, a cross-sectional study was selected utilizing T. P. Robinson's (2014) Self-Confidence Survey for VEX Robotics Participants (SCSVRP) to measure the self-efficacy of VRC participants and collect other demographic data, along with the Post-Secondary Choices Survey to gather data about participants' educational choices after high school graduation. The SCSVRP instrument measured self-efficacy in three different constructs, including Mechanical & Design, Programming, and Teaming & Professional Traits, as well as overall self-efficacy relating to tasks that are typical for students to complete during the course of participation in VRCs, such as designing a lift mechanism, programming a while loop, or resolving conflicts among team members.

Study participants were recruited during large VRC events such as the Utah State

VRC Championships and the CREATE U. S. Open Robotics Championships, as well as through recruitment efforts directed towards VRC coaches nationwide, with the assistance of the CREATE Foundation as well as the researcher's own efforts. Over a period of three years (corresponding to three VRC seasons), 390 students who participated in VRCs submitted complete and valid responses to the SCSVRP instrument, and 28 participants also submitted complete and valid responses to the Post-Secondary Choices Survey. These responses were collected at or near the conclusion of each VRC season for the duration of the study.

The data were analyzed utilizing standard correlation and regression techniques (discussed in detail in Chapters III and IV) with the goal of developing regression models for predicting self-efficacy, preference for choosing a STEM major, and preference for choosing an Engineering major. In addition, correlation results were calculated for students' choice of STEM and engineering majors after graduating high school and enrolling in post-secondary education programs. The sample size of participants who completed the Post-Secondary Choices Survey was insufficient to support regression analysis of this data, thus only correlational results were obtained for that portion of the study.

The first goal of this study was the development of regression models for VRC participants' self-efficacy in order to determine what factors influence participant self-efficacy within each of the three constructs as well as overall. The second goal of this study was the development of regression models for predicting VRC participants' college major preference prior to high school graduation, along with obtaining correlational

results about VRC participants' actual choice of major upon enrolling in post-secondary education programs.

While specific findings and the results of statistical tests are presented in the previous chapter, this chapter offers interpretation of the results with conclusions and implications for future research. Conclusions based on the results of this study for each of the research questions and associated hypotheses will be discussed, followed by other observations that were not necessarily part of the focused research questions, but were still worth noting.

Discussion and Conclusions

Research Question 1

Research Question 1 asked, *"What factors influence VRC participants' self-efficacy?"* Four supporting hypotheses were developed relating to this research question.

First, it was hypothesized that VRC participants' self-efficacy would increase as they gained more experience in VRCs in the form of years of participation. Although some might contend that self-efficacy would naturally increase over time as a result of maturation or simple experience, it is by no means obvious that self-efficacy naturally increases with time and/or experience. As discussed in the literature review, a major factor impacting the self-efficacy of an individual is the successes or failures they experience while doing a particular task. Vicarious experience gained through watching others succeed or fail also impact self-efficacy. Successes (experienced directly or vicariously) tend to result in increased self-efficacy, while failures tend to result in

decreased self-efficacy. During the course of participation in VRCs, there are many opportunities for students to succeed or fail, thus there are opportunities in which students' self-efficacy might be positively or negatively affected. A challenge that is overwhelmingly difficult and leads to a preponderance of failures rather than successes might well result in decreased self-efficacy leading to avoidance behaviors when participants are faced with similar challenges. Thus, a key question is whether VRCs are structured such that students generally experience more success than failure while still being appropriately challenged., leading to increased self-efficacy over time.

The results of this study indicated that students with more years of experience can be expected to score higher on both overall and Mechanical & Design self-efficacy. In addition, although a direct impact on Programming self-efficacy and Teaming & Professional Traits self-efficacy was not apparent, self-efficacy in both constructs was predicted by Mechanical & Design self-efficacy, suggesting that perhaps an indirect effect on self-efficacy in these two constructs exists and is mediated by Mechanical & Design self-efficacy. This seems plausible, considering that in order to successfully program a VRC robot, it is necessary to be very familiar with its mechanical workings. Likewise, it seems plausible that in order to feel confident when talking to a judge about the design of one's robot, one must also feel confident in being able to explain the mechanical aspects of its function. Another nuance to consider in interpreting these results is the fact that, in most VRC teams, only one or possibly two students on the team is responsible for programming. The fact that seasons of experience was not found to be a statistically significant predictor of Programming self-efficacy could be explained by the

fact that only a few students become programmers on their teams. In general, these results support the conclusion that VRC participants' self-efficacy does indeed increase over years of participation. This conclusion is based on a critical assumption that any group of first-year VRC participants with limited VRC experience is substantially similar to any other group of first-year VRC participants, thus comparisons between participants of differing levels of experience can offer useful information about how any one group may progress over time. The question of whether VRC participants' self-efficacy increases over time is key to understanding the educational impacts of VRC participants, as self-efficacy has been shown through many studies to influence students' academic and career interests, choices, and attainment. Since VRC participation leads to increased self-efficacy over time, particularly within the Mechanical & Design construct, it seems reasonable to expect positive impacts on students' educational and career interests, choices, and success in terms of leading them to pursue STEM careers.

The second hypothesis stated that students who identified themselves as biological males would have higher self-efficacy in VRCs. Much has been said in the scholarly community about the disparity between males and females in terms of participation in STEM activities, education, and careers. The lack of female participation has been exhaustively documented, with many theories being put forth as to why and as to how it can be addressed. In light of the findings of previous studies on female versus male participation in robotic competitions in general, as well as VRCs specifically, it was hypothesized that females would exhibit lower self-efficacy in VRCs than males. If true, this could well offer a partial explanation for low female participation rates in VRCs,

given that the literature on self-efficacy suggests that individuals with low self-efficacy in a given area are more likely to avoid that area in the future because they view it as threatening. Of course, other potential barriers likely exist, including the lack of female mentors and instructors in robotics competitions (Bers & Sullivan, 2019), but, even so, if females score lower on self-efficacy in VRCs, then it stands to reason that they would be less likely to continue participating. As shown in the results, overall self-efficacy and self-efficacy in all constructs except Teaming & Professional Traits was strongly predicted by the self-reported biological sex of the participant, with males having higher self-efficacy on average. After obtaining these results from the correlation and regression analysis, the question arose whether self-efficacy over years of experience looked differently for males versus for females. Although a more rigorous investigation of this question should be conducted in a future longitudinal study, the researchers charted the mean self-efficacy for males and females based on seasons of experience in order to suggest possible interpretations of the results of this study. Figures 1-4 show a graphical representation of these data. Self-efficacy is abbreviated as S/E in these charts.

Interestingly, as shown in these charts as well as the correlation results, females tended to participate in fewer VRC seasons than males. Females also tended to track lower in self-efficacy than males at all levels of experience (with the exception of Teaming & Professional Traits self-efficacy) even though female self-efficacy generally seems to increase over time at a similar rate compared to males. This study did not seek to establish why any differences in self-efficacy between males and females might exist, but one possible explanation is the tendency for males to overestimate their own abilities

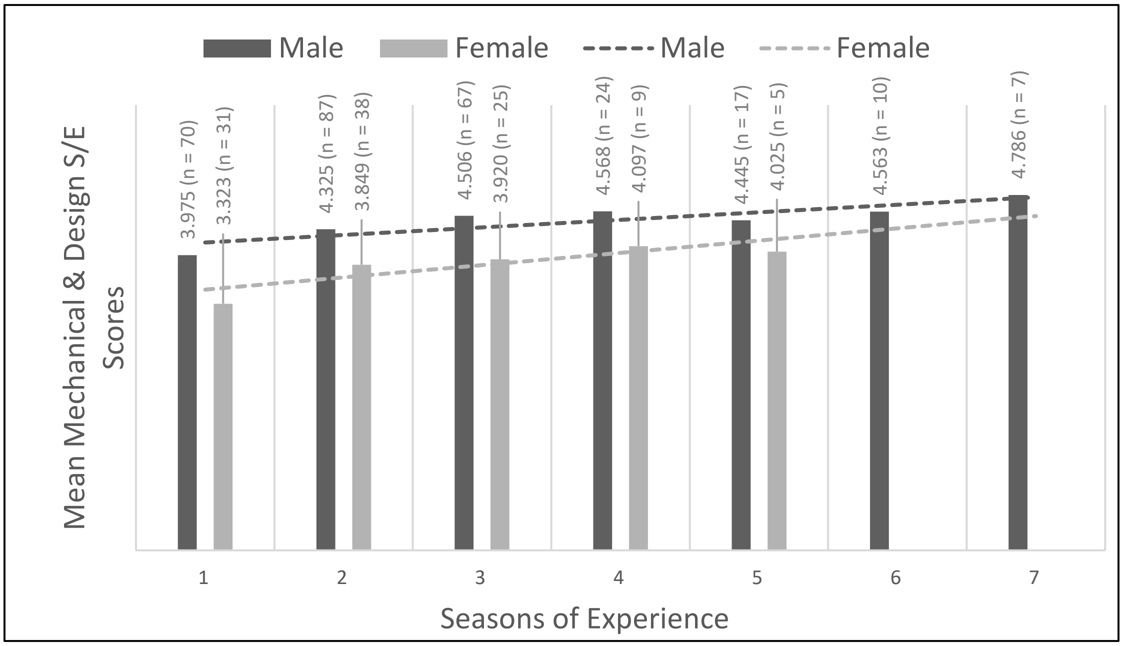

Figure 1. Mean Mechanical & Design self-efficacy scores with linear trends for males and females over seasons of experience.

