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The Development of an Instrument to Measure the Self-Efficacy of Students Participating in VEX Robotics Competitions

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THE DEVELOPMENT OF AN INSTRUMENT TO MEASURE THE

SELF-EFFICACY OF STUDENTS PARTICIPATING

IN VEX ROBOTICS COMPETITIONS

by

Trevor P. Robinson

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ABSTRACT

The Development of an Instrument to Measure the Self-Efficacy

of Students Participating in VEX Robotics Competitions

by

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Utah State University, 2014

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The number of robotics competitions has steadily increased over the past 30 years. Schools are implementing robotics competitions to increase student content knowledge and interest in science, technology, engineering, and mathematics (STEM). Companies in STEM-related fields are financially supporting robotics competitions to help increase the number of students pursuing careers in STEM among other reasons. These financial supporters and school administrations are asking what the outcomes of students participating in competitive robotics are. Few studies have been conducted to investigate these outcomes. The studies that have been conducted usually compare students in robotics to students not in robotics. There have not been any studies that compare students to themselves before and after participating in robotics competitions. This may be due to the lack of available instruments to measure student outcomes.

This study developed an instrument to measure the self-efficacy of students participating in VEX Robotics Competitions (VRC). The VRC is the world’s largest and fastest growing robotics competition available for middle and high school students. Self-efficacy was measured because of its importance to the education community. Students with higher self-efficacy tend to persevere through difficult tasks more frequently than students with low self-efficacy. A person’s self-efficacy has major influence over what interests, activities, classes, college majors, and careers he or she will pursue in life.

The self-efficacy survey instrument created through this study was developed through an occupational and task analysis (OTA), and initial content and face validity was established through the OTA process. Exploratory and confirmatory factor analyses were also conducted to assist in instrument validation. The reliability was calculated using Cronbach’s alpha. Face validity was established through the OTA process. Construct validity was established through the factor analyses. The processes of the OTA and factor analyses have created an instrument that results indicate is reliable and valid to use in further research studies.

(139 pages)

PUBLIC ABSTRACT

The Development of an Instrument to Measure the Self-Efficacy
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A research study was conducted in the Technology and Engineering Education program at Utah State University. The purpose of the study was to develop a survey instrument to measure the self-confidence of students who have participated in the VEX Robotics Competitions. The survey instrument developed was tested to be appropriate and consistent in measuring the self-confidence of middle school and high school students in the United States. The process to ensure that the survey instrument was appropriate utilized an investigation of the tasks completed by successful VEX Robotics teams through an occupational and task analysis. The investigation utilized expert coaches, mentors, and instructors from across the country.

Data were collected in two rounds to test the survey instrument. Data were collected by sending the survey to coaches, mentors, and instructors asking them to administer the survey to their students. Data were also collected at the 2014 VEX Robotics World Championship. The data were analyzed through factor analyses. The results of the factor analyses showed that the survey instrument was appropriate for

measuring the self-confidence of middle school and high school students who have participated in competitive VEX robotics.

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Trevor P. Robinson

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CHAPTER I

INTRODUCTION

Robotics competitions have been gaining popularity in the United States since the 1980s. One factor influencing the development of robotics competitions is society's need to produce individuals capable of developing and maintaining technology that will continue to improve the quality of life. There are countless robotics competitions taking place around the United States and the world, including, but in no way limited to: VEX Robotics Competition (VRC), For Inspiration and Recognition of Science and Technology (FIRST) Robotics Competition, the National Robotics Challenge (NRC), and Boosting Engineering, Science, and Technology (BEST) competition. Countless resources including time, money, and human energy are being spent and used to produce and fund teams to compete in these robotics competitions. Depending on the competition, teams can spend hundreds of dollars or over $15,000 annually for fees, materials, and other expenses (Johnson & Londt, 2010). Teachers and mentors work hours beyond those required by their employers to ensure that their teams will find success in their respective competitions.

Researchers have investigated some of the outcomes of students participating in robotics competitions (Hendricks, Alemdar, & Ogletree, 2012; Kolberg & Orlev, 2001; McIntyre, 2002; Nourbakhsh et al., 2005; Nugent, Barker, Grandgenett, & Adamchuk, 2010; M. Robinson, 2005; Sklar, Johnson, & Lund, 2000). Are more students pursuing STEM majors in college as a result of their experience? Are more students seeking STEM careers after participating in robotics competitions? Are students learning specific content knowledge from participation in robotics competitions? Only a few studies have explored these questions and other related questions that address the outcomes of student participation in robotics competitions. This researcher sought to explore student self-efficacy from participating in VEX Robotics Competitions.

Statement of the Purpose

The purpose of this research study was to develop a reliable and valid instrument to measure the self-efficacy of middle and high school students participating in VRC. Reliability was measured using Cronbach's alpha. Instrument validity was measured through a confirmatory factor analysis (CFA). Content validity was established through an occupational and task analysis of VRCs.

Instrument Development Milestones

The following milestones were used to guide the process of this dissertation. These milestones were developed through a combination of two models used for developing similar instruments—the model used to create the My Class Activities (Gentry & Gable, 2001) instrument, and the model for developing online surveys by Strachota, Conceicao, and Schmidt (2006).

1. Determine the outcomes obtained by students participating in VEX Robotics Competitions (VRC) utilizing an occupational and task analysis (OTA).

2. Develop initial survey instrument using the outcomes determined during milestone one.

3. Conduct an exploratory factor analyses (EFA) on the initial instrument.

4. Reduce the number of items and revise the survey instrument using the results of the EFA and the OTA.

5. Conduct a confirmatory factor analyses (CFA) on the revised survey instrument.

6. Calculate the reliability of the instrument using Cronbach's alpha.

7. Detect bias of the instrument between various groups based on demographics of survey participants using modeling techniques.

Statement of the Need for the Study

In a request for proposal by the Robotics Education and Competition Foundation (RECF, 2011), it was stated that research needs to be conducted that brings "legitimacy to the idea that hands-on robotics activities, in concert with competition, motivates and inspires youth while building real-world skills that are transferable to college and career" (item 6, Objectives). With thousands of students participating in various robotics competitions around the world, research needs to be conducted to investigate this "legitimacy." This researcher chose to investigate the VRC. VEX robotics is the largest and fastest growing competition for middle and high school students in the world (Innovation First International [IFI], 2013; Robinson & Stewardson, 2012; Robotics Education and Competition Foundation, 2010). During the 2012-2013 season, there were over 7,300 teams competing in over 400 local competitions around the world. VRCs utilize a format that requires teams to align with another team and compete against two additional teams. Teams competing head-to-head creates a sporting event mentality that is exciting for students, teachers, and parents. The VEX Robotics Competition is relatively affordable for schools when compared to similar robotic competitions. This lower cost is due to the requirement to only use VEX components. This requirement also creates a level playing field for all teams to compete, because one team cannot purchase better equipment to outperform their opponents. These attributes have made the VEX Robotics Competition the largest and fastest growing competition and an ideal candidate for exploring student outcomes of participation in robotics competitions.

The research could not stop with simply determining the outcomes of student participation in VEX Robotics. The question needed to be asked if students actually felt that they were reaching these outcomes (e.g., did a student feel that they could calculate gear ratios). Measuring a student's self-efficacy towards these outcomes would answer that question. Bandura and Schunk (1981) wrote that "a sense of personal efficacy in mastering challenges is apt to generate greater interest in the activity…." If a person feels confident towards a subject in school, they will most likely be interested in that subject, and, in turn, take more courses in that subject area and are more likely to pursue those areas as college majors and as potential careers (Betz & Hackett, 1981; Lent, Brown, & Larkin, 1986). Bandura (1982) stated, "Judgments of self-efficacy also determine how much effort people will expend and how long they will persist in the face of obstacles or adverse experiences" (p. 123). However, there are no instruments or studies that specifically investigate the self-efficacy towards related outcomes of students that participate in robotics competitions. As a result, without such an instrument, no means to conduct a longitudinal study to investigate the impact of VEX Robotics Competitions on student participants is available.

While measuring the self-efficacy of students participating in competitive VEX robotics, demographic data was also collected. Knowing the number of seasons that a student has competed in competitive VEX robotics will allow researchers to discover trends in the efficacy of students over time. Students were asked about their responsibilities on their team. This information will allow researchers to determine if certain responsibilities on a team can lead to higher or lower self-efficacy in specific constructs related to VRCs. Students were asked whether their team met in formal or informal learning environments. This question will allow the exploration of “how does meeting during school and receiving a grade for participation compare to meeting after school and not receiving a grade?” Students were asked about their college aspirations. These questions will allow researchers to investigate the influence of participation in competitive VEX robotics on student plans for their futures.

Limitations of the Study

The following limitations were inherent in this study.

1. The study was limited to participants in the United States of America.
2. The instrument developed was limited to VEX Robotics Competitions.
3. The instrument is limited to measuring only the outcomes identified by the expert committee.
4. The instrument was developed using only a sample of the population of

participants in VEX Robotics Competitions.

5. The validity and reliability of the instrument was limited to initial data, and should be reinforced overtime with larger sample sizes.

Assumptions of the Study

The following assumptions were inherent in this study.

1. The student participants answered the instrument truthfully.
2. The student participants completed the instrument without coercion.
3. The sample of student participants was representative of the population of VEX Robotics Competitions.
4. The expert committee thoroughly compiled the list of identified outcomes.
5. Sample data collected through coaches, mentors, and instructors would be representative of the population of VEX robotics participants as far as team responsibilities are concerned (e.g., builders and programmers).

Summary of the Study Procedure

The procedure followed in this study was a combination of the methods used in the development of the My Class Activities (Gentry & Gable, 2001) instrument, and a method used in the development of online surveys (Strachota et al., 2006). Figure 1 graphically represents the procedure that was followed for this study.

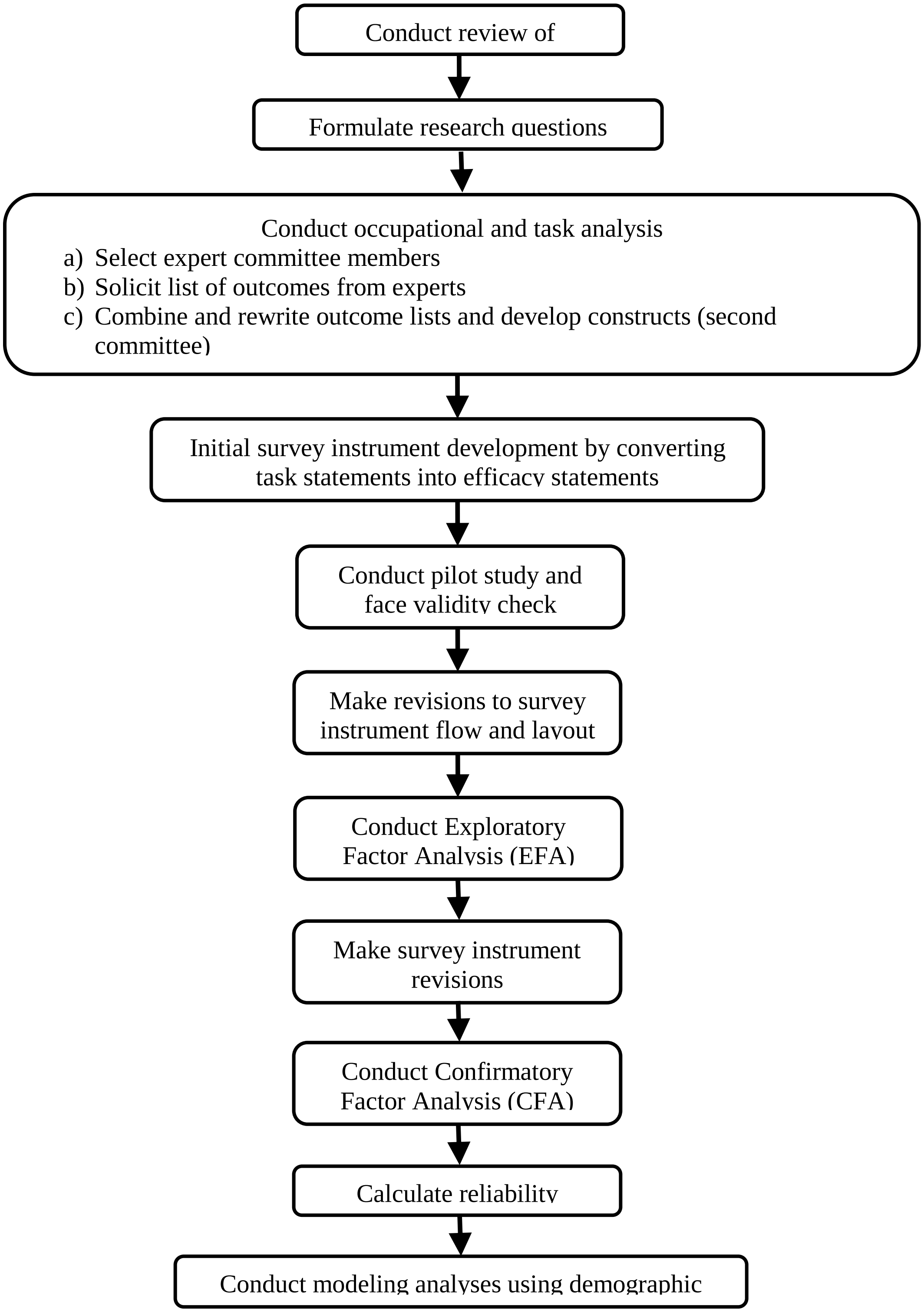

Figure 1. Graphic representation of the procedure followed to design the self-efficacy instrument developed in this research project.