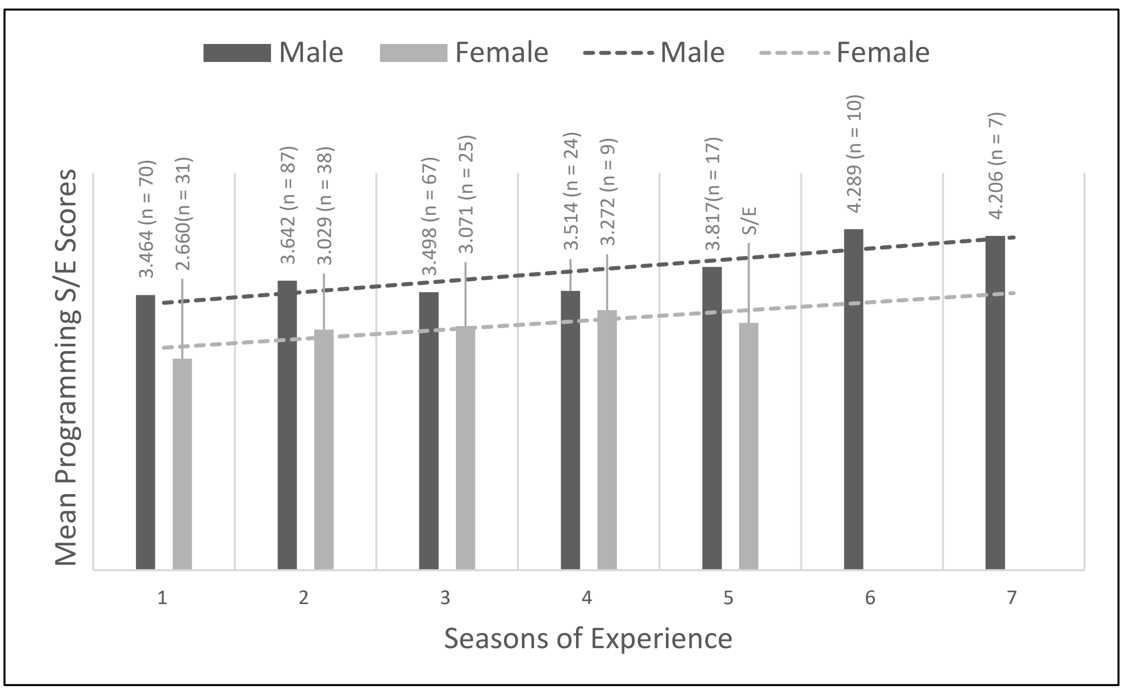

Figure 2. Mean Programming self-efficacy scores with linear trends for males and females over seasons of experience.

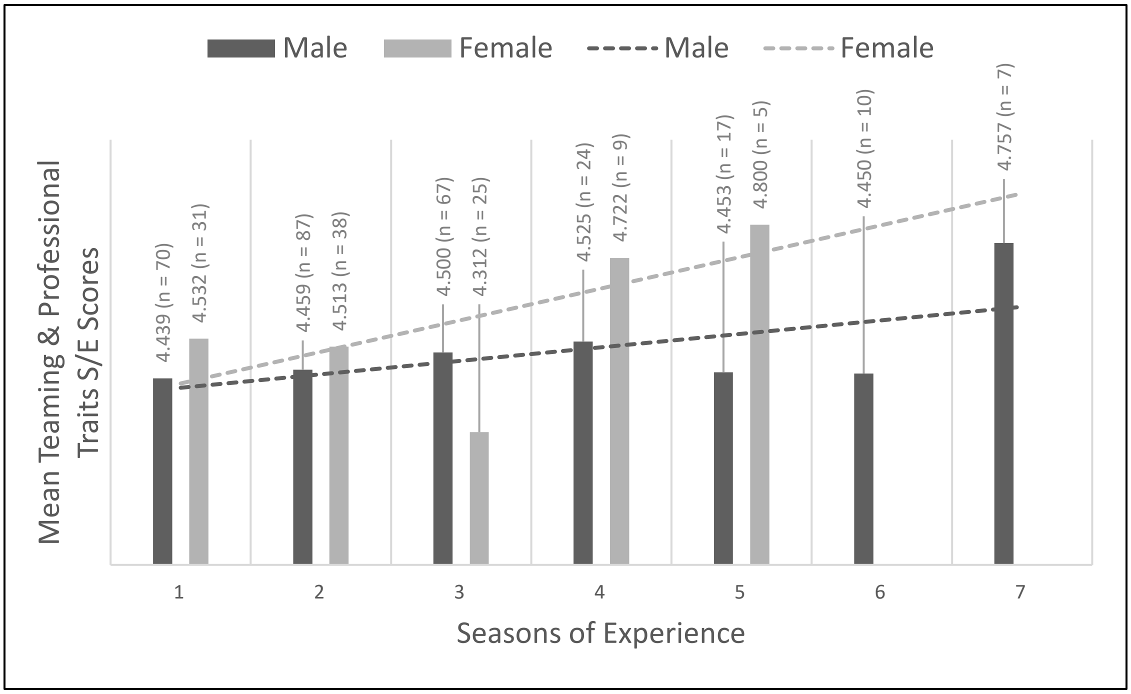

Figure 3. Mean Teaming & Professional Traits self-efficacy scores with linear trends for males and females over seasons of experience.

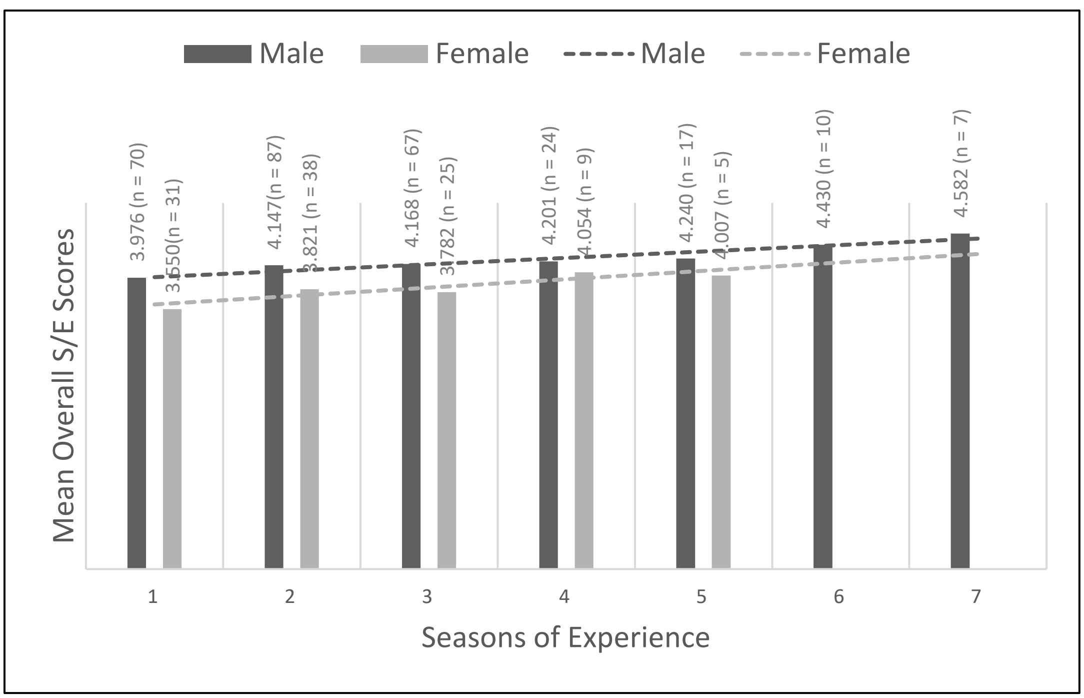

Figure 4. Mean overall self-efficacy scores for males and females over seasons of experience.