Definition of Acronyms and Terms

Coaches, mentors, and instructors: Individuals that lead VEX robotics teams. The title for the individual changes whether the team is a community team, 4-H team, or a school based team.

DACUM (Developing A Curriculum): A training program used to instruct a committee on how to develop curricula that can be used in training employees/operators of equipment (Norton, 1997).

EFA (Exploratory factor analysis): EFA is a statistical process used in instrument development. It is commonly used to reduce the number of items and constructs in a survey instrument (Suhr, 2006).

FIRST (For Inspiration and Recognition of Science and Technology): FIRST is a robotics competition that engages students "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" (Foundation for Inspiration and Recognition of Science and Technology [FIRST], 2013a)

FRC (FIRST Robotics Competition): FRC is a robotics competition for 9-12 graders (FIRST, 2013b).

FTC (FIRST Tech Challenge): A robotics competition for 7-12 graders (FIRST, 2013b).

IFI (Innovation First International): IFI is a private corporation and a "leader in educational and competitive robotics products" (IFI, 2013).

OTA (Occupational and Task Analysis): A systematic means used to determine the tasks necessary to complete a specific occupation. This method is usually used to develop training material for new or beginning workers (Mager & Beach, 1967).

Self-efficacy: ". . . self-efficacy is concerned with judgments about how well one can organize or execute course of action required to deal with prospective situations containing many ambiguous, unpredictable, and often stressful elements" (Bandura & Schunk, 1981, p. 587).

RECF (Robotics Education and Competition Foundation): Commonly referred to as the REC Foundation. The RECF "exists to connect students, mentors, and schools in every community to a variety of successful and engaging technology-based programs" (RECF, 2013a).

STEM (Science, Technology, Engineering, and Mathematics): STEM is a term that refers to the fields of science, technology, engineering, and mathematics.

VRC (VEX Robotics Competition): The VRC is a worldwide robotics competition for middle and high school students (RECF, 2013b).

CHAPTER II

REVIEW OF LITERATURE

Introduction

Robotics competitions have continued to gain popularity in the United States and around the world. Supporters of robotics competitions want to know what the student outcomes from participating in competitive robotics are. In order to answer that question and to guide this study, a review of literature was completed. The review begins by exploring popular robotics competitions including the FRC and the VRC. Then the major studies that have been conducted to explore the benefits of participation in robotics competitions are discussed. This research study is developing a survey instrument to measure self-efficacy. Therefore the review of literature provides an in-depth look of self-efficacy. The sources of self-efficacy, the relationship between self-efficacy and interest, and how to measure self-efficacy are areas that are detailed in the review of literature. Various methods of instrument development are then explored, including occupational and task analysis, factor analyses, and alpha reliability. The review of literature presented was used to guide the instrument development process.

Robotics

Robotics competitions have seen incredible growth in the number of middle and high school student participants in the last decade. This growth for several of the more popular robotics competitions can be seen in Figure 2. During the 2012-2013 competition

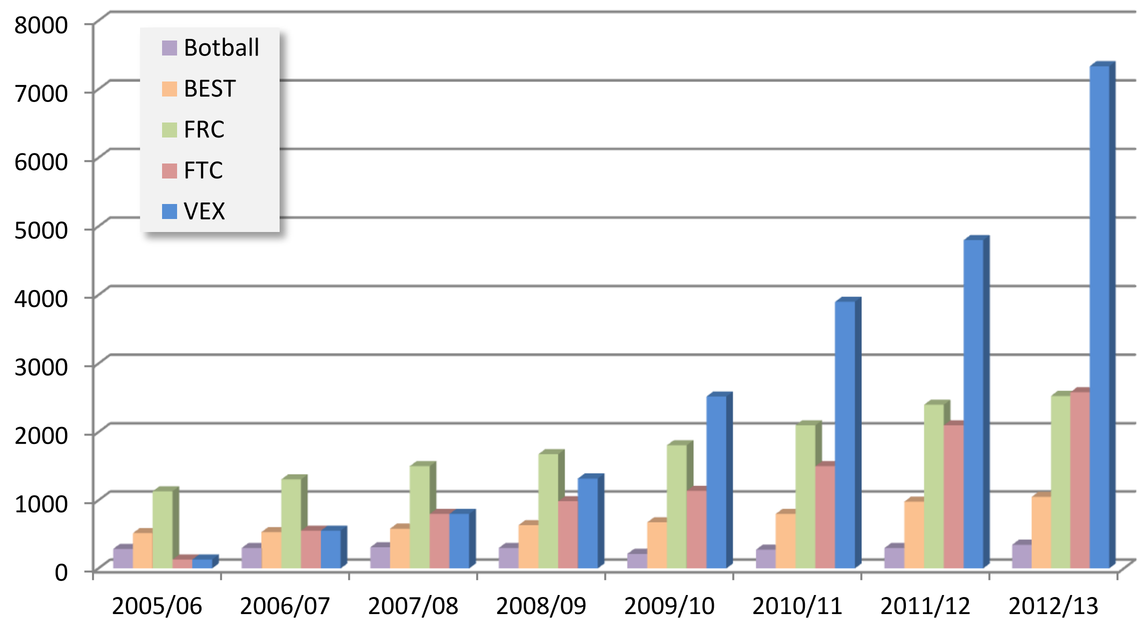

*Figure 2.*The growth of select robotics competitions represented by the number of teams competing in each competition for the last 9 years (Robotics Education and Competition Foundation, 2013a). *Note*. BEST = Boosting Engineering, Science, and Technology; FRC = FIRST Robotics Competition; FTC = FIRST Tech Challenge; VEX: VEX Robotics Competition.

season there were over 325,000 students that participated in the VEX Robotics Competition and in the various FIRST competitions (FIRST, 2013c; RECF, 2013c). What is the reason for this growth? “Competitions add a level of engagement that is often hard to achieve in a traditional classroom” (Caron, 2010, p. 21). Robotics competitions provide hands-on applications for students to gain a better understanding of the knowledge they are learning in the classroom. The next section describes some of the attributes of popular competitions that make them exciting for students, teachers, and spectators.

Robotics Competitions

The FIRST Robotics Competition began in 1992 (FIRST, 2013c). FIRST competitions brought something new to the table for robotics competitions. Traditional robotics competitions require teams to compete against a design challenge, one robot at a time would be placed on a field and perform within the constraints of the rules to score points. The FIRST Robotics Competition, however, required teams to build and design a robot that would compete directly against other team's robots while still completing a specific design challenge. Teams also form alliances to compete against other alliances. This creates a cooperative learning environment that encourages teams to not hide their ideas, but to share and help other teams improve. A primary benefit of this style event was the creation of a sport-like environment that generates an exciting atmosphere to draw students into the competitions. Teams that compete in the FRC have six weeks to design and build their robots for competition. This competition is similar to sending a robot to mars. A National Aeronautics and Space Administration (NASA) team has one shot at landing a robot on mars; there are no second chances. At a FIRST Robotics Competition the teams compete with their initial design. There is little time to make drastic changes to the design of the robot. Teams may compete in multiple regional competitions; however each competition costs approximately $5,000 to register. Thousands more dollars may be spent on building the robot. Many teams partner with industry to help ease the burden of the cost of materials, fees, and travel. If teams are successful at a regional tournament, they are qualified to compete at national events.

The style of robotics competition implemented by the FRC created more excitement and enthusiasm for robotics than previous competitions. Nearly a decade after the development of the FRC, the VEX Robotics platform began to emerge. Initially partnered with FISRT and Radio Shack, the VEX Robotics platform was used in the FTC (Robinson & Stewardson, 2012). The VEX Robotics platform combined with the FTC created a more cost friendly competition while still utilizing the sporting event mentality created by the FRC. In 2006, the VEX Robotics platform split from FIRST to create a new competition known as the VEX Robotics Competition (VRC).

The VRC utilizes the excitement of the sporting event and the cooperative learning environment as a result of the use of alliances, while leveling the playing field between teams by lowering the cost (e.g., lower registration fees) and standardizing robot components. Teams competing in the VRC are required to use VEX components or an equivalent part. Teams are also limited to a maximum robot size of 18 inches cubed as well as a maximum of ten motors. These types of limitations prevent teams from buying a better robot with expensive components. Teams must focus more on the design and construction of their robot and view the limitation of parts as a design constraint of the competition. Teams may compete in multiple tournaments in a single season. Competing in multiple tournaments allow teams to improve the design of their robot for each competition, similar to designing an automobile that evolves over time. A car manufacturer will design a car and release it one year. Then the manufacturer will continue to make design changes and release the new version of the car in following years. As a result of these changes, the VRC has since become the world's largest and fastest growing robotics competition for middle and high school students (IFI, 2013;

RECF, 2010; Robinson & Stewardson, 2012; see Figure 2).

With hundreds of thousands of students competing in various robotics competitions around the world, many resources are needed to make teams and competitions successful. Teams competing in the FRC can spend upwards of $15,000 per season to be competitive (Johnson & Londt, 2010). Teams that compete in the VRC may spend upwards of $1,500 a season to be competitive. It is not only money that is being spent; thousands of hours are being spent by countless volunteers to mentor teams, and to help run the over 400 local tournaments available to teams in the VEX Robotics Competition (RECF, 2013d), and the 69 regional events available to FRC teams (FIRST, 2012). With all of these resources continuing to make robotics competitions grow, researchers have begun to ask; what are the outcomes of students participating in such activities?

Research on Outcomes of Robotics Competitions

A limited number of studies have been conducted to explore this and similar questions about robotics competitions. Barker and Ansorge (2007) stated that teachers are using robotics in the classroom to teach programming languages, construction and programming of robots, and critical thinking skills. Students across a broad age range who participate in robotics competitions gain excitement through the process of designing, building, and programming (Nourbakhsh et al., 2005). This excitement can lead to students further participating in robotics competitions. Other research studies have shown that students are more motivated to learn STEM after participating in robotics competitions (Hendricks et al., 2012; Kolberg & Orlev, 2001; McIntyre, 2002; Melchior, Cohen, Cutter, & Leavitt, 2005; Nourbakhsh et al., 2005; Nugent et al., 2010; M. Robinson, 2005; Sklar et al., 2000). Some of these studies even went as far to say that participation in robotics competitions can improve STEM content knowledge (Barker & Ansorge, 2007; Nourbakhsh et al., 2005; Nugent et al., 2010; Robinson, 2005; Sklar et al., 2000; Williams, Ma, Prejean, & Ford, 2007). "Through hands-on experimentation, such technologies can help youth translate abstract mathematics and science concepts in concrete real-world applications" (Nugent et al., 2010, p. 392).