(Syzmanowicz & Furnham, 2011). Further research needs to be done to determine the cause of lower female self-efficacy in VRCs. Females' lower self-efficacy may cause them to be less likely to persist, even though their self-efficacy tends to increase over time. This is consistent with the findings of the literature review, which indicated that individuals with lower self-efficacy are less likely to persist. An alternative explanation that was explored was the possibility that females tend to begin participating in VRCs at a later time than males, and therefore participate in fewer seasons than males, on average, before graduating from high school. In consideration of this possibility, the average grade level of males and females in their first season of VRC participation were compared. The average grade level of females in their first VRC season was 8.87 (*SD* = 1.784) while the average grade level of males in their first VRC season was 9.26 (*SD* = 1.791). This comparison suggests that males and females participating in this study tended to start participating in VRCs at roughly the same grade level, thereby suggesting that the disparity between males and females in their length of participation in VRCs was not due to females starting later than males (in fact, males in this study started slightly later than females on average). The results of this study suggest that males and females may experience VRCs differently in a way that correlates with lower self-efficacy and less persistence among females. This conclusion has important implications for best practices if a goal of VRCs is to encourage increased female participation. However, it should also be noted that female participation rates in VRCs for this study were extraordinarily high compared to female participation in engineering careers (Fouad, 2014), with 28% of VRC participants in this study identifying themselves as biological females.

The third hypothesis under Research Question 1 stated that students who had participated in other types of robotic competitions would have higher self-efficacy. The primary reason for including this hypothesis was to begin to understand how participation in other robotic competitions might impact students educationally. A goal of future research may be to investigate how other robotic competitions compare to VRCs in terms of self-efficacy, thus it seemed appropriate to investigate whether self-efficacy in VRCs was impacted by participation in other types of robotic competitions, since other robotic competitions may incorporate many of the same types of tasks. The results of this study indicated that participation in other robotic competitions was a factor correlated with self-efficacy only within the Programming construct. Although further research is needed in order to compare different robotic competitions directly, it at least appears that students who participate in other robotic competitions in addition to VRCs are likely no better off in terms of self-efficacy, with the exception of Programming self-efficacy. A plausible reason for the significance of the impact of participation in other robotic competitions on Programming self-efficacy could be that students are exposed to other programming languages through participation in other competitions, thus allowing them to generalize programming principles across different languages and environments and thus become more adept at programming, leading to higher self-efficacy. Another possible reason could be the type of programming language used in VRCs. At the time the data was collected for this study, many VRC participants utilized a graphical block programming language called EasyC, rather than a language involving the writing out of actual computer code (although languages such as RobotC which require coding skills were an

available option). If other competitions focus more heavily on programming in a language requiring coding skills, it is possible that this results in higher programming self-efficacy. Future studies with a focus on the programming aspect of robotic competitions as it relates to students' programming self-efficacy may shed more light on this finding.

The final hypothesis under Research Question 1 stated that students who participated in VRCs as part of a formal, graded class would have higher self-efficacy in VRCs. Although previous studies found no association between self-efficacy and the format in which a student participated in VRCs, this question seemed worth further investigation with a larger sample size due to its implications for state and local school administrators and other decision-makers tasked with determining curricula and course offerings in schools. However, it should be noted that there is some lack of resolution in ascertaining whether students participated in VRCs as part of a graded course or otherwise. This is because it is possible that a student might have participated in VRCs as part of a graded course, and then participating in a non-graded setting as a result of geographic relocation, advancing to a new grade, or other reasons, or vice versa. The question on the SCSVRP survey asked students whether their current team meets primarily as part of a graded class, but there was no question collecting data about the setting of any past participation, which could differ. Future studies, especially longitudinal studies, should address this issue when investigating this question. The results of this study indicated that there was no statistically significant association between self-efficacy in VRCs and whether a student participated as part of a graded

class or otherwise. The conclusion that there is no association between participation format and self-efficacy is important for individuals who must decide how resources must be allocated within a school setting, as it appears that an optional after-school or community-based VRC program is just as effective in terms of student self-efficacy as a program that is conducted as part of a formal, graded class.

In addition to the results related to each of the hypotheses discussed above, additional factors were shown to impact self-efficacy within one or more constructs. Students' preference for pursuing an engineering degree was found to be a statistically significant predictor of overall self-efficacy and Mechanical & Design self-efficacy, and vice versa. This finding is interesting in that this relationship presents a proverbial 'chicken or the egg' scenario; in other words, it is not obvious based on the data collected in this study which variable (if either) is antecedent to the other. It is equally reasonable to presume that higher overall self-efficacy and Mechanical & Design self-efficacy leads to a preference for pursuing an engineering degree as it is to presume that students who are interested in pursuing an engineering degree tend to develop higher self-efficacy overall and in Mechanical & Design. Alternatively, it is possible or even likely that either scenario can be true depending on the individual student. Similarly, students' preference for pursuing a STEM degree was predictive of Mechanical & Design self-efficacy, though the reverse was not true. In order to fully parse these effects, a longitudinal study would be ideal.

Another finding not subsumed under one of the hypotheses, but which was nevertheless relevant to Research Question 1 was that self-efficacy in some construct

areas predicted self-efficacy in others. Specifically, self-efficacy in Mechanical & Design was a statistically significant predictor of, as well as being predicted by self-efficacy in Programming and Teaming & Professional Traits. For reasons discussed earlier in this section, this seems not altogether unexpected, though again it presents the question of how these relationships come about in reality. Clearly, additional research, especially longitudinal research, is needed to find answers to these questions.

Research Question 1 asked, *"What factors influence VRC participants' self-efficacy?"* According to the conclusions just discussed, it appears that the variables with the largest and most general influence on self-efficacy were biological sex and years of experience in VRCs. Additionally, self-efficacy in the Mechanical & Design construct both predicts and is predicted by self-efficacy in Programming and Teaming & Professional Traits. Students' preference for pursuing an engineering degree was also a factor in predicting Mechanical & Design self-efficacy and overall self-efficacy. Students' preference for pursuing a STEM degree was a factor in predicting Mechanical & Design self-efficacy as well. Students' Participation in other robotic competitions also had a significant influence on Programming self-efficacy.

Research Question 2

Research Question 2 asked, *"What is the relationship between self-efficacy in VRCs and students' interest in and choice of STEM majors?* Four supporting hypotheses were developed relating to this research question.

The first hypothesis stated that students with higher self-efficacy would be more likely to express interest in choosing a STEM major. As discussed in the literature

review, self-efficacy has been shown to have a profound influence on educational and career interests. Thus, it seemed reasonable to hypothesize that students with higher levels of self-efficacy in VRCs, which incorporate elements of all four components of STEM, would be more likely to express a preference for choosing to pursue a STEM degree. The results of this study indicated that although both overall self-efficacy and Mechanical & Design self-efficacy were positively correlated predictors in a statistically significant regression model for predicting VRC participants' preference for pursuing a STEM major, neither was statistically significant as a predictor in the model. Furthermore, although statistical significance was achieved in the overall model and post-hoc tests confirmed that it correctly classified cases significantly better than by chance, the variance accounted for in the model was very small (Nagelkerke R^2 = .027). This result suggests that there are likely additional variables strongly influencing VRC participants' interest in pursuing a STEM major that were outside the scope of this study and thus were not addressed. Thus, although for this study the conclusion that self-efficacy had an influence on students' interest in STEM is only weakly supported, additional studies focused specifically on the factors influencing VRC participants' educational interests would be helpful to identify what factors most profoundly influence VRC participants' educational and career interests.

The second hypothesis under Research Question 2 stated that VRC participants with higher self-efficacy would be more likely to choose a STEM major upon graduating from high school and enrolling in post-secondary studies. As discussed in the literature review, self-efficacy has a strong influence on educational and career choices, thus it was

reasonable to hypothesize that VRC participants with higher self-efficacy would be more likely to choose STEM majors, since participation in VRCs incorporates many elements of STEM. Although the sample of VRC participants who had graduated high school and enrolled in post-secondary education programs was of insufficient size to permit regression analysis, correlation results indicated that overall self-efficacy and Programming self-efficacy were significantly and positively correlated with choice of STEM majors, with a medium to large effect size. This result seems to support the conclusion that self-efficacy, at least in some areas, influences students' choice of STEM majors, but more rigorous studies with larger sample sizes are needed to fully investigate this issue.

The third hypothesis relating to Research Question 2 stated that students with higher self-efficacy would be more likely to express interest in choosing an engineering major (specifically, as opposed to all STEM majors not limited to engineering). The results of this study indicated that both Mechanical & Design self-efficacy and overall self-efficacy were statistically significant predictors of engineering major preference among VRC participants. These results support the conclusion that self-efficacy, at least in some areas, is related to students' interest in pursuing an engineering major. The implications of this conclusion are important, as it aligns with previous research findings about the relationship between self-efficacy and career/educational interest. In the context of VRCs, it appears that not only does participation in VRCs tend to result in increased self-efficacy for participants, but that this self-efficacy influences participants' interest in choosing an engineering major.

The final hypothesis presented under Research Question 2 stated that students with higher levels of self-efficacy would be more likely to choose an engineering major upon enrolling in post-secondary education. Although the sample of VRC participants who had graduated high school and enrolled in post-secondary education programs was of insufficient size to permit regression analysis, correlation results indicated that there was no significant relationship between self-efficacy and choice of engineering majors. As with participants' choice of STEM majors more generally, further investigation into the factors which influence VRC participants' choice of major would provide further clarification.

In addition to the conclusions presented above, additional findings arose which were relevant to Research Question 2. One finding of particularly high interest was that participants' choice of an engineering major was negatively correlated with the level of mathematics courses that they took during high school, with a medium to large effect size. This finding was surprising, considering that one major reason college engineering students drop out or change major may be the difficulty of the required mathematics courses in engineering degree programs. During the process of interpreting this result, the question arose as to whether there was a difference between males and females in the correlation between higher math attainment and choosing an engineering major. Additional correlation tests were run to determine whether any differences existed. Although the sample sizes of males and females were small (n = 16 for males and n = 12 for females), the correlation between females' math attainment and their choice of an engineering major was large and remained negative (r = -.717, p = .002), while the same

test for males resulted in a non-significant correlation (r = -.076, p = .815). These additional results suggest that the negative correlation between math attainment and choice of engineering majors in this study was highly dependent on gender, though the small sample size seriously limits the generalizability of this finding. If female VRC participants who are most prepared for rigorous college mathematics courses are indeed choosing majors other than engineering as this finding seems to suggest, finding out why may provide valuable information to help increase retention in engineering degree programs by encouraging those students who are most prepared to choose to study engineering. One possible explanation for this finding which could be investigated is whether current methods of mathematics instruction create an environment which disproportionately affects female students in such a way that they choose not to pursue degree programs that require rigorous mathematics coursework. Another alternative may be investigating whether female students who excel in mathematics are not being encouraged to pursue engineering degrees for reasons such as gender bias, or lack of female role models in engineering disciplines. Or, perhaps, differences in personality traits (e.g., extraversion, agreeableness, etc.) between males and females offer a better explanation. Because of the small sample size of post-secondary participants in this study, these findings should be viewed as very preliminary and interpreted with caution, but further investigation of this surprising finding could yield profound results.

Another finding of interest which was touched on only briefly earlier was that in for VRC participants' choice of STEM majors and engineering majors specifically, their earlier interest in those choices was highly correlated with their actual choice. This

finding should not be particularly surprising, since it aligns well with the career choice model discussed in the literature review, but it does reinforce that efforts to generate interest in STEM careers (and engineering in particular) may be fruitful in generating results in terms of students going on to choose to study and work in those areas. Furthermore, as shown in this study, the development of self-efficacy in these areas through participation in VRCs may be a valuable way to address this issue, particularly with respect to generating interest in engineering careers.

Research Question 2 asked *"What is the relationship between self-efficacy and VRC participants' interest in and choice of STEM majors?"* The findings of this study support the conclusion that higher self-efficacy, particularly Mechanical & Design and overall self-efficacy, likely produces positive effects on VRC participants' interest in pursuing STEM majors, especially engineering. The findings of this study also support the conclusion that there may be a positive relationship between VRC participants' overall self-efficacy and programming self-efficacy and choosing a STEM major, but not engineering specifically.

Recommendations

Several recommendations for best practices related to VRCs, self-efficacy, and students' educational interests and choices, as well as recommendations for further research and analysis arose from this study. These recommendations are based on the quantitative results presented in Chapter IV and the conclusions just discussed in this chapter, and should serve as a catalyst for further study, discussion, and inquiry into the

educational impacts of VEX Robotics Competitions, and educational robotic competitions more generally.

Recommendations for Best Practices

As shown in this study, VRC participants' self-efficacy was greatly impacted by their self-reported biological sex and the extent of their experience in participating in VRCs. Males were more likely to have high self-efficacy than females in all areas except Teaming & Professional Traits, and students who had more years of experience in VRCs tended to have higher levels of self-efficacy.

Self-efficacy also seems to contribute to students' interest in choosing STEM careers, especially engineering, and this interest tends to carry through in students educational and career choices after they graduate from high school.

Addressing gender issues. It is clear from the results of this study and others that gender is a significant issue facing the VRC community in terms of participation and its impact on self-efficacy. Although, based on the results of this study, female participation in VRCs appears to outpace that of related industries (e.g., engineering), some concerning trends were observed. First, females tended to have lower self-efficacy in most areas, and second, females tended to have fewer seasons of participation in VRCs, implying that females tend to quit after only a few seasons. Although all the reasons this is occurring are not directly apparent from the results of this study, some explanations and recommendations may be offered which could benefit the VRC community at large, but especially participants who are female.

Increasing formal emphasis on teamwork and professionalism. VEX Robotics

Competitions are structured as sporting event-like competition between two alliances made up of two or three teams each. In light of the findings of this study with regard to the relationship between students' biological sex and their self-efficacy, it becomes imperative to ask whether females are 'winning' in VRCs. Since success in a challenging situation (such as a VRC event) tends to increase self-efficacy, it follows that we must ask whether females are experiencing success in VRCs less than males, leading to generally lower self-efficacy and consequently lower levels of persistence. In order to succeed in VRCs, cooperation and professionalism are needed not only within the team unit, but also between teams in any given alliance. Based on the results of this study, Teaming & Professional Traits appeared to be the single area in which males and females were at least equal in terms of self-efficacy. Thus, it seems pertinent that if female participation and self-efficacy is to be increased, a good place to start may be increasing the emphasis on teamwork in terms of awards and recognition at VRC events, potentially allowing females more opportunities to experience success. Although teamwork is an implied and oft-discussed necessity for success at VRC events, including the receiving of awards, there is little formal, quantifiable emphasis on this aspect of the competition when it comes to the selection of teams for awards and recognition at VRC events. According to the Robotics Education & Competition Foundation VRC Judge Guide (RECF, 2018c) for the 2018-19 VRC season, awards offered at most VRC events are mainly limited to the Excellence Award, Tournament Champion, Robot Skills Award, Design Award, Judges Award, and Volunteer Awards. Only the very largest events such as the World Championship typically offer awards focused on teamwork and

professionalism, such as the Service Award, Sportsmanship Award, and Teamwork Award, among others, and these are noticeably situated as third-tier awards in the Judge Guide. Notably, although the Excellence Award and Robot Skills Awards can qualify the recipients to compete at higher level events such as State and World Championships, no awards focused on teamwork and professionalism are attached to such qualifications. The criteria for the Excellence Award do note that judges are to consider whether the team is student-centered and exhibits good sportsmanship and professionalism, but it is unclear how much of a role this plays in the selection of a team for this award after considering other team qualities such as the strength of the Engineering Notebook and on-field performance, especially in a typically sized VRC where only a few teams may even meet all the minimum requirements for the Excellence Award.

One recommendation stemming from the findings of this study is that females' interest and participation in VRCs may be benefitted by increasing and formalizing the emphasis on teamwork and professionalism in terms of recognition at all VRC events. For example, including a teamwork-based award as a standard award recognized at most VRC events, qualifying the recipients of teamwork-based awards for higher-level VRC events, and clarifying and strengthening teamwork and professionalism criteria for the selection of the Excellence Award recipient would represent clear steps to increase emphasis on this facet of the competition. In addition to broad actions such as those suggested above which could be taken by governing organizations, individuals within the VRC community can make a difference in recognizing and supporting teamwork and professionalism at the event or team level. Event organizers can take steps to increase

emphasis on teamwork and professionalism by choosing to offer teamwork-based awards at their events and training judges to recognize these attributes when considering teams for awards. Coaches and mentors likewise can increase emphasis on teamwork and professionalism within their individual programs by recognizing and rewarding students who exhibit related skills or qualities such as conflict resolution, addressing judges professionally, and sacrificing personal gain for the benefit of the team.

Partner with other organizations which serve female students. Many local, national, and international organizations exist which serve middle and high school-age females. Many of these are focused on or support initiatives to increase female participation in STEM education and careers. Examples of national or international organizations include the Girl Scouts, Frontier Girls, SWENext, etc., and many other regional or local organizations exist also. One recommendation to improve female participation in VRCs and to potentially find ways to increase female VRC participants' self-efficacy through modification of VRC events to appeal more to females is to partner with such organizations directly. Partnerships of this nature could result in valuable insights for VRC organizers and individual teams on how to attract and retain more female participants. A successful example is Girl Powered, a "global movement launched by the Robotics Education & Competition Foundation and VEX Robotics, and supported by Google" (RECF, 2019d, para.1). According to the REC Foundation, this partnership has resulted in a large increase in the number of female participants in VRCs. Partnerships of this nature, and especially those which could be forged with already-existing organizations, have the potential to change the face of VRCs in a fundamental

way to encourage female participation and development of self-efficacy among females. Local or regional partnerships could provide similar benefits on a smaller scale.