Learning is not constrained to STEM content knowledge. Learning can "extend beyond the content of technical challenges and into broader scientific and social lessons" (Nourbakhsh et al., 2005, p. 27). One of those social lessons is teaming (Melchior et al., 2005; Williams et al., 2007). Students are encouraged to work in teams; and when students do not, they are sometimes hurt by this when competing for various awards that take into account how well students work together. Another social area that can be improved is self-efficacy (Nugent et al., 2010). Students are able to gain more confidence in STEM areas, as well as working with others when they perform tasks in those areas on a weekly basis. These studies have investigated a broad range of robotics courses and competitions; only one major study has specifically investigated the VRC and few have investigated the FIRST robotics competitions.

Melchior and colleagues (2005) took an in-depth look at the participants of the FRC to explore the impact of the FRC, specifically the impact on student academic and career trajectories. The study compared students who participated in FRC to a "matched comparison group." The matched group was chosen from students who took the Beginning Postsecondary Student Survey (BPS; Melchior et al., 2005). With this dataset matches were made based on similar demographic and high school academic backgrounds. Comparisons were conducted on several key outcomes including college major and expected career choice. Students who had participated in the FRC were more than three times likely to have majored in engineering compared to the average college student (Melchior et al., 2005). Students who had participated in the FRC were also more than two times likely to expect to pursue a science or technology career, and nearly four times likely to expect to pursue a career in engineering (Melchior et al., 2005).

The authors presented several "challenges" to using the "matched comparison group" for their study. The first "challenge" is that the BPS was an existing dataset, therefore limiting the questions that could be answered. With this limitation the groups could only be compared on certain outcomes, not all outcomes. Another "challenge" presented in the study was the timing of the BPS. The data collected by the BPS was collected from 1995-1996, while the data collected on the FRC students were collected from 1999-2003 (Melchior et al., 2005). While the difference in years is not large, the authors also noted that there was "nothing to suggest that trends in key college outcomes (majors, etc.) changed significantly during that time period" (Melchior et al., 2005, p. 11).

Although the researchers expressed the challenges they faced, one might still be concerned with the approach used in the study. The researchers took the effort to match the FRC students to a comparison group, but concerns still exist on whether or not these two groups can be compared. It seems obvious to some that if students choose to participate in an engineering activity that those students are interested in engineering and therefore will be more likely to choose to pursue engineering as a college major and career. It is similar to saying that students who participate in band and/or orchestra in high school are more likely to major in a music related field compared to students who do not participate in band or orchestra. Students more often than not pursue their interests in high school and college. Students will participate in actives that further their interest in a subject, whether it is robotics, music, or agriculture. Comparing the goals and interest of students who participate in an activity to those that do not is an unfair comparison. An alternative research design would be a pre-/posttest format where students are compared to themselves.

More recent research by Deken, Koch, and Dudley (2013) focused on the second tier FIRST competition─FTC. The study analyzed data from 68 student surveys from a FTC competition in a “technologically and underserved region” to explore the influence of the robotics competition on “students selecting a STEM discipline [and] college majors” (Deken et al., 2013, p. 2). The study was unique in that it asked students what their interest in technology and engineering was prior to participating in the FTC. The research found that “students between 7th and 10th grade had an overwhelming prior interest in engineering and technology” (Deken et al., 2013, p. 7). Students in grades 11 and 12 had an even mix of students both interested and not interested in technology and engineering. The research also found that after the FTC over 70% of the students had decided on a college major and 43% of the students answered that participation in the

FTC had an influence on that decision.

What was not reported and could have strengthened the research was the amount of change in student interest in technology and engineering after competing in the FTC. There were students who reported that they were not interested in technology and engineering prior to the competition, did their interest change after the FTC? The same could have been asked of students who were already interested in technology and engineering. Did their interest in technology and engineering increase or did it remain the same? Answering these follow up questions could have strengthened the research presented.

VEX Robotics Competition

Hendricks and colleagues (2012) conducted the first major study on the VEX Robotics Competition. This research team worked closely with the RECF to explore "whether VRC students and Team Leaders perceived that VRC participation was affecting students in the areas articulated in RECF's vision" (Hendricks et al., 2012, p. 3). The main vision being "hands-on robotics activities, in concert with competition, motivates and inspires youth while building real-world skills that are transferable to college and career" (RECF, 2011, item 6, Objectives). The study used surveys and interviews to collect data from VRC participants and team leaders. The survey was completed online by 341 students. One section of the survey focused on student interest in STEM areas. Over 92% of the students agreed or strongly agreed that "participating in the VEX Robotics Competition has made" them want to learn more about robotics (Hendricks et al., 2012, p. 7). While over 82% of the respondents said participating in the

VRC made them more interested in taking engineering courses in college. When asked if participating in the VRC made them more interested in taking math and science classes in college over 78% of students agreed. This study did not report on questions that specifically asked what students were thinking about majoring in if they attend college. However it was reported that team leaders thought that by participating in the VRC, some "student's interest in STEM majors or STEM fields had increased…" (Hendricks et al., 2012, p. 11).

This research is a start to exploring the outcomes of student participation in robotics competitions. This study may have been strengthened by having a benchmark of the student's interests before participating in the VRC. A longitudinal design would allow for this approach and be able to see how much a student's interest changed after participation in the VRC. In order for a quality longitudinal study to be conducted a valid and reliable instrument is needed that can measure students before any participation in the VRC has occurred and at yearly benchmarks thereafter.

Self-Efficacy

"Self-efficacy is concerned with judgments about how well one can organize or execute course of action required to deal with prospective situations containing many ambiguous, unpredictable, and often stressful elements" (Bandura & Schunk, 1981, p. 587). In other words, a person's self-efficacy measures how they think they will do when given a specific task to complete. A person's self-efficacy towards specific tasks helps determine what tasks that person might choose to pursue or to abandon. Bandura (1982) states that “judgments of self-efficacy also determine how much effort people will expend and how long they will persist in the face of obstacles or adverse experiences” (p. 123). Lawanto, Santoso, and Liu (2012) summarized several researchers with the following statement, “...strong self-efficacy is more likely to stimulate the exertion of greater effort to overcome a challenge, while weak self-efficacy tends to reduce one’s efforts or even cause a person to quit” (p. 154). A person’s self-efficacy can play a major role in determining what activities students pursue in high school, as well as what career or college path they may choose to follow after graduation. Self-efficacy also plays a role in helping students transfer knowledge from one subject area to other similar subjects.

Sources of Self-Efficacy

Bandura (1977) explained his theory and thoughts on self-efficacy based on the social learning theory. He described four sources of information that play a role in determining a person’s self-efficacy: (a) performance accomplishments, (b) vicarious experience, (c) verbal persuasion, and (d) emotional arousal. Figure 3 shows a flowchart of the four sources and methods one could use to improve efficacy as displayed in Bandura’s journal article. Performance accomplishments are based on personal experiences that a person has in everyday life. If a person has successful experiences, his/her efficacy related to that and similar experiences will be higher. In contrast, a person who continuously fails at the same or similar experiences will have lower efficacy. If a person has several successful experiences, and has developed a high level of efficacy, it will be difficult for failures to have a negative impact on that person’s efficacy (Bandura, 1977).

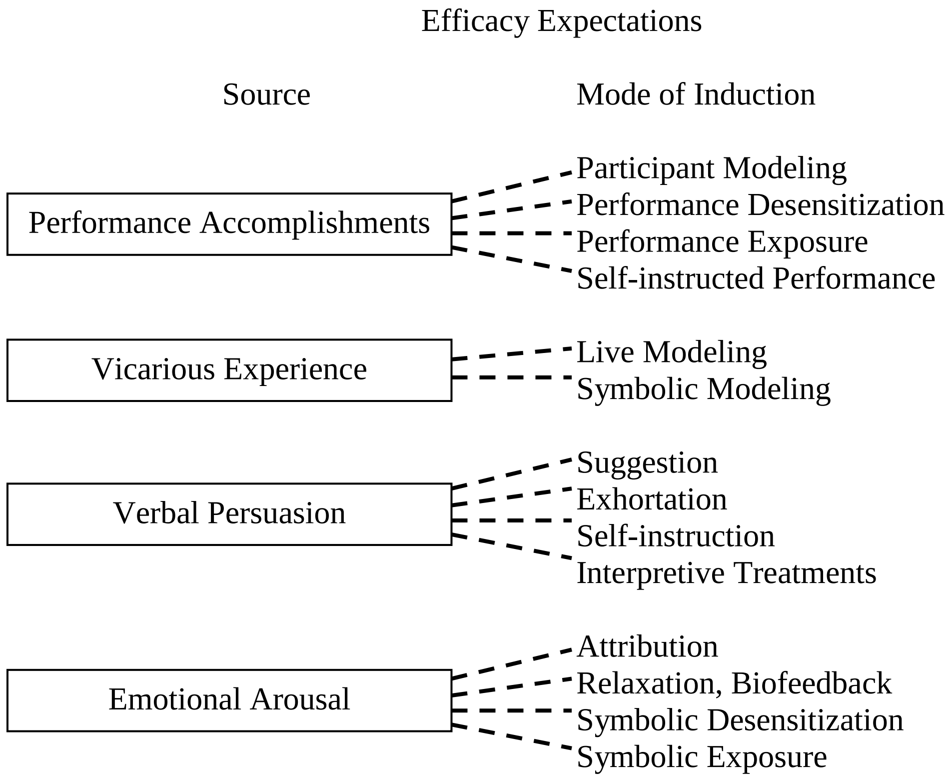

Figure 3. Major sources of efficacy information and the principal sources through which modes of treatment operate (Bandura, 1977, p. 195).

A person going through specific experiences is not the only factor that influences efficacy. A person watching others participate in specific experiences can have an effect on the spectator's efficacy. These effects can be positive or negative. "Seeing others perform threatening activities without adverse consequences can generate expectations in observers that they too will improve if they intensify and persist in their efforts" (Bandura, 1977, p. 197). It is like a little boy who observes his older brother climbing a tree in the back yard. If the older brother is successful, this can make the little boy feel that he can climb the tree as well. This improvement through a vicarious experience can have negative effects if the little boy is not physically equipped to climb the tree.

“Vicarious experience, relying as it does on inferences from social comparison, is a less dependable source of information about one’s capabilities than is direct evidence of personal accomplishments” (Bandura, 1977, p. 197). However, if a person has a strong fear of certain experiences and they are in no way capable of participating in those experiences, watching another succeed at that experience is a good stepping stone toward overcoming that fear.

The third source of self-efficacy as presented by Bandura is verbal persuasion. Verbal persuasion is relatively weaker at influencing a person’s self-efficacy when compared to performance accomplishments and vicarious experiences. Bandura (1977) explained that a person can be given verbal suggestions that they will be able to accomplish a specific task. These suggestions can lead people to believe that they will be successful when attempting that task. However, simply informing a person that they can accomplish a task does not mean that they will believe what they are told, especially when it goes against their knowledge gained from previous personal experiences (Bandura, 1977). Verbal persuasion can be used as an important tool to encourage the efforts of a student to complete a task, especially if they have failed at that task previously. The fourth source, emotional arousal is an important source of self-efficacy because “stressful and taxing situations generally elicit emotional arousal that, depending on the circumstances, might have informative value concerning personal competency” (Bandura, 1977, p. 198). If a student has a test at school, and the student is stressing out about the test, their level of efficacy is not going to be very high. If the same student is not very stressed about the test coming up, then their level of efficacy should be reasonably higher.