Increase the presence of female role models in the VEX Robotics community. Sullivan & Bers (2019) found that female mentors in VRCs are strongly outnumbered by their male counterparts. This is true particularly when VRC participants reach high school (Hendricks et al., 2012). Existing research has highlighted the importance of female role models in increasing female students' interest, performance, and persistence in STEM disciplines (e.g., Herrman et al., 2016; Weber, 2011). As discussed in the literature review, interest, performance, and persistence are all influenced by self-efficacy, and self-efficacy can be increased when individuals observe someone with whom they share common characteristics succeed at a given task. Increasing the presence of female role models in VRC leadership, events, and teams may help female students develop more confidence as they see that females can succeed in VRCs and in STEM disciplines. Examples of how this could occur include recruiting female judges, referees, announcers, and other officials for VRC events (particularly large-scale events such as the World Championships), recruiting female mentors and coaches for VRC teams, and increasing female leadership in the VRC community.

Participation in VRCs. Another major finding of this study was that self-efficacy appears to increase over time for VRC participants. Based on this conclusion, it can be stated with some confidence that VRCs provide an avenue through which students' self-efficacy in high-demand areas such as mechanical design and programming can be developed and enhanced. Self-efficacy in these areas seems to be associated with

students' interest in choosing STEM careers, especially engineering, and this interest tends to manifest itself in students' educational and career decisions. These findings are significant in that they may represent the best data so far measuring some of the educational impacts of VRC participation. Considering this, it is recommended for stakeholders and decision-makers to support efforts to increase student participation in VRCs by supporting VRC programs both within schools (either as formal classes or after-school clubs) and community-based education initiatives such as maker spaces, 4-H, Scouting, etc. Support for these efforts can be monetary in nature, but other forms of support such as volunteering time, use of facilities, etc. can be extremely beneficial as well.

Recommendations for Further Study

In addition to the recommendations for best practices discussed above, the results of this study gave rise to several recommendations for additional research and discussion within the academic community. Additional study is of critical importance in order to continue to assess the educational impacts of participation in VRCs, and robotic competitions generally. In no way should the findings of this study be considered definitive, as many of the findings have generated at least as many questions as answers. It is important that further investigation is conducted, since the financial and human resources being committed to support student participation in VRCs are enormous.

Longitudinal research. One of the most promising avenues for continued research into the self-efficacy of VRC participants is through longitudinal studies. Although this study was able to offer important insight into how VRC participants' self-

efficacy changes over time, a longitudinal study would offer a more rigorous and exhaustive approach as a result of allowing researchers to follow the progress of individual students through years of participation in VRCs and beyond. A large-scale longitudinal study with adequate supports could accomplish goals such as the following.

- Verify the findings of this study that the self-efficacy of VRC participants tends to increase over time
- Offer insight into the dynamics of these changes (e.g., whether self-efficacy in a particular construct rises more quickly than in others)
- Offer insights into the conditions under which self-efficacy in a particular construct area is developed (e.g., whether programming self-efficacy is linked to becoming a team programmer)
- Establish the direction of the relationship between self-efficacy and its contributing factors (e.g., determine whether Mechanical & Design self-efficacy predicted by or a predictor of interest in STEM careers)
- Provide needed data on the disparities between males and females (e.g., determine whether self-efficacy is a reason that females tend to have fewer seasons of participation in VRCs)
- Provide more robust findings relating to post-secondary education and career choices
- Investigate the relationship between self-efficacy of VRC participants and success in post-secondary engineering programs by tracking students' progress through college graduation

There are challenges inherent in conducting a longitudinal study of the necessary scope to accomplish goals such as those listed above. One of the primary challenges is the long-term retention of study participants. In this study, only a small number of students submitted multiple responses to the SCSVRP instrument, and even fewer continued their participation past high school graduation. It is suggested that researchers seeking to conduct a longitudinal study in this area should give ample thought to

addressing this challenge. Offering incentives such as entering participants names into a prize drawing may provide one way of mitigating participant attrition, though this could present IRB-related complexities that will need to be addressed. Additionally, offering effective incentives or decreasing attrition through other means will certainly require financial support through research grants or other sources.

A second major challenge in conducting a longitudinal study of this type is access to VRC participants. This study relied heavily on the generosity of the CREATE Foundation, which organizes the CREATE U.S. Open Robotics Championships where a large number of participants in this study were recruited. The CREATE Foundation is primarily a regional organization centered in the midwestern United States, though it does have a national reach as their VRC event attracts teams representing most U.S. states. However, in order to achieve the number of participants required to combat attrition in a large-scale longitudinal study which tracks students for several years, including after high school graduation, access to thousands of VRC participants willing to participate in the study will likely be necessary. A longitudinal study should include a power analysis and consult existing literature (including this study) to estimate the impact of attrition in order to determine the appropriate sample size. Any longitudinal study of this scale will almost certainly require the support of the Robotics Education and Competition Foundation, which is the main governing organization over VRC events, in order to access the required numbers of VRC participants.

Despite the obvious challenges with conducting a large-scale longitudinal study investigating the questions presented above, such a study would provide invaluable data

to inform stakeholders and decision-makers about the educational impact of VRCs. And, if the results of this study are an indication, the potential findings of such a study seem promising. Researchers and national organizations such as the REC Foundation need to work together to prioritize additional research of this type.

Focused studies on self-efficacy. In addition to large-scale longitudinal studies, smaller studies with more narrowly focused goals can also provide valuable insight into the educational impact of VRCs. Based on the results of this study, additional research on the development of self-efficacy within particular constructs is needed to flesh out details on how self-efficacy is developed within these areas. For example, self-efficacy in the Programming construct may present some unique differences compared to other construct areas, since in most VRC teams only one or possibly two students do all or most of the programming, and these same students may take on this role over multiple years. Findings in this study indicated that students who participated in other robotic competitions developed higher self-efficacy in programming, but not in other constructs. Studies which focus in on self-efficacy development in particular constructs may highlight interesting and useful nuances, adding to our understanding of how to encourage and support students' interest in these areas.

Focused studies on VRC participants' career interest and choices. Another area which may prove to be a fruitful line of research is investigating how VRC participants choose career and educational paths. This study added to the current scholarly discussion by investigating whether self-efficacy was related to students' interest in and choice of STEM majors and produced interesting findings which prompt

further questions on this subject.

Investigating additional factors influencing VRC participants' choice of major. One major question that still needs to be answered is what factors influence VRC participants' interest in and choice of major. Self-efficacy is but one possible factor, and the results of this study suggest that there is much more to the story. Another question that needs to be addressed more fully is the relationship between VRC participants' self-efficacy (and other potential factors) on their actual choices after they graduate from high school. The findings of this study were limited by the small sample size of post-secondary participants, and more investigation with larger sample sizes is needed. Additional studies on VRC participants' career interests and choices—particularly studies which include larger samples of post-secondary students—would be extremely valuable in assessing the educational impacts of participation in VRCs.

Investigating the relationship between gender, mathematics attainment, and career choices. One surprising finding in this study was the negative association between female VRC participants' mathematics attainment (i.e., the level of mathematics taken in high school), and their likelihood of choosing an engineering major in college. One possible explanation for this finding that should be investigated is whether current practices in mathematics instruction may be contributing to this effect in some way. Another potential avenue for inquiry is whether other issues such as gender bias and/or lack of female role models could be at play, as is the role of personality differences (e.g., agreeableness, openness, etc.) between males and females. In large part due to the small sample size of post-secondary participants in this study, but also because of the surprising

nature of this result, it is highly recommended that additional studies should be conducted investigating the relationship between mathematics attainment and female VRC participants' choice of major, with regard to the potential issues mentioned above. A study replicating this finding with a much larger sample and gathering additional data to help explain the result would be of immense value.

Investigating the impact of team makeup and leadership with respect to gender. One question that was raised during this study was the impact of team makeup and leadership on self-efficacy with respect to gender. Many females who participate in VRCs do so as part of all-female teams, while others participate alongside males in co-ed teams. In addition, as noted by Sullivan & Bers (2019) most adult mentors who interact with VRC teams are male while only a few are female. A study investigating how team makeup and leadership covaries with female participants' self-efficacy and educational choices would provide valuable insight into how to support female VRC participants.

Modifying the self-efficacy instrument for other uses. Another potential avenue of further research arising from this study could be to conduct similar studies investigating the impact of other robotic competitions. Robinson's Self-Confidence Survey for VEX Robotics Participants has proven to be a reliable and effective means of measuring the self-efficacy of VRC participants. Conducting research to modify and validate this instrument for use with other robotic competitions and conducting studies investigating the self-efficacy of students participating in other robotic competitions could provide a means of directly comparing the strengths and weaknesses of various robotic competitions in terms of participants' self-efficacy. Alternatively, translating and

validating this instrument for use in countries outside the United States would provide valuable opportunities to determine whether the findings resulting from this and similar studies hold true internationally, since VRCs are popular worldwide.

Conclusion

The findings of this study led to several useful conclusions and recommendations for best practices based on the results of this study. In addition, several recommendations for further research were suggested based on the results of this study.