Schunk and Pajares (2002) further discussed self-efficacy with regards to the social cognitive theory, “which postulates that human achievement depends on interactions between one’s behaviors, personal factors (e.g., thoughts, beliefs), and environmental conditions” (p. 2). A person begins to develop their level of self-efficacy as early as infancy (Schunk & Pajares, 2002). Infants observe their parents and other people whom they interact with in their daily lives. These observations can influence the child positively and/or negatively depending on what happens and how the child applies it to their own actions. “Parents who provide an environment that stimulates youngsters’ curiosity and allows for mastery experiences help to build children’s self-efficacy” (Schunk & Pajares, 2002, p. 4). Parents are a vicarious source for children. Parents can model different experiences for children, and when parents encourage their children to participate in the same experiences, it can strengthen the child’s self-efficacy. At the same time, when parents discourage their children from participating in new activities or exploring new ideas, the child’s self-efficacy can suffer.

Interest and Self-Efficacy

A person’s self-efficacy and interest are closely related, and each can be influenced by the other. Bandura and Schunk (1981) wrote “a sense of personal efficacy in mastering challenges is apt to generate greater interest in the activity than is self-perceived inefficacy in producing competent performances” (p. 587). If a person feels confident towards a subject in school, they will most likely be interested in that subject, and, in turn, take more courses in that subject area (Betz & Hackett, 1981; Lent et al., 1986). If a student does not have confidence in his/her math skills, he/she is less likely to go above and beyond the minimum requirement of math courses.

Bandura and Schunk (1981) conducted an experiment with young children who displayed gross deficits in math skills and strong disinterest in activities related to mathematics. The research investigated the use of small sub goals to see if sub goals could build self-efficacy and interest in students that struggled in mathematics. The students were given a pretest consisting of 25 subtraction problems. After the pretest, mathematical self-efficacy of the students was measured. Then the students were briefly exposed to subtraction problems of varying difficulty. Students were then prompted to judge their capability to solve the problem. The children were then randomly placed into one of three treatment groups. After the treatment, students were given a second test to measure subtraction skills, and a second test to measure their perceived self-efficacy. The results related to interest and efficacy, were summarized as follows. In general, “children showed comparable gains in self-efficacy...” (Bandura & Schunk, 1981, p. 590). The research also found that students with moderate to high efficacy had a positive correlation to interest in the problems presented during testing. A main finding of the experiment was that students with low efficacy or strong disinterest in a subject cannot change their beliefs in a short amount of time. Changing a strong dislike to a strong interest, may require mastery experiences over a period of time. Over this period, one can develop a strong enough efficacy that can translate into strong interest (Bandura & Schunk, 1981).

Measuring Self-Efficacy

Research has shown the effects of having low and high self-efficacy. Studies have shown what makes up a person's self-efficacy. How does one go about measuring a person's self-efficacy? Bandura (1982) explained that in order to accurately and adequately measure one's self-efficacy, it "requires detailed assessment of the level, strength, and generality of perceived self-efficacy..." (p. 124). Self-efficacy is usually measured using written surveys. The survey is given directly to the person's whose efficacy is being measured. The survey can vary in the number of questions that are asked. The questions are worded in a way to see how confident a student is that they can achieve or complete a task. The Motivated Strategies for Learning Questionnaire (MSLQ) developed from 1986-1991 used the following types of statements when asking students questions about their "self-efficacy for learning and performance" (Pintrich, Smith, Garcia, & McKeachie, 1991, p. 13).

a) "I'm confident I can . . ."

b) "I'm certain I can. . ."

c) "I believe I will . . ."

These questions are usually answered on a Likert-type scale (Pintrich et al., 1991; Zimmerman, Bandura, & Martinez-Pons, 1992). Jamieson (2004) stated that typically there are five categories of response when using Likert scales. Jamieson (2004) also stated that a common example of a ranges is from 1 = strongly disagree to 5 = strongly agree. The My Class Activities (Gentry & Gable, 2001) survey asked students to respond to questions on a five point Likert-type scale. The responses ranged from never to always. There are other researchers that felt a larger range in scale was needed. For example, Zimmerman and colleagues used a survey similar to those described above to measure ninth and tenth grade students' self-efficacy for self-regulated learning and self-efficacy for academic achievement. The two surveys had eleven and nine items respectively. The scale for each item in Zimmerman and colleaguea' survey used a 7-point Likert scale. The surveys are usually administered during a period when all of the subjects are able to complete the survey. If a study was investigating the self-efficacy of students in mathematics, the survey would normally be administered in the students' math course. The style of scales used by Zimmerman and colleagues proved to be a reliable style of survey. "A coefficient of .87 was found for the 11-item self-efficacy for self-regulated learning scale, and a coefficient of .70 was found for the 9-item self-efficacy for academic achievement scale" (Zimmerman et al., 1992, p. 668). Other scales that have been used to measure self-efficacy had students rate their efficacy on a 100-point scale. The 100-point scale was in 10-unit increments that ranged from highly uncertain to complete certitude (Bandura & Schunk, 1981). There are varying scales that are used to measure self-efficacy, but they are very similar and have been shown to be very reliable at measuring students' self-efficacy.

Importance of Self-Efficacy

Zimmerman and colleagues (1992) concluded that a student's perceived self-efficacy is directly and indirectly related to a student's academic achievement. The research presented by Zimmerman and colleagues supported the notion that students should create goals for themselves. When students create small, easily achievable goals, they are more likely to see an increase in self-efficacy. The results of their study show that a student's goals and perceived efficacy account for 31% of a student's academic attainment. If self-efficacy accounts for almost a third of how well a student will do in a course, it should definitely be taken into consideration when students are looking into which courses they should take. Bandura (1993) summarized his study stating that students with low self-efficacy will shy away from difficult tasks. Students with low efficacy in a given subject will create low attaining goals for that class, if they create any goals at all, and they will have low commitment, if any, to the goals that they do create. One can see the complete opposite reaction in students with high self-efficacy. "People with high efficacy approach difficult tasks as challenges to be mastered rather than as threats to be avoided" (Bandura, 1993, p. 144). Bandura reported that students react differently to failure depending on their level of efficacy. If a student has high efficacy and fails at something, he/she sees the failure as a result of a lack of effort on his/her part. In contrast, a student with low efficacy sees his/her failure as a lack of ability to accomplish the given task (Bandura, 1993).

Out of the many research studies that have been conducted, there have not been many that have focused on technology and engineering education. Technology and engineering education has established itself as a group that presents students with hands on applications of science and math concepts. Do these hands on applications improve a student's self-efficacy? Schunk and Pajares (2002) stated that research is needed to see how students develop self-efficacy in technology related fields. In the last couple decades there has been a push for participation in robotics competitions. Do students who participate in robotics competitions have higher levels of efficacy after participation? If research can show that students who participate in robotics competitions have higher self-efficacy after participation, then supporters of robotics competitions will have data to confirm their thoughts and anecdotal evidence.

Instrument Development

The processes described to develop survey instruments were investigated because of their use in the instrument development process of the *My Class Activities* survey instrument (Gentry & Gable, 2001). *My Class Activities* was developed to assess the dimensions of interest, challenge, choice, and enjoyment of students and their perceptions of their classroom activities (Gentry & Gable, 2001). The instrument contains 31 statements related to the four dimensions. Students rate each statement on a 5-point Likert scale. The methods utilized by Gentry and Gable (e.g., use of experts, a pilot study, and factor analyses) developed a valid and reliable instrument for measuring the four dimensions of motivation.

The first phase of development for this self-efficacy instrument was to determine the outcomes of participation in the VRC. The outcomes determined would translate directly into the questions asked on the instrument, and therefore needed to be produced through a valid process. This validation process was used to ensure the content and face validity of the instrument. Garson (2013a) described content validity as having “to do with items seeming to measure what they claim to” (p. 22). There are several processes that can be used to determine if the content of an instrument is really measuring what it should be measuring. “Use of panels of experts, the Delphi method, or focus groups of representative subjects are ways in which content validity may be established...” (Garson, 2013a, p. 22). The method used in this study was an occupational and task analysis (OTA), which relies on a panel of experts to determine the outcomes, ensuring content validity.

Occupational and Task Analysis

The process of conducting an Occupational and Task Analysis has been used to develop curriculum and training materials for vocational education for over 100 years. It was used by Stimson (1922) in 1911 to analyze agriculture jobs for teaching the jobs to students. Stimson referred to the process as a job analysis. Mager and Beach (1967) described the process that was developed under the National Defense Education Act. The Task Analysis Working Group (1992) defined a task analysis as “the study of what an operator (or team of operators) is required to do, in terms of actions and/or cognitive processes, to achieve a system goal” (p. 1). Typically this process is used to develop curricula for teaching purposes. This process was ideal to use to determine the outcomes of participation in the VRC. Building competitive VEX robots is a job for students with a teacher/coach being the supervisor. If robotics teams are to be successful, the team must be able to complete certain tasks before, during, and after a competition.

In their book, Mager and Beach (1967) described “the steps involved in preparing instruction that can be demonstrated to facilitate learning” (p. x). The first step in the OTA process is to list all of the tasks that might be included in performing the job. Mager and Beach recommend not relying on memory to list the tasks, but to talk with individuals on the job or managers overseeing the job being analyzed. Stanton (2006) suggested that one verify the tasks with subject-matter experts.

For curriculum development, the list of tasks is translated into the list of objectives each student should achieve in the classroom. After the list of tasks is compiled, three questions should be asked of each task. These questions include (a) What is the frequency of the task; how often is the task performed? (b) How important is the performance of the task? and (c) How difficult is the task to perform? Asking these three questions allows the tasks to be organized into an ordered list which aids in curriculum development in a later stage. Once this is complete, all of the steps necessary to complete each task are listed under each task. These lists of steps translate into the enabling objectives taught in each lesson plan of a curriculum. The OTA approach has shown to be successful at identifying the tasks that are needed to make employees successful at their job. A similar process used to analyze a job is known as DACUM or Developing A Curriculum (Norton, 1997).

DACUM began to evolve in 1966; “It was created initially in a joint effort by the Experimental Projects Branch, Canada Department of Manpower and Immigration, and General Learning Corporation of New York, which provided technical direction to the Women’s Job Corps program at Clinton, Iowa” (Norton, 1997, p. 298). DACUM was used as an alternative evaluation process for onsite occupational training programs. DACUM training has been conducted all over the world to train committees to develop work place training for new employees. It has been used in Canada, New Zealand, Sri Lanka, Sweden, and many other countries (Norton, 1997). It has been used at universities and colleges in the United States to train future educators to develop curricula for use in the classroom. A few of the universities that have used DACUM are Bowling Green

University, Oklahoma State University, Ohio State University, and Temple University (Norton, 1997). DeOnna (2002) stated DACUM is able to reduce two common errors that can occur during curriculum development, (a) the failure to teach what should be taught, and (b) teaching what should not be taught (p. 6). When a committee is used to determine what should be taught and what should not be taught, it is more likely that the correct decisions will be made, compared to when one teacher is trying to make all of the decisions. That is why DACUM recommends a committee of 5-12 experts to generate the list of tasks performed by a worker/student. The DACUM technique is very similar to the OTA technique and would serve as an alternative to the OTA approach in determining the outcomes of student participation in the VEX Robotics Competition.

Validity and Reliability

It is important to establish content validity when developing an instrument. An instrument needs to measure what it is intending to measure, if it does not, the instrument would not be appropriate to use. Content validity can be established through the Occupational and Task Analysis method if the process described above is followed.

Factor analysis (FA) is commonly used in the instrument development process to measure construct validity. "Factor analysis seeks to uncover the underlying structure of a relatively large set of variables" (Garson, 2013b, p. 10). The use of FA allows a researcher to confirm if a set of variables listed under a factor or construct is truly measuring that construct. There are two types of factor analysis, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA allows the researcher to determine the factor structure of the variables, while a CFA allows the researcher to test the relationship between the observed variables and the constructs that were established in an EFA (Suhr, 2006).