The most important conclusions of this study were: (1) the self-efficacy of VEX Robotic Competition (VRC) participants tends to increase with years of participation in VRCs, and that increased self-efficacy—particularly in certain areas—among VRC participants may impact their college major preferences and choices (2) females tend to have lower self-efficacy than males, and they tend to participate in fewer seasons than males despite beginning their participation slightly earlier on average, and (3) female VRC participants' choice of engineering majors was strongly and negatively correlated with the level of mathematics coursework in high school, but the small sample size in this study warrants further research.

These conclusions led to several recommendations for best practices and for further study. The most important of these recommendations were: (1) the need for a rigorous, large-scale longitudinal study with support from major players in the VRC community—specifically the Robotics Education and Competition Foundation, (2) the need to increase institutional support from educational institutions and other stakeholders

to encourage and facilitate student participation in VRCs, and (3) the need to address female participation and success in VRCs through increased emphasis on teamwork and professionalism in VRC events and at the team level, increasing the number of and continuing existing partnerships with organizations which serve female students, and increasing the presence of female role models in the VEX Robotics community.

It is hoped that these conclusions and recommendations provide valuable insight to educators, parents, students, and other stakeholders and decision-makers about the educational impact of VEX Robotic Competitions and how best to provide supports for student participation and engagement. Additionally, it is hoped that these conclusions and recommendations will add constructively and meaningfully to the scholarly discussion regarding the educational impact of robotic competitions and provide a basis for additional avenues of research in this area.

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APPENDICES

Appendix A

Parent Letter of Information

UtahState University
Department of Agricultural Systems
Technology and Education
6000 Old Main Hill
Logan UT 84322-6000
Telephone: (435) 797-1802

IRB Approval Date: 09/10/2015
IRB Approval Expires: 09/09/2017
Protocol #6809
IRB Password Protected per IRB Coordinator

PARENTAL LETTER OF INFORMATION

A Longitudinal Study to Investigate the Change in Self-Efficacy in Students Who Compete in VEX Robotics

Introduction/ Purpose Dr. Gary A. Stewardson, PhD, and Joseph S. Furse, in the School of Applied Sciences, Technology, and Education at Utah State University are conducting a research study to find out more about the self-confidence students gain through participation in VEX Robotics Competitions (VRCs). Your child is being asked to take part because of his or her participation in competitive VEX Robotics. There will be approximately 2000 total participants in this research.

Procedures If your child agrees to be in this research study, he or she will be asked to complete an online survey that should take approximately 15-20 minutes to complete. He or she will be asked to take this survey once per year, at the end of the competition season, until he or she graduates from high school. If this is your child's first year participating in VEX Robotics Competitions, he or she will also be asked to complete the survey at the beginning of their VEX robotics experience as well as at the end of the season. This survey will ask participants to rate their confidence level in completing certain tasks relating to VEX Robotics Competitions.

After your child graduates from high school, he or she will be asked to complete a different online survey once per year until he or she leaves college or until the study ends, whichever comes first. This survey will take about 10-15 minutes to complete, and will ask questions about your child's major and his or her progress toward completion. If your child is not currently planning to attend college, he or she may still participate in this study.

Risks Participation in this research study may involve minimal risk to your child. There is a small risk of loss of confidentiality, but we will take steps to reduce this risk.

Benefits There is no direct benefit to you or your child for participating in this research study. The information gained from this study will benefit future students, curriculum developers, planners, and sponsors of future VEX Robotics Competitions.

Explanation & offer to answer questions This letter has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may reach (PI) Dr. Gary Stewardson at (435) 797-1802, or by email at gary.stewardson@usu.edu.

Voluntary nature of participation and right to withdraw without consequence Participation in research is entirely voluntary. If you would prefer that your child not participate, please contact Gary Stewardson at (435) 797-1802 or at gary.stewardson@usu.edu within ten days of the date of receipt (via email) or within ten days of the date of postmark (via regular mail). You may still withdraw your child's participation at any time after those ten days. Your child may refuse to participate or withdraw at any time without consequence or loss of benefits by simply discontinuing answering any survey questions. In addition, you may withdraw your consent for your minor child to participate in this research study at any time without consequence or loss of benefits by contacting Dr. Gary Stewardson at (435) 797-1802, or by email at gary.stewardson@usu.edu and requesting a reply. Your child may be withdrawn from this study by the investigators without consent if any of his or her surveys are incomplete or missing data.

UtahState University
Department of Agricultural Systems
Technology and Education
6000 Old Main Hill
Logan UT 84322-6000
Telephone: (435) 797-1802

PARENTAL LETTER OF INFORMATION

A Longitudinal Study to Investigate the Change in Self-Efficacy in Students Who Compete in VEX Robotics

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. The only personally identifiable information that will be collected will be your child's name, current email address, and phone number for the purpose of contacting him or her and maintaining a record of his or her participation. Only the investigators will have access to the data which will be kept in a locked file cabinet or on a password protected computer in a locked room. To protect your child's privacy, personal, identifiable information will be removed from study documents and replaced with a study identifier. Identifying information will be stored separately from data and will be kept until your child's participation in the study is concluded, or until the conclusion of the study on June 30, 2021 (whichever comes first).

IRB Approval Statement The Institutional Review Board for the protection of human participants at Utah State University has approved this research study. If you have any questions or concerns about your rights or a research-related injury and would like to contact someone other than the research team, you may contact the IRB Director at (435) 797-0567 or irb@usu.edu to obtain information or to offer input.

Investigator Statement "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

Signature of Researcher(s)

Gary Stewardson, PhD
Principal Investigator
(435) 797-1802
gary.stewardson@usu.edu

Joseph Furse
Student Researcher
(435) 216-8783
joseph.s.furse@aggiemail.usu.edu

Appendix B

Student Letter of Information

UtahState University
Department of Agricultural Systems
Technology and Education
6000 Old Main Hill
Logan UT 84322-6000
Telephone: (435) 797-1802

IRB Approval Date: 09/10/2015
IRB Approval Expires: 09/09/2017
Protocol #6809
IRB Password Protected per IRB Coordinator

STUDENT LETTER OF INFORMATION

A Longitudinal Study to Investigate the Change in Self-Efficacy in Students Who Compete in VEX Robotics

Introduction/ Purpose Dr. Gary A. Stewardson, PhD, and Joseph S. Furse, in the School of Applied Sciences, Technology, and Education at Utah State University are conducting a research study to find out more about the self-confidence students gain through participation in VEX Robotics Competitions (VRCs). You have been asked to take part because of your participation in competitive VEX Robotics. There will be approximately 2000 total participants in this research.

Procedures If you agree to be in this research study, you will be asked to complete an online survey that should take approximately 15-20 minutes to complete. You will be asked to take this survey once per year, at the end of the competition season, until you graduate from high school. If this is your first year participating in VEX Robotics Competitions, you will also be asked to complete the survey at the beginning of your VEX robotics experience as well as at the end of the season. This survey will ask you to rate your confidence level in completing certain tasks relating to VEX Robotics Competitions.

After you graduate from high school, you will be asked to complete a different online survey once per year until you leave college or until the study ends, whichever comes first. This survey will take about 10-15 minutes to complete, and will ask you questions about your major and your progress toward completion. If you are not currently planning to attend college, you may still participate in this study.

Risks Participation in this research study may involve minimal risk to you. There is a small risk of loss of confidentiality, but we will take steps to reduce this risk.

Benefits There is no direct benefit to you for participating in this research study. The information gained from this study will benefit future students, curriculum developers, planners, and sponsors of future VEX Robotics Competitions.

Explanation & offer to answer questions This letter has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may reach (PI) Dr. Gary Stewardson at (435) 797-1802, or by email at gary.stewardson@usu.edu.

Voluntary nature of participation and right to withdraw without consequence Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits by simply discontinuing answering any survey questions. You may be withdrawn from this study without your consent by the investigator if any of your surveys are incomplete or missing data.

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. The only personally identifiable information that will be collected will be your name, current email address, and phone number for the purpose of contacting you and maintaining a record. Only the investigators will have access to the data which will be kept in a locked file cabinet or on a password protected computer in a locked room. To protect your privacy, personal, identifiable information will be removed from study documents and replaced with a study identifier. Identifying information will be

UtahState University
Department of Agricultural Systems
Technology and Education
6000 Old Main Hill
Logan UT 84322-6000
Telephone: (435) 797-1802

IRB Approval Date: 09/10/2015
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Protocol #6809
IRB Password Protected per IRB Coordinator

STUDENT LETTER OF INFORMATION

A Longitudinal Study to Investigate the Change in Self-Efficacy in Students Who Compete in VEX Robotics

stored separately from data and will be kept until your participation in the study is concluded, or until the conclusion of the study on June 30, 2021 (whichever comes first).

IRB Approval Statement The Institutional Review Board for the protection of human participants at Utah State University has approved this research study. If you have any questions or concerns about your rights or a research-related injury and would like to contact someone other than the research team, you may contact the IRB Director at (435) 797-0567 or email irb@usu.edu to obtain information or to offer input.

Investigator Statement "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

Signature of Researcher(s)

Gary Stewardson, PhD
Principal Investigator
(435) 797-1802
gary.stewardson@usu.edu

Joseph Furse
Student Researcher
(435) 216-8783
joseph.s.furse@aggiemail.usu.edu

Appendix C

Self-Confidence Survey for VEX Robotics Participants

Self-Confidence Survey for VEX Robotics Participants

Start of Block: Self-Confidence Survey for VEX Robotics Participants

Self-Confidence Survey for VEX Robotics Participants

Please read the Letter of Information you received, then watch the following video for instructions on how to complete this survey.

- [ ] Yes, I have read the Letter of Information and watched the instructional video. (1)

Page Break

Are you currently participating on a VEX Robotics Competition team?

- ○ Yes (1)
- ○ No (2)

Skip To: Q36 If Are you currently participating on a VEX Robotics Competition team? = No

Page Break

What is your first name?

____

What is your last name?

____

What is your team number?

____

What is your sex?

- ○ Male (1)
- ○ Female (2)

During this year's VEX robotics season, what grade in school were you in?

- ○ 5th Grade or younger (1)
- ○ 6th Grade (2)
- ○ 7th Grade (3)
- ○ 8th Grade (4)
- ○ 9th Grade (5)
- ○ 10th Grade (6)
- ○ 11th Grade (7)
- ○ 12th Grade (8)

Please provide an email address that will remain active for at least a year.

**Please avoid using a school email address, as many school email systems do not allow students to receive outside email. If you only have a school email, please use it.

____

Please retype your email address for accuracy

____

Page Break

Would you like to receive next year's survey link via text message?

◯ Yes (1)

◯ No (2)

Skip To: Q6 If Would you like to receive next year's survey link via text message? = No

Page Break

Display This Question:
If Would you like to receive next year's survey link via text message? = Yes

*

Please write your phone number to receive text messages, including the area code. This will only be used to send you a survey link, and will not be shared with any third party. (Example: (123) 123-1234)

____

Display This Question:
If Would you like to receive next year's survey link via text message? = Yes

*

Please retype your phone number for accuracy.

____

Page Break

The following questions will address your participation in competitive VEX robotics.

How many seasons have you been competing in VEX Robotics Competitions?

◯ 1 (This is my first season) (1)

◯ 2 (2)

◯ 3 (3)

- 4 (4)
- 5 (5)
- 6 (6)
- 7 (7)
- 8 or more (8)

Display This Question:
If How many seasons have you been competing in VEX Robotics Competitions? = 1 (This is my first season)

How many official VEX Robotics Competitions have you participated in so far this year?

- 0 (1)
- 1 (2)
- 2 (3)
- 3 or more (4)

What is your primary responsibility on your VEX team, your most important role? (Please check only one.)

- Builder (1)
- Designer (2)
- Driver (3)
- Programmer (4)
- Team Leader (5)
- Team Promotion (6)
- Fundraising (7)

- Other (8)

What is your secondary responsibility on your VEX team, your second most important role? (Please check only one.)

- Builder (1)
- Designer (2)
- Driver (3)
- Programmer (4)
- Team Leader (5)
- Team Promotion (6)
- Fundraising (7)
- Other (8)

Select the choice that best describes your team affiliation.

- School team (1)
- Community team (2)
- 4-H (3)
- Scouting (e.g., Boy Scouts or Girl Scouts) (4)

Does your team primarily meet as a scheduled class in which you receive a grade and credit?

- Yes (1)
- No (2)

Have you ever participated in another type of robotics competition? (Example: FIRST, VEX IQ, CREATE Open, etc.)

◯ Yes (1)

◯ No (2)

Display This Question:
If Have you ever participated in another type of robotics competition? (Example: FIRST, VEX IQ, CREA... = Yes

Which other robotics competitions have you competed in?

____

Page Break

The following question(s) ask you about your future college plans.

At this point, do you plan on continuing your education after high school?

◯ Yes (1)

◯ No (2)

Display This Question:
If At this point, do you plan on continuing your education after high school? = Yes

What do you plan on studying after high school? At this time, if you are unsure of what you plan to study, write “unsure.”

____

Page Break

Directions: In the following three sections, you will be presented with a list of task statements related to competitive VEX robotics. Respond to each task statement by agreeing or disagreeing with the statement. You will be asked to respond to each task statement on a scale from 1 to 5; 1 meaning that you “strongly disagree” with the

statement, and 5 meaning that you “strongly agree” with the statement. Select only one response per statement.

Mechanical and Design Outcomes (Section 1 of 3)

	Strongly Disagree (1) (1)	Disagree (2) (2)	Neither Agree nor Disagree (3) (3)	Agree (4) (4)	Strongly Agree (5) (5)
I feel confident that I can design and construct a structurally sound and stable robot--chassis, lift, end effectors. (1)	○	○	○	○	○
I feel confident that I can explain the design tradeoffs between various lift systems--linear, single arm, parallel arm (4-bar), or six-bar. (2)	○	○	○	○	○
I feel confident that I can design and construct various lift systems--linear, single arm, parallel arm (4-bar), and six-bar. (3)	○	○	○	○	○
I feel confident that I can design and construct various end-effectors (for example, conveyor, scoop, rollers, and gripper). (4)	○	○	○	○	○
I feel confident that I can calculate the ratios for simple and compound drive trains--gears; chain &	○	○	○	○	○

sprocket. (5)					
I feel confident that I can design and construct a drive-train that increases rpm or torque (6)	○	○	○	○	○
To demonstrate that you are still focused on the survey, select the “strongly agree” circle. (9)	○	○	○	○	○
I feel confident that I can explain the design tradeoffs between regular and high-strength VEX components (for example, motors, gears, and chain & sprocket). (7)	○	○	○	○	○
I feel confident that I can work through several design iterations of a robot. (8)	○	○	○	○	○

Page Break

Programming Outcomes (Section 2 of 3)

	Strongly Disagree (1) (1)	Disagree (2) (2)	Neither Agree nor Disagree (3) (3)	Agree (4) (4)	Strongly Agree (5) (5)
I feel confident that I can program conditional statements (for example, if statements and while loops). (1)	○	○	○	○	○

I feel confident that I can update the master code (firmware) on the Cortex microcontroller and joystick. (2)	○	○	○	○	○
I feel confident that I can troubleshoot programming error messages. (3)	○	○	○	○	○
I feel confident that I can install and write a program to utilize an optical shaft encoder. (4)	○	○	○	○	○
To demonstrate that you are still focused on the survey, select the “Strongly Disagree” circle. (10)	○	○	○	○	○
I feel confident that I can install and write a program to utilize a potentiometer. (5)	○	○	○	○	○
I feel confident that I can program user functions to accept and return values. (6)	○	○	○	○	○
I feel confident that I can install and write a program to utilize	○	○	○	○	○

a bumper/limit switch. (7)					
I feel confident that I can program automated routines to assist in driver control mode. (8)	○	○	○	○	○
I feel confident that I can program a PID control loop to change outputs based on an input(s). (9)	○	○	○	○	○

Page Break

Teaming and Professional Traits Outcomes (Section 3 of 3)

	Strongly Disagree (1) (1)	Disagree (2) (2)	Neither Agree nor Disagree (3) (3)	Agree (4) (4)	Strongly Agree (5) (5)
I feel confident that I can collaborate with other team members to accomplish tasks. (1)	○	○	○	○	○
I feel confident that I can resolve conflicts among team members. (2)	○	○	○	○	○
I feel confident that I can approach and work with other alliances. (3)	○	○	○	○	○
I feel confident that I can make decisions for the good of the group versus personal gain. (4)	○	○	○	○	○

I feel confident that I can receive constructive feedback from others without taking it personally (for example, team members, alliances, and judges) (5)	○	○	○	○	○
I feel confident that I can structure my team to best use individual strengths and mitigate weaknesses. (6)	○	○	○	○	○
I feel confident that I can provide constructive feedback about others' designs and strategies. (7)	○	○	○	○	○
To demonstrate that you are still focused on the survey, select the "Neither Agree nor Disagree" circle. (11)	○	○	○	○	○
I feel confident that I can manage time to complete qualifying matches, skill challenges, and judging. (8)	○	○	○	○	○
I feel confident that I can follow assigned tasks and responsibilities (follower). (9)	○	○	○	○	○
I feel confident that I can maintain a professional behavior when negative and	○	○	○	○	○

positive
circumstances occur.
(10)

Page Break

Display This Question:
If Are you currently participating on a VEX Robotics Competition team? = No

Are you planning to participate on a VEX Robotics Team in the future?