When using EFA researchers must choose an extraction method for determining the number of factors present in a set of variables or items. The most common extraction method is principle components analysis (PCA); however, it is not really a factoring method, but rather a components analysis (Garson, 2013b). Costello and Osborne (2005) have described choosing a factor extraction method as a confusing process:

> There are several factor analysis extraction methods to choose from. SPSS has six (in addition to PCA; SAS and other packages have similar options): unweighted least squares, generalized least squares, maximum likelihood, principal axis factoring, alpha factoring, and image factoring. Information on the relative strengths and weaknesses of these techniques is scarce, often only available in obscure references. To complicate matters further, there does not even seem to be an exact name for several of the methods; it is often hard to figure out which method a textbook or journal article author is describing, and whether or not it is actually available in the software package the researcher is using. This probably explains the popularity of principal components analysis – not only is it the default, but choosing from the factor analysis extraction methods can be completely confusing. (p. 2)

Using the results of the extraction method, the researcher is able to decide how many factors to retain. Determining the correct number of factors to keep is an extremely important decision. “Both overextraction and underextraction of factors retained for rotation can have deleterious effects on the results...the best choice for researchers is the scree test” (Costello & Osborne, 2005, pp. 2-3). Fabrigar, Wegener, MacCallum, and Strahan (1999) described the scree test procedure: “[T]he eigenvalues of the correlation matrix (or the reduced correlation matrix) are computed and then plotted in order of descending values. This graph is then examined to identify the last substantial drop in the magnitude of the eigenvalues” (p. 278). The number of factors above the break is the number of factors to be retained.

Another decision that must be made is the rotation method. “Rotation serves to make the output more understandable and is usually necessary to facilitate the interpretation of factors” (Garson, 2013b, p. 17). There are a variety of rotation methods available. First the research must determine the data being analyzed is orthogonal or oblique. “Orthogonal rotations produce factors that are uncorrelated; oblique methods allow factors to correlate” (Costello & Osborne, 2005, p. 3). Generally when developing an instrument the researcher can assume that the factors will be at least somewhat correlated. For this reason, oblique rotation methods should generally produce a more accurate solution (Costello & Osborne, 2005). Fabrigar and colleagues (1999) suggested that even if the factors are not correlated, an oblique rotation will produce similar results as an orthogonal rotation. Types of oblique rotation include direct oblimin, quartimin, and promax. “There is no widely preferred method of oblique rotation; all tend to produce similar results” (Costello & Osborne, 2005, p. 3).

“Strict rules regarding sample size for exploratory factor analysis have mostly disappeared” (Costello & Osborne, 2005). Costello and Osborne explored best practices for performing EFA through examining 303 previously conducted studies. The study found a range of subject (sample size) to item ratios from less than 2:1 to 100:1. The most common (25.8%) practice used when conducting EFAs was a subject to item ratio between 2:1 to 5:1. The second most common ratio used was between 5:1 to 10:1, at 22.7%. The least common ratio used was 100:1 with only 3% of the studies using a ratio this high. Some studies (14.7%) even used a ratio that was 2:1 or less. This means when using the most common practice, an instrument with 50 items should have a minimal sample size between 100 and 250 subjects.

The rules for conducting CFAs are somewhat open as well. However there are more consistent subject to item ratios used by researchers. Suhr (2006) stated that a CFA should have a subject to item ratio between 5:1 to 20:1.

Another technique used to perform instrument reliability is calculating Cronbach's alpha. Reliability is "the degree to which measurement error is absent from the scores yielded by the test" (Gall, Gall, & Borg, 2007, p. 200). Measurement error is the difference between the true score and the actual score a person actually received. "Both true score and measurement error are hypothetical constructs..." (Gall et al., 2007, p. 200). This means that a tests true score and measurement error cannot be directly calculated, but only estimated. Test reliability is measured between .00 and 1.00; the higher the score, the more reliable the test. "Cronbach's alpha is a widely used method for computing test score reliability" (Gall et al., 2007, p. 200). Cronbach's alpha is used to calculate test reliability when the test questions are not scored dichotomously. When test questions are measured with a Likert scale or similar method, calculating Cronbach's alpha is one of the more preferred methods.

There is debate among researchers whether or not goodness of fit indices should be calculated when developing instruments. Goodness of fit indices are tests used in structural equation modeling (SEM) to establish if a model is acceptable (Moss, 2009). Researchers do not always calculate and/or present goodness of fit indices when they develop instruments. Examples of researchers that did not report and/or calculate goodness of fit are Cork, Detmer, and Friedman (1998) in the *Computers in Medical Care* instrument and the model presented by Strachota and colleagues (2006). The *My Class Activities* instrument reported (Gentry & Gable, 2001) however presented several fit indices. Those indices included the Tucker Lewis Index (TLI), goodness of fit index (GFI), and the root mean square residual.

Moss (2009) compiled a list of widely used fit indices and the accepted levels of fit for each of the tests by reviewing past studies. However, Moss (2009) explained that "acceptable fit indices do not imply the relationships are strong. Indeed, high fit indices are often easier to obtain when the relationships between variables are low rather than high—because the power to detect discrepancies from predictions are amplified" (par. 1). There are positives and negatives to every fit index. For this reason, Moss explained that it is recommended that researchers explore a range of fit indices when explaining the goodness of fit referencing research by Marsh, Balla, and Hau. A list of popular fit indices and their acceptable levels as reported by Moss (2009) can be seen in Table 1.

Table 1

Popular Fit Indices and Acceptable Levels as Reported by Moss (2009)

Fit index	Acceptable fit
Normed fit index (NFI)	>.90[a] sometimes >.95[a]
Goodness of fit index (GFI)	>.90
Comparative fit index (CFI)	>.93
Root mean square residual (RMS or RMR)	<.08[a] ideally <.05[a]
Tucker Lewis index (TLI) or non-normed fit index (NNFI)	>.90[a] >.95[a]

[a]There is still debate in which level of acceptance is appropriate.

The acceptance levels reported in Table 1 are still debated by researchers today. Some researchers state that the value of the NFI is underestimated when small sample sizes are used (Moss, 2009). There is also debate whether to calculate the RMR or RMS or the standardized version of the RMS. “Because the maximum is unbounded, the RMS is difficult to interpret and consensus has not been reached on the levels that represent acceptable models. Some researchers utilized the standardized version of the RMS instead to override this problem” (Moss, 2009, par. 10). These reported levels of acceptance are merely guidelines and have changed in value or time. The levels of acceptance were sometimes lower in earlier research (Moss, 2009). Therefore, researchers may report a range of fit indices to meet the acceptance of his or her field. A researcher also has the freedom to consider their model acceptable based on varying acceptance levels presented in the literature.

Conclusion

The research showed that robotics competitions continue to grow throughout the United States and world. The exploration of the literature indicated that more evidence is needed to determine the outcomes of participation in robotics competitions. A valid approach to determining the outcomes is through an occupational and task analysis. Once the outcomes of participation are determined an instrument will be needed to explore students’ relationships to these outcomes. An important relationship to be explored is a student’s self-efficacy. Self-efficacy is important when students are deciding their interests and choosing their courses in school. Higher efficacy in certain areas can lead to higher interest in those areas. Students with higher self-efficacy are more likely to persevere through difficult tasks as compared to those with lower self-efficacy. No instruments exist to measure the self-efficacy of students participating in the VRC; therefore, a valid and reliable instrument is needed. The instrument should measure a student's efficacy on a Likert-type scale. The reliability of an instrument can be calculated using factor analyses and Cronbach's alpha. The literature discussed above was used to guide the development of the self-efficacy instrument following the specifics mentioned.

CHAPTER III

METHODOLOGY

Introduction

The purpose of this study was to develop and validate an instrument to measure the self-efficacy of middle and high school students participating in VRC. The VRC is the largest and fastest growing robotics competition in the world for middle and high school students. There have been limited studies conducted to measure the outcomes of student participation in robotics competitions. Even fewer have been conducted to investigate the VRC. The methodology followed in this research study was adapted from the model used to create the My Class Activities (Gentry & Gable, 2001) instrument, and a model for developing online surveys by Strachota and colleagues (2006). A graphic representation of the methodology can be seen in Figure 4.

Review of Literature and Research Question

The review of literature on the VRC did not reveal many research studies identifying the outcomes of student participation. The few studies that have investigated the VRC have mainly looked at student interest after participation. Therefore, one research question explored in this study was, what are the outcomes of student participation in the VRC? Because a complete answer could not be found in the literature, an occupational and task analysis was used to determine potential outcomes.

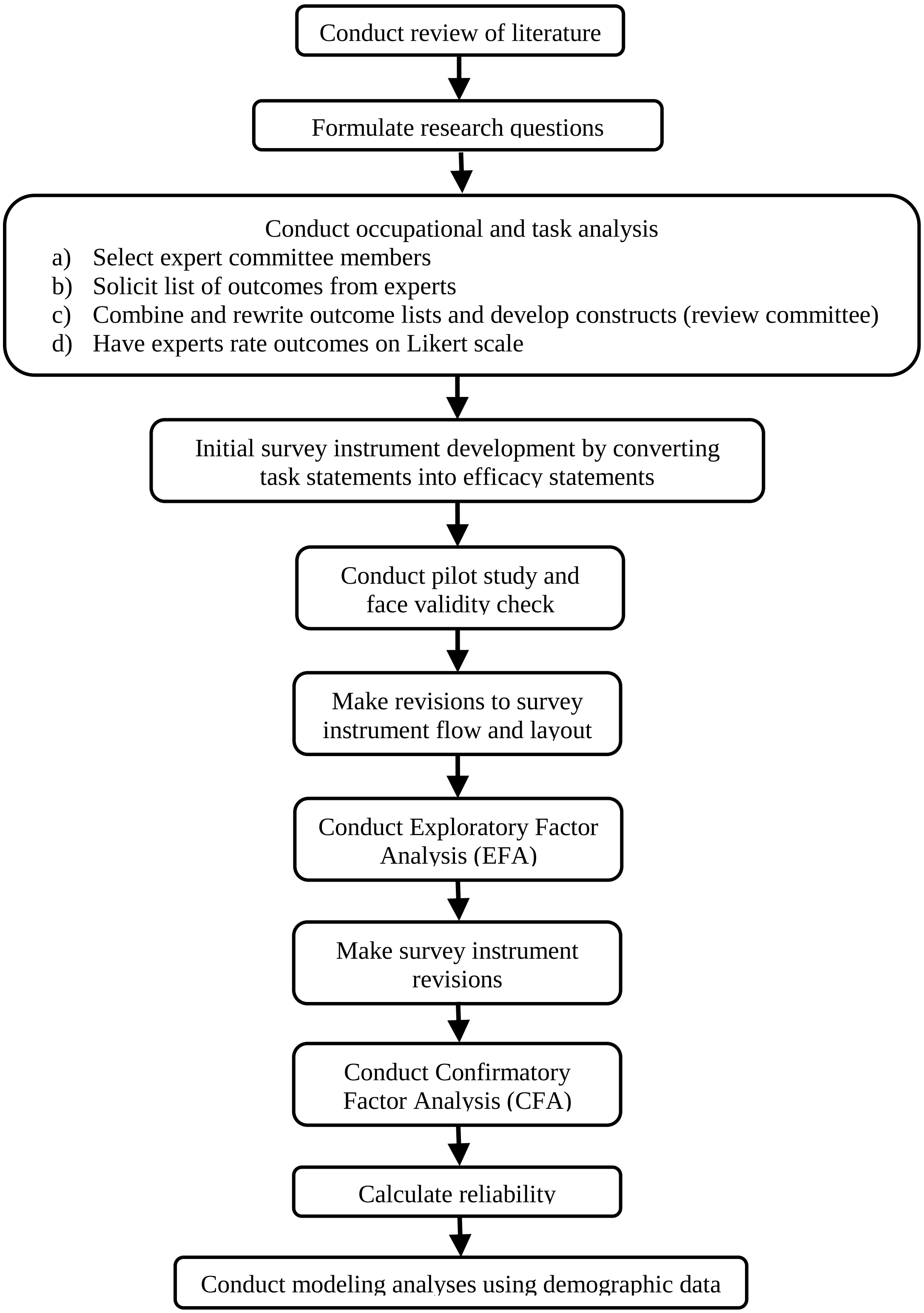

Figure 4. Flow chart for the procedure followed to design the self-efficacy instrument developed in this research project.

Construct Development and Content Validity Check

There were two options available to identify, collect, and rank outcomes. The first option was through the use of a Delphi study. A Delphi study is a process utilizing experts during multiple rounds (four to six) until a consensus is reached among the experts. The other option was an OTA. An OTA also utilizes a group of experts, however only two rounds are necessary. The first rounds of both a Delphi study and an OTA ask the experts to develop a complete list of outcome statement. During the second round of an OTA, specific questions are asked of the experts where the experts rate each outcome on a Likert scale. Initially the Delphi method was chosen to determine the outcomes. Later it appeared that an OTA might be more appropriate, and therefore after round one, the OTA process was followed. Using the OTA allowed the researcher to achieve the necessary results utilizing only two rounds.

The group of experts that participated in the OTA was chosen from eligible coaches, mentors, and instructors from across the United States. The experts were considered eligible if at least one of their competing VRC teams qualified for the VRC World Championships three out of four years from 2009-2012. For example, one high school had four teams competing (i.e., 1497A, 1497B, 1497C, and 1497D) during the 2009-2012 seasons. If team 1497A qualified for the world championship in 2009, team 1497B qualified for the world championship in 2010, and team 1497C qualified for the world championship in 2012, then the coach would be considered eligible to be an expert on the committee. Once a complete list of eligible coaches, mentors, and instructors was identified, the coaches, mentors, and instructors were approached at the 2012 VRC World

Championship and invited to participate on the expert committee.

The next step asked each expert to "list the outcomes you believe students gain through participating in VEX robotics. List outcomes as task statements, preferably starting with a verb. Both hard and soft skills should be listed. In addition outcomes may reflect cognitive, psychomotor or affective domains of learning" (the complete e-mail sent to the expert committee can be viewed in Appendix A). Once the lists were received from the experts, it was necessary for a second committee, the review committee, to examine the outcome lists. The purpose of the review committee was to organize the list of outcomes, combine like outcomes, and reword outcomes to begin with a verb. The review committee also grouped the outcomes into naturally occurring groups or constructs.

After the review committee performed the examination of the outcomes, the outcomes were sent back to the expert committee. The experts were asked to rate how critical each outcome is to a successful VEX team on a 5-point Likert scale. The possible ratings were 0 = Not Performed, 1 = Not Critical, 2 = A Little Critical, 3 = Moderately Critical, and 4 = Extremely Critical. An average score was calculated for each outcome, allowing the outcomes in all constructs to be organized from most critical to least critical.

Initial Instrument Development

Once all outcomes were rated based on how critical they are to team success, the outcomes that were rated above a 2.0 were transformed into efficacy statements to be used on the instrument. The survey was developed using Qualtrics: Online Survey

Solutions. Each outcome included on the instrument was rewritten to be in statement form from a student perspective. The phrase “I feel confident that I can...” was added to each outcome. An example outcome reads, “I feel confident that I can calculate the ratios for simple and compound drive trains—gears; chain & sprocket.” The instrument asks the respondent to rate each statement on a 5-point Likert scale. A 5-point scale was chosen, because it is one of the more common scales used in surveys (Jamieson, 2004). The rating scale was 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree. Because the instrument was developed using Qualtrics, the outcome statements were able to be delivered to the students randomly. The constructs were presented in random order (i.e., the mechanical outcomes were not always presented first, and the teaming outcomes were not always presented last). The outcome statements within each construct were also presented in a random order.

Pilot Study, Exploratory Factor Analysis, and Revisions

The purpose of the pilot study was to insure the face validity of the instrument. The instrument needed to be tested with students that were similar to the students that would be using the final version. During the pilot study, a group of students from a local high school and elementary school were used in a focus group. The high school students were on the school’s FIRST Robotics Competition team. The elementary students were fifth grade students that had participated in a VEX IQ (robotics competition designed for students fourth through eighth grade) program at their school. These students were chosen because of their experience in robotics, and because they were not part of the

VRC population. The pilot was conducted in the student's regular school classroom. The students were made aware that there were no right or wrong answers, and that the purpose of the study was to ensure that the instrument made sense to them. Questions were asked while the students were taking the survey, and while the survey was available for the students to view. The students were asked specific questions regarding the layout of the instrument (e.g., Does the instrument make logical sense to you, and did you understand how to answer the questions?). The students were also asked specific questions about the content of the instrument (e.g., did any of the questions confuse you? and did the statement "I feel confident that..." confuse you?). Using the feedback from the focus group, changes were made to the instrument.

Once the changes were implemented, the instrument was administered to a rolling sample with a minimum of 200 participants that had participated in the 2013-2014 VRC season. To collect the sample data, initially a convenience sample of coaches, mentors, and instructors was used. Coaches, mentors, and instructors were contacted to see if they were willing to administer the survey to their team. Coaches were asked to administer the survey to their entire team including the designers, builders, programmers, and so forth. By having the coaches administer the survey to their entire team, a representative sample of the various team roles would have been collected. The sample collected does not appear to contain any abnormalities. Demographics of VEX participants is not readily available (e.g., number of males and females). By surveying entire teams, the sample should be representative of the VEX population. The sample size of 200 was based on Costello and Osborne's (2005) research. The results from the pilot were analyzed using an EFA. This initial EFA determined if the outcomes listed under the constructs actually measured the specific construct the outcome was supposed to measure. If the EFA determined that an outcome was listed under the wrong construct, the outcome was moved to the correct construct. This initial EFA also reduced the number of outcomes in each construct based on the loadings of the outcomes. The number of outcomes for the final instrument was reduced to a number that is reasonable for students to complete in a half an hour.

Confirmatory Factor Analysis and Data Analyses

Once the instrument revisions were completed, the instrument was administered to a second rolling sample. This rolling sample was in line with the literature suggesting between a 5:1 and 20:1 statement to sample ratio be used in CFAs (Suhr, 2006). The same convince sampling of coaches' technique utilized during the EFA was used to collect the sample data for the CFA. The data was then processed through a confirmatory factor analysis and internal consistency alpha reliability tests. Had the factors not loaded high enough, more samples would have been collected.

Data were collected on the demographics of the subjects. The demographic data included grade in school, age, sex, and number of years competing in VEX. To mitigate bias, modeling was conducted to detect biases among various groups. The modeling to determine bias was conducted on groups with a large enough *N* size. Additional questions were asked regarding the primary reasonability of the student on the VEX team and if the team was a school team or community team. If students were on a school team, they were asked a follow up question of whether their team met primarily during school or after school. Because this instrument was intended to be used in longitudinal studies, the students were asked if they planned on attending college in the future and what they intended to choose as a major.

Conclusion

The methodology presented was used to develop and validate the Self-efficacy Instrument created during this study. The methodology followed a model that was presented in other research used to develop survey instruments. Results of the instrument development process can be seen in Chapters IV and V.

CHAPTER IV

FINDINGS

Introduction

The purpose of this research study was to develop a survey instrument that would measure the self-efficacy of students participating in VRC. The instrument was validated for use with middle and high school students in the United States. The procedure followed for this research study was guided by seven milestones. The seven milestones were developed through a combination of two models used for developing similar instruments—the model used by Gentry and Gable (2001) to create the My Class Activities instrument, and the model for developing online surveys by Strachota and colleagues (2006). The seven milestones were as follows.

1. Determine the outcomes obtained by students participating in VEX Robotics Competitions (VRC) utilizing an occupational and task analysis (OTA).
2. Develop initial survey instrument using the outcomes determined during milestone one.
3. Conduct an exploratory factor analyses (EFA) on the initial instrument.
4. Reduce the number of items and revise the survey instrument using the results of the EFA and the OTA.
5. Conduct a confirmatory factor analyses (CFA) on the revised survey instrument.
6. Calculate the reliability of the instrument using Cronbach’s alpha.

7. Detect bias of the instrument between various groups based on demographics of survey participants using modeling techniques.

This chapter discusses the research findings discovered during the development of the instrument, including details for each of the milestones described above.

Milestone 1—Determination of Outcomes of Participation in VEX Robotics Competitions

The first milestone utilized an expert committee through the use of an OTA to determine the outcomes of student participation in competitive VEX robotics. The method used to determine the experts is outlined in the Chapter III. Twenty-three coaches, mentors, and instructors from across the United States agreed to serve on the expert committee (see Appendix B for a complete list of experts on the committee). The first round of the OTA asked the experts to compile a complete list of outcomes that they observed students had achieved through their participation in competitive VEX robotics. During this round of the process, 11 experts submitted completed lists of outcomes. These 11 experts submitted a total of 586 individual outcomes.

Many of the statements submitted identified similar outcomes, and often statements were not in the proper format desired. As a result, a review committee was needed. The purpose of the review committee was to combine similar outcomes and reformat outcomes to be in the desired format. The review committee consisted of three individuals with varying expert backgrounds (see Appendix C for details on the panel for the review committee). The review committee was limited to three people to allow for concise discussion and decision making when working with the 586 outcomes. After the analysis of the outcomes by the review committee, there were 99 outcomes grouped under five constructs remaining. The five constructs were determined from natural groupings seen in the given list of outcomes. The five constructs were as follows.

- Mechanical
- Programming
- Design
- Teaming
- Professional traits

These 99 outcomes in their respective construct were sent to the original expert committee of coaches, mentors, and instructors. The outcomes were sent to all 23 volunteers and in this round 19 experts submitted responses, but only 17 of the responses were complete and used in data analyses. In this round the experts were asked to rate each outcome on a 5-point Likert scale based on how critical each outcome was to team success. The Likert rating scale used to rate each outcome was as follows.

Not performed	=	0 points
Not critical	=	1 point
A little critical	=	2 points
Moderately critical	=	3 points
Extremely critical	=	4 points

A mean score was calculated for each outcome. The mean score was used to organize the outcomes in each construct from most critical to least critical. Tables 2-6 show the rank order of each outcome respectively. The mean rating and standard deviation for each outcome is also listed in the tables.