- Yes (1)
- Maybe (2)
- No (3)

Page Break

Display This Question:
If Are you planning to participate on a VEX Robotics Team in the future? = Yes
Or Are you planning to participate on a VEX Robotics Team in the future? = Maybe

Would you like to be included in this study when you are a member of a VEX Robotics Team?

- Yes (1)
- Maybe (2)
- No (3)

Page Break

Display This Question:
If Would you like to be included in this study when you are a member of a VEX Robotics Team? = Yes
Or Would you like to be included in this study when you are a member of a VEX Robotics Team? = Maybe

Please provide your first name

____

Display This Question:
If Would you like to be included in this study when you are a member of a VEX Robotics Team? = Yes
Or Would you like to be included in this study when you are a member of a VEX Robotics Team? = Maybe

Please provide your last name.

____

Display This Question:
If Would you like to be included in this study when you are a member of a VEX Robotics Team? = Yes
Or Would you like to be included in this study when you are a member of a VEX Robotics Team? = Maybe

Please provide an email address that will remain active for at least a year.

**Avoid using your school email address, if possible, as many school districts prevent outside emails.

____

Display This Question:
If Would you like to be included in this study when you are a member of a VEX Robotics Team? = Yes
Or Would you like to be included in this study when you are a member of a VEX Robotics Team? = Maybe

Please retype your email address for accuracy.

____

End of Block: Self-Confidence Survey for VEX Robotics Participants

Appendix D

Post-Secondary Choices Survey

POST-SECONDARY CHOICES SURVEY

Survey questions are to be administered about one year after high school graduation. These questions are to determine whether students have selected an engineering major and their level of academic preparation upon entering college.

1. What is your first name?

2. What is your last name?

3. Please enter an email address that were active for at least 1 year.

4. Please enter a phone number that is available for texting which were active for at least 1 year. If no number is available, write "N/A."

5. Which of the following most closely describes your current educational status?

    a. Enrolled in a bachelor's degree program at a college or university
    b. Enrolled in an associate's degree program at a college or university
    c. Enrolled in a certificate program at a technical college or trade school
    d. Not enrolled in a degree or certificate program, but plan to in the future
    e. Not enrolled in a degree or certificate program, and do not plan to in the future

6. If you are not enrolled in a degree or certificate program, but plan to in the future, please indicate when you plan to enroll. Otherwise, write "N/A."

7. If you are enrolled in a degree or certificate program, what is the name of the institution you are attending? If you are not enrolled, write "N/A."

8. If you are enrolled in a degree or certificate program, what is the name of your chosen major or course of study? If you are not enrolled, write "N/A."

9. Which of the following best describes the highest level mathematics course you took in high school?

    a. Pre-Algebra
    b. Algebra
    c. Statistics
    d. Pre-Calculus or Trigonometry
    e. Calculus
    f. AP Statistics
    g. AP Calculus
    h. Other:__________

10. Which of the following courses did you take in high school? (Select all that apply)
    AP/Honors Biology
    AP/Honors Calculus (AB or BC)
    AP/Honors Chemistry
    AP/Honors Computer Science
    AP/Honors Physics (any)
    AP/Honors Statistics
    Biology
    Chemistry
    Computer Science
    Calculus
    Engineering/Pre-Engineering
    Physics
    Statistics

11. When you registered for your first semester of classes in college, did you meet your school's minimum requirements to enroll in a calculus course?

    a. Yes
    b. Yes, after completing a pre-test
    c. No
    d. Not sure/Calculus was not required for my major
    e. I have not enrolled in college classes

We're finished! Thank you for your time and effort in completing this survey!

CURRICULUM VITAE

JOSEPH S. FURSE

Utah State University
College of Agriculture & Applied Sciences
School of Applied Sciences, Technology, and Education
Technology and Engineering Education

6000 Old Main Hill
Logan, UT 84322-6000
(435)-216-8783
jsfurse@gmail.com

EDUCATION

2019 — ***Doctor of Philosophy***
Utah State University
Logan, Utah
Major: Education
Specialization: Curriculum and Instruction
Concentration: Career and Technical Education
Dissertation: *Measuring the Self-efficacy of Students Participating in VEX Robotics Competitions*

2014 — ***Bachelor of Science***
Utah State University
Logan, Utah
Major: Technology and Engineering Education

TEACHING EXPERIENCE

2018 – Present — ***Technology Education Teacher***
Washington County School District
Desert Hills Middle School
Career and Technical Education Department
St. George, Utah

Teaching course load included: Construction Technology, Engineering Technology, Exploring Technology, Manufacturing

Technology, and Transportation Technology. Other accomplishments included starting an after-school Technology Academy at the school where students had the opportunity to participate in extracurricular STEM activities including VEX Robotics and ROAVcopter competitions.

2014 – 2018 ***Graduate Assistant***
Utah State University
School of Applied Sciences, Technology, and Education
Technology and Engineering Education
Logan, Utah

Responsibilities included assisting with various research and curriculum-development projects. A major outgrowth of this position was developing the curriculum for an undergraduate electronics course for pre-service technology and engineering teachers and industrial technologists, as well as restructuring the course for online delivery. In addition, this position included work as the head instructor for the Design Academy, an after-school STEM outreach program for secondary students, which provides instruction and mentoring in VEX Robotics and other STEM activities.

2015 ***Substitute Teacher***
Cache County School District
Kelly Educational Services
Logan, Utah

Taught/supervised a variety of classes for absent teachers.

2014 ***Student Teacher***
Cache County School District
South Cache 8-9 Center
Hyrum, Utah

Taught courses in Manufacturing Technology, Engineering, and Communications Technology. Also assisted in coaching the school VEX Robotics teams.

RELATED WORK AND VOLUNTEER EXPERIENCE

2017 – Present ***Ag STEM Curriculum Developer***
Utah State University

School of Applied Sciences, Technology, and Education
National Center for Agricultural Literacy
Logan, Utah

Developed science curriculum for the National Agriculture in the Classroom curriculum matrix. Curriculum was developed for grades 3-5 (Aquaponics), 6-8 (Aeroponics & Vertical Farming), and 9-12 (Algaculture & Biofuels).

2015 - Present **_Volunteer Scoutmaster_**
Troop 13
Old Juniper District
Trapper Trails Council
Logan, Utah

Overseeing the development and implementation of outdoor education experiences and life skills training for boys age 11-18.

2017 **_Assistant Cross-Country Coach_**
Sky View High School
Cache County School District
Smithfield, Utah

Assistant coaching duties included assisting with or running workouts and assisting with inter-scholastic cross-country meets.

2014 **_Volunteer Assistant Scoutmaster_**
Troop 91
Old Ephraim District
Trapper Trails Council
Logan, Utah

Assisting in developing and implementing outdoor education experiences and life skills training for boys age 12-13.

2012 **_Systems Integration and Hardware Engineering Intern_**
YESCO Electronics
Logan, Utah

Responsibilities included testing new components and assisting with the development of control systems for large-format LED video displays, as well as developing and disseminating new hardware testing procedures to ensure a robust and fully tested product.

AWARDS AND RECOGNITION

2018	Utah State University Graduate Student Teacher of the Year Finalist
2018	Utah State University Graduate Enhancement Award
2017	Utah State University College of Agriculture & Applied Sciences Graduate Student Teacher of the Year
2014	Utah State University Presidential Doctoral Research Fellow

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PROFESSIONAL ORGANIZATIONS

International Technology and Engineering Educators Association

Association for Career and Technical Education

Utah Association for Career and Technical Education

Technology & Engineering Education Collegiate Association (Utah State University Chapter)

REFEREED PUBLICATIONS

Nadelson, L., Cain, R., Cromwell, M., Edgington, J., Furse, J., Hofmannova, A., Lund, E., Matyi, J., Morris, S., Sais, C., Xie, T. (2015). A world of information at their fingertips: College students' motivations and practices in their self-determined information seeking. *International Journal of Higher Education,* 5(1), 220-231. doi: 10.5430/ijhe.v5n1p220

Stewardson, G.A., Robinson, T.P., Furse J.S., Pate, M.L. (2017). Investigating the impact of VEX Robotics on student self-efficacy: An initial look. *International Journal of Technology and Design Education*. *Investigating the impact of VEX Robotics on student self-efficacy: An initial look.* Advance online publication. doi:10.1007/s10798-018-9461-4

OTHER PUBLICATIONS

Bartholomew, S., Furse, J.S. (2015). Successfully integrating robotics into your curriculum. *Techniques,* October 2015, 15-17.

PROFESSIONAL PRESENTATIONS

Robinson, T. P., Stewardson, G. A., Furse, J. S. (2015). *Measuring the self-efficacy of VEX Robotics participants.* 77th Annual International Technology and Engineering Educators Association Conference, Milwaukee, WI, March 26-28, 2015.

Furse, J. S., Robinson, T. P., Stewardson, G. A. (2016). *Delivering pre-service electronics in a new era.* 78th Annual International Technology and Engineering Educators Association Conference, Washington, D.C., March 2-4, 2016.

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