Table 2

List of Mechanical Outcomes with Mean Score and Standard Deviation as Identified and Rated by the Expert Committee

Rank	Outcome	Mean	*SD*
1	Explain the design tradeoffs between speed and torque	3.76	.44
2	Construct a structurally sound and stable robot—chassis, lift, end-effectors	3.76	.44
3	Troubleshoot and maintain a competitive robot	3.76	.44
4	Explain the design tradeoffs between various end-effectors (e.g., conveyor, scoop, rollers, and gripper)	3.53	.62
5	Demonstrate proper safety practices while utilizing tools and equipment, and when operating the robot	3.53	.62
6	Explain the design tradeoffs between various lift systems—linear, single arm, parallel arm (4-bar), or 6-bar	3.53	.62
7	Demonstrate the proper use of tools and equipment (e.g., Dremel, drill press, file, and hex wrench)	3.41	.62
8	Construct various lift systems—linear, single arm, parallel arm (4-bar), and 6-bar	3.35	.61
9	Maintain VEX battery packs for competition	3.35	.70
10	Construct various end-effectors (e.g., conveyor, scoop, rollers, and gripper)	3.35	.61
11	Explain how friction effects robot performance—speed, traction, and amperage draw	3.35	.79
12	Calculate the ratios for simple and compound drive trains—gears; chain & sprocket	3.29	.47
13	Construct a drivetrain that increases rpm and torque	3.29	.59
14	Explain the design tradeoffs between VEX steel and aluminum structure	3.00	.94
15	Explain the design tradeoffs between regular and high strength VEX components (e.g., motors, gears, and chain & sprocket)	2.94	.83
16	Calculate robot speed—feet per second	2.65	.79
17	State proper names for VEX parts and components, tools, and fasteners	2.59	1.06
18	Define mechanical advantage and related terms	2.59	.80
19	Utilize datasheets for VEX components (e.g., microcontroller, motors, and sensors)	2.35	1.17
20	Construct and maintain a pneumatic system	2.18	1.07
21	Measure voltage, current, and/or resistance using a multimeter	1.94	1.03

Table 3

List of Programming Outcomes with Mean Score and Standard Deviation as Identified and Rated by the Expert Committee

Rank	Outcome	Mean	*SD*
1	Program conditional statements (e.g., if statements and while loops)	3.59	.71
2	Update the master code (firmware) on the Cortex microcontroller and joystick	3.53	.80
3	Program a robot to operate autonomously for a competition	3.53	.62
4	Troubleshoot programming error messages	3.35	.79
5	Update programming software	3.35	.93
6	Install and write a program to utilize an optical shaft encoder	3.29	.85
7	Program using logical operators	3.24	.83
8	Identify various types of variables	3.12	.99
9	Install and write a program to utilize a potentiometer	3.06	.90
10	Identify design tradeoffs of utilizing various VEX sensors	3.00	.94
11	Program user functions to accept and return values	2.94	1.09
12	Program and operate a robot in various driving modes—tank and arcade	2.94	.97
13	Utilize commenting of code in programming	2.88	1.17
14	Install and write a program to utilize a bumper/limit switch	2.88	.78
15	Program automated routines to assist in driver control mode	2.71	.96
16	Explain the difference between digital and analog, inputs and outputs, and normally open and normally closed	2.65	1.06
17	Install and write a program to utilize an integrated encoder module	2.53	1.13
18	Outline a program utilizing pseudo-code or flowcharting	2.53	.87
19	Draw the configuration (schematic) of the robot with input and output addresses	2.53	1.18
20	Install and write a program to utilize an ultrasonic range finder	2.29	1.11
21	Program a PID control loop to change outputs based on an input(s)	2.18	1.19
22	Install and write a program to utilize a line tracking (infrared) sensor	2.06	.90
23	Program a registered repeating timer to control a robot (EasyC)	1.82	1.51
24	Install and write a program to utilize a servo motor	1.76	1.20
25	Count in binary	1.65	1.22
26	Install and write a program to utilize a yaw rate gyroscope	1.59	1.18
27	Install and write a program to utilize a light sensor	1.29	1.11
28	Install and write a program to utilize an analog accelerometer	1.24	1.10

Table 4

List of Design Outcomes with Mean Score and Standard Deviation as Identified and Rated by the Expert Committee

Rank	Outcome	Mean	*SD*
1	Design various end-effectors (e.g., conveyor, scoop, rollers, and gripper)	3.71	.47
2	Design various lift systems—linear, single arm, parallel arm (4-bar), and 6-bar	3.65	.49
3	Work through several design iterations of a robot	3.65	.61
4	Explain the tradeoffs of a simple design versus a complex design	3.59	.51
5	Document game strategies—competition, robot skills, and programming skills	3.59	.51
6	Maintain an engineering design notebook	3.59	.62
7	Justify added complexity against potential benefits and disadvantages	3.53	.62
8	Test and prototype initial designs before building the actual robot	3.53	.51
9	Design a light, structurally and kinematically sound, and stable robot	3.47	.87
10	Design a drive train that increases rpm or torque	3.41	.51
11	Use a design process in the development, construction, and testing of a robot	3.41	.51
12	Describe how robot design can change when going from theory to reality	3.18	1.08
13	Design a robot using sketching techniques	3.00	.71
14	Design a robot using a Computer Aided Drafting and Design(CADD)	2.35	.93
15	Create a parts list (bill of materials) for a robot	1.94	1.03
16	Create a Gantt chart or equivalent organization and scheduling plan	1.76	1.09
17	Explain the benefit of using a Gantt chart or equivalent organization and scheduling plan	1.71	.99

Table 5

List of Teaming Outcomes with Mean Score and Standard Deviation as Identified and Rated by the Expert Committee

Rank	Outcome	Mean	*SD*
1	Collaborate with other team members to accomplish tasks	3.82	.39
2	Develop a competitive strategy within the game’s rules and guidelines	3.71	.47
3	Accept responsibility for team outcomes—positive and negative	3.65	.61
4	Develop a solution from multiple designs and strategies	3.65	.49
5	Resolve conflicts among team members	3.59	.51
6	Behave in an appropriate manner knowing that your actions reflect on the team	3.47	.87
7	Confidently approach and work with other alliances	3.47	.514
8	Make decisions for the good of the group versus personal gain	3.47	1.01
9	Receive constructive feedback from others without taking it personally (e.g., team members, alliances, and judges)	3.47	.87
10	Structure team to best use individual strengths and mitigate weaknesses	3.47	1.07
11	Provide constructive feedback about other’s designs and strategies	3.41	.80
12	Verbalize your design and strategies to others (e.g., team members, alliances, and judges)	3.41	.71
13	Manage time to complete qualifying matches, skill challenges, and judging	3.41	1.06
14	Follow directions	3.35	1.00
15	Follow assigned tasks and responsibilities (follower)	3.29	.85
16	Effectively delegate tasks to team members (leader)	3.29	.92
17	Develop and implement alliance selection strategies	3.18	.88
18	Develop and analyze scouting documents	3.12	.78
19	Mentor less experienced team members	3.06	.97

Table 6

List of Professional Trait Outcomes with Mean Score and Standard Deviation as Identified and Rated by the Expert Committee

Rank	Outcome	Mean	*SD*
1	Demonstrate persistence and patience when faced with difficult tasks	3.88	.33
2	Demonstrate a positive work ethic	3.71	.47
3	Maintain a professional behavior when negative and positive circumstances occur	3.59	.62
4	Demonstrate commitment to the goals of the team	3.53	.72
5	Prepare for unplanned situations by having the necessary parts and tools	3.41	.87
6	Demonstrate punctuality—attendance and completing assigned tasks	3.35	1.06
7	Research solutions using electronic media (e.g., VEX Forum, YouTube, and Facebook)	3.29	.77
8	Anticipate problems and allow time for developing solutions	3.29	1.11
9	Demonstrate craftsmanship with a quality finished product	3.18	.73
10	Develop both formal and informal presentations (e.g., for judges, other alliances, and press)	3.12	1.05
11	Demonstrate confidence in abilities	3.00	.94
12	Build an online presence in the robotics community (e.g., regionally, nationally, internationally)	2.41	1.12
13	Work with outside technical experts	2.29	1.11
14	Operate Tournament Manager software	1.29	1.21

Milestone 2—Develop Initial Survey Instrument

The initial survey instrument was developed using Qualtrics: Online Survey Solutions. Any outcome that was rated 2.00 (less than a little critical) or lower by the expert committee was not included on the instrument. There were 11 statements from the 99 that were not transformed into efficacy statements; leaving 88 statements on the initial survey instrument. During the second milestone the remaining outcome statements were transformed into efficacy statements. Each outcome was transformed by adding the phrase “I feel confident that I can...” before each statement. As an example, one statement would read, I feel confident that I can design various end-effectors (e.g., conveyor, scoop, rollers, and gripper). General demographic questions were added to the beginning of the survey. The following demographic information was asked of the students.

- Name
- Team number
- Gender
- Grade in school

General VEX team and participation information was also retrieved from the students. The following information was asked of the students:

- Number of seasons competing
- Primary responsibility on team
- Secondary responsibility on team
- Team affiliation (e.g., school, community team, 4-H)
- Formal or informal meetings by team (e.g., received a grade, did not receive a grade).

Knowing the number of seasons that a student has competed in competitive VEX robotics will allow researchers to discover trends in the efficacy of students over time. By knowing a student’s responsibilities on their team can help determine if certain responsibilities on a team can lead to higher or lower self-efficacy. Having information about formal or informal meeting environments for students will allow researchers to ask, “How does meeting during school and receiving a grade for participation compare to meeting after school and not receiving a grade?” Students were also asked if they planned on attending college at the time of completing the survey. If the student indicated that they did plan on attending college, then they were asked what they planned to major in. This information can tell researchers if participation in competitive VEX robotics has an effect on college aspirations.

To assist in the validation of the survey, one focus statement was added to each construct. The focus statements asked students to select a specific item on the Likert scale (e.g., For this item, please select the “strongly agree” circle). If a student did not properly respond to one or more of the focus statements, their survey responses were not used in the data analysis. A video explaining the Letter of Information (required by the Institutional Review Board) and instructions for completing the survey was added to the beginning of the survey. The Letter of Information can be found in Appendix G.

Once the initial survey instrument was developed in Qualtrics, it was piloted with a small group of students. During the pilot study, eight high school students who had previously participated in the FRC were administered the survey. In addition, to insure that questions were not too complex for middle school students, the survey was administered to three VEX IQ participants. The students were asked specific questions to ensure the survey flowed properly and was intuitive to them. Other questions were asked in regards to the outcome statements to ensure that they made sense to the students. After the pilot study several changes were implemented in the survey. Students felt that the focus statements were confusing; therefore, the focus statements were reworded to read as follows, “To demonstrate you are still focused on the survey, select the "strongly agree" circle.” Students were also confused by the abbreviations (“i.e.” and “e.g.”); therefore, for clarity purposes, the abbreviations were replaced with the phrases “that is” or “for example.” Students were not able to see the Likert scale descriptions after they answered a few questions, because it stayed at the top of each construct; therefore the descriptions were repeated after every five statements. Several statements that confused students were reworded by the review committee. One statement was removed from the survey. It read “I feel confident that I can demonstrate confidence in my abilities.” This question did not fit in the survey because it did not ask about a specific ability as did all of the other statements. After the completion of the pilot study there were 87 efficacy statements that remained on the survey instrument.

Milestone 3—Conduct Exploratory Factor Analysis

The survey instrument link was sent out to teachers from across the country and administered to students in their classroom. These teachers included the coaches, mentors, and instructors that participated in OTA, teachers in Utah, and teachers who volunteered to assist in the research. Using this method, the proper sample size was not reached; therefore the survey was administered to students at the 2014 VEX Robotics World Championship. Computers were setup in a manner to allow students to complete the survey outside of the competition area. These methods allowed for 282 attempts of the survey, of those, 25 attempts were blank. These were most likely left blank due to teachers previewing the survey or showing the video of explanation to their students prior to administering the survey. There were 257 surveys completed by students; 54 of the surveys were removed from the data before analysis. The 54 surveys removed were determined to be invalid because the students did not properly answer one or more of the five focus statements, one embedded question in each of the five constructs (e.g., To demonstrate you are still focused on the survey, select the "Neither Agree or Disagree" circle). After the invalid surveys were removed, 203 surveys (see Appendix D for data frequencies) were analyzed through an EFA utilizing the Statistical Package for the Social Sciences (SPSS). The EFA was calculated using maximum likelihood extraction and promax rotation with Kaiser Normalization. The scree plot from the EFA is displayed in Figure 5. The factor loading results of the EFA reduced the number of constructs from five to three, and are displayed in Table 7. The labels used in the tables for the EFA are based on the OTA and include the following.

M = Mechanical outcomes

D = Design outcomes

P = Programming outcomes

T = Teaming outcomes

PT = Professional trait outcomes.

Milestone 4—Revisions to Survey Instrument

After analysis of the data through an EFA utilizing SPSS, changes were made to the survey instrument by the review committee. The review committee also referenced

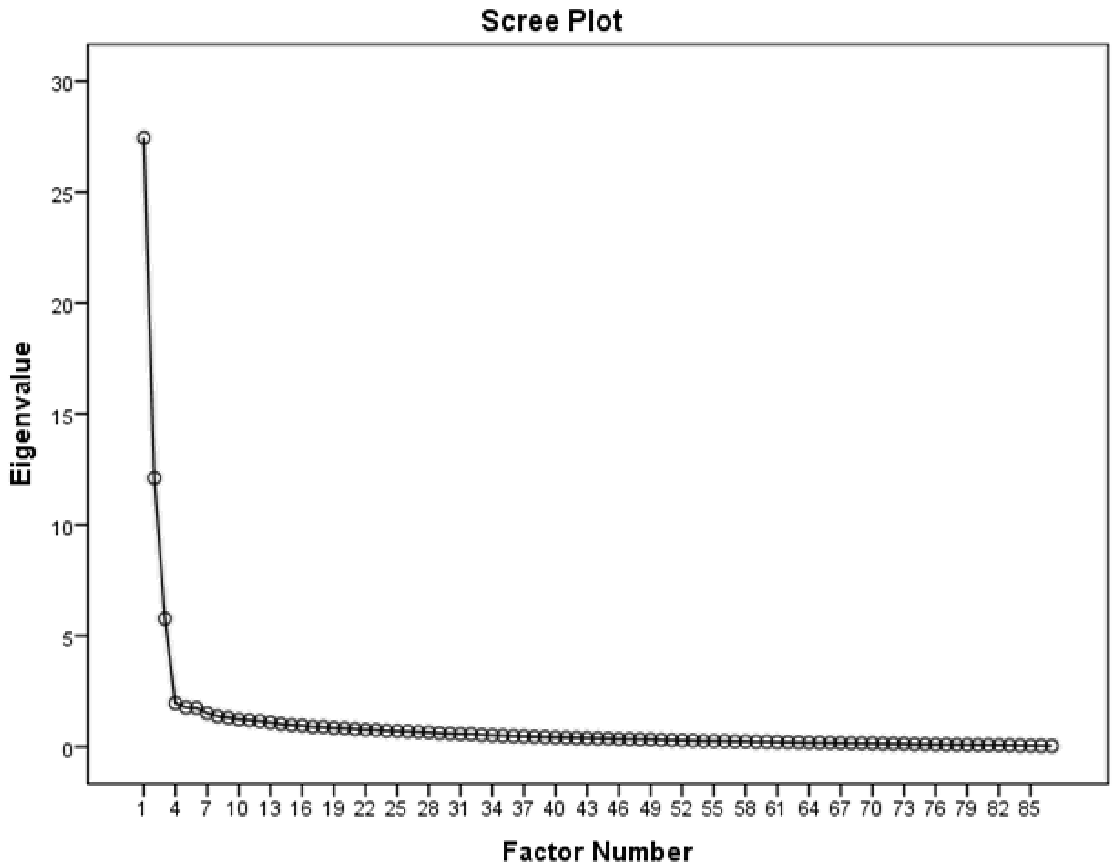

Figure 5. Scree plot results from the exploratory factor analysis.

the rankings of the various outcomes developed by the expert committee when making decisions. The scree plot suggested that only three constructs were being measured by the efficacy statements and not five as originally thought by the review committee. Based on the loadings of each statement in the three constructs, mechanical outcomes and design outcomes became one construct, teaming outcomes and professional trait outcomes became one construct, and programming remained a single construct. The review committee aimed to have a minimum of five statements and a maximum of ten in each construct. By reviewing the factor loadings, each construct had at least 22 statements loading above .40 and qualified to remain on the revised survey instrument.

Table 7

Exploratory Factor Analysis Results

Construct 1 (programming)		Construct 2 (mechanical and design)		Construct 3 (teaming and professional traits)	
Outcome	Load	Outcome	Load	Outcome	Load
P15	.920	M8	.893	T10	.798
P11	.912	D2	.884	T1	.794
P1	.902	M10	.875	T15	.790
P3	.891	D1	.863	T8	.771
P4	.891	M2	.827	T11	.761
P9	.890	M6	.816	T9	.750
P14	.865	M15	.806	T14	.697
P17	.861	M13	.796	T13	.696
P13	.847	D9	.771	T6	.686
P7	.840	M12	.761	T5	.675
P18	.817	M14	.747	T7	.667
P8	.807	M4	.732	T2	.650
P21	.802	M1	.717	T17	.640
P6	.798	M18	.709	T12	.632
P5	.770	D3	.693	PT3	.624
P22	.766	D8	.689	PT2	.619
P20	.757	M17	.582	PT4	.614
P12	.755	M3	.581	PT11	.598
P2	.725	M11	.566	D6	.576
P16	.725	D10	.554	M9	.572
P19	.699	D4	.552	T16	.565
P10	.579	D7	.504	PT6	.555
		D11	.497	T3	.539
		M20	.495	PT5	.535
		M7	.483	PT1	.523
		T4	.410	PT12	.506
				T19	.484
				PT9	.483
				T4	.440
				PT10	.438
				PT8	.430
				D5	.427
				T18	.421
				PT13	.419
				D12	.403

Note. EFA conducted with maximum likelihood extraction and promax rotation. The outcome labels represent the construct and construct rank by the expert committee. D=Design, M=Mechanical, P=Programming, PT=Professional Traits, and T=Teaming. Only loadings above .40 are displayed. T4 loaded on both construct 2 and 3. Outcomes M5, M16, M19, D13, and PT7 did not load above .40 on any of the three constructs.

Each qualified statement was analyzed by the review committee to determine if it should remain on the revised instrument or if it should be removed. The review committee kept statements in each construct that measured both the low end and high end of each construct. The low end was considered outcomes that students would most likely perform during their first year of competing; while a high end outcome would not likely be performed until a student's second or third season of competing. The EFA results for the mechanical and design outcomes were especially interesting because outcomes that were highly related in terms of what they were asking students to perform (e.g., M8—construct various lift systems—linear, single arm, parallel arm [4-bar], and 6-bar, versus D2—design various lift systems—linear, single arm, parallel arm [4-bar], and 6-bar) loaded at nearly the exact weight and were ranked very close to each other. The same was true for M10 and D1; therefore the two outcomes were combined to read as "I feel confident that I can design and construct various lift systems—linear, single arm, parallel arm (4-bar), and 6-bar. The same modification was applied to M8 and D2, M2 and D9, and M13 and D10. After discussions on each outcome statement in each of the three constructs, the mechanical and design construct contained eight efficacy statements, the programming construct contained nine efficacy statements, and the teaming and professional trait construct contained 10 items. Tables 8-10 show the efficacy statements that remained for each construct respectively. The labels used in the tables for the CFA are based on the results from the EFA and include: MD = mechanical and design outcomes, PR = programming outcomes; and TP = teaming and professional trait outcomes.

Table 8

Remaining Mechanical and Design Efficacy Statements after EFA

New ID	Org. ID(s)	Statement
MD1	M2 & D9	I feel confident that I can design and construct a structurally sound and stable robot—chassis, lift, end-effectors
MD2	M6	I feel confident that I can explain the design tradeoffs between various lift systems—linear, single arm, parallel arm (4-bar), or 6-bar
MD3	M8 & D2	I feel confident that I can design and construct various lift systems—linear, single arm, parallel arm (4-bar), and 6-bar
MD4	M10 & D1	I feel confident that I can design and construct various end-effectors (for example, conveyor, scoop, rollers, and gripper)
MD5	M12	I feel confident that I can calculate the ratios for simple and compound drive trains—gears; chain & sprocket
MD6	M13 & D10	I feel confident that I can design and construct a drivetrain that increases rpm or torque
MD7	M15	I feel confident that I can explain the design tradeoffs between regular and high strength VEX components (for example, motors, gears, and chain & sprocket)
MD8	D3	I feel confident that I can work through several design iterations of a robot

Note. The original ID column displays the two statements that were combined.

Table 9

Remaining Programming Efficacy Statements after EFA

New ID	Org. ID	Statement
PR1	P1	I feel confident that I can program conditional statements (for example, if statements and while loops)
PR2	P2	I feel confident that I can update the master code (firmware) on the Cortex microcontroller and joystick
PR3	P4	I feel confident that I can troubleshoot programming error messages
PR4	P6	I feel confident that I can install and write a program to utilize an optical shaft encoder
PR5	P9	I feel confident that I can install and write a program to utilize a potentiometer
PR6	P11	I feel confident that I can program user functions to accept and return values
PR7	P14	I feel confident that I can install and write a program to utilize a bumper/limit switch
PR8	P15	I feel confident that I can program automated routines to assist in driver control mode
PR9	P21	I feel confident that I can program a PID control loop to change outputs based on an input(s)

Table 10

Remaining Teaming and Professional Trait Efficacy Statements after EFA

New ID	Org. ID	Statement
TP1	T1	I feel confident that I can collaborate with other team members to accomplish tasks
TP2	T5	I feel confident that I can resolve conflicts among team members
TP3	T7	I feel confident that I can approach and work with other alliances
TP4	T8	I feel confident that I can make decisions for the good of the group versus personal gain
TP5	T9	I feel confident that I can receive constructive feedback from others without taking it personally (for example, team members, alliances, and judges)
TP6	T10	I feel confident that I can structure my team to best use individual strengths and mitigate weaknesses
TP7	T11	I feel confident that I can provide constructive feedback about other's designs and strategies
TP8	T13	I feel confident that I can manage time to complete qualifying matches, skill challenges, and judging
TP9	T15	I feel confident that I can follow assigned tasks and responsibilities (follower)
TP10	PT3	I feel confident that I can maintain a professional behavior when negative and positive circumstances occur

Milestone 5—Conduct Confirmatory Factor Analysis on Revised Survey Instrument

Once the instrument was revised, the changes were implemented in Qualtrics. The Qualtrics link was sent to teachers from around the country. Along with the link were instructions and a video explaining the survey and right of the students through the explanation of the Letter of Information. The teachers were asked to administer the survey to their students during class or team meeting times. When the survey was closed there were 237 attempts of the survey. Of those, 37 surveys were blank. This could have been from teacher previews and teachers showing the video to their students prior to completing the survey. Of the remaining completed surveys, 59 were deemed invalid due to students incorrectly answering one or more of the focus statements throughout the survey. Once the survey previews and the invalid surveys were removed, there were 141 valid survey responses. Complete frequency breakdown of the respondents can be seen in Appendix F. Table 11 displays the response percentages for each item, along with the mean and standard deviation of the responses by the students. The confirmatory factor analysis was conducted using maximum likelihood extraction and promax rotation. The results of the confirmatory factor analysis, including the item loadings for each construct can be seen in Table 12.

Milestone 6—Calculate Instrument Reliability

Reliability of the instrument was conducted using Cronbach’s alpha. Reliability was calculated on the instrument using all three constructs. The Cronbach’s alpha reliability score for the overall instrument was .916. The complete results of the alpha estimates for the entire instrument can be seen in Table 13. To further test the reliability of the instrument, Cronbach’s alpha was calculated for each individual construct. The alpha reliability for programming was .957. Complete alpha estimates for programming can be seen in Table 14. The alpha reliability for mechanical and design was .934. Complete alpha estimates for mechanical and design can be seen in Table 15. The alpha reliability for the teaming and professional traits construct was .834. The complete alpha estimates for teaming and professional traits can be seen in Table 16. Reliability of the instrument was also measured using goodness of fit test to compare the theorized model

Table 11

Response Percentages with Mean and Standard Deviation

		Response percentage						
Construct	Item	1	2	3	4	5	Mean	*SD*
Programming	PR1	12.8	15.6	16.3	22.0	33.3	3.48	1.417
	PR2	17.7	14.9	11.3	2.6	35.5	3.41	1.526
	PR3	13.5	14.9	17.7	29.1	24.8	3.37	1.360
	PR4	24.1	24.1	22.0	7.8	22.0	2.79	1.461
	PR5	22.7	20.6	17.0	19.1	20.6	2.94	1.463
	PR6	14.9	16.3	22.0	15.6	31.2	3.32	1.441
	PR7	18.4	13.5	16.3	16.3	35.5	3.37	1.528
	PR8	17.0	11.3	18.4	24.1	29.1	3.37	1.441
	PR9	285.4	24.1	18.4	18.4	10.6	2.59	1.353
Mechanical and Design	MD1	2.1	1.4	12.8	31.2	52.5	4.30	.902
	MD2	2.1	9.2	12.1	30.5	46.1	4.09	1.068
	MD3	2.1	6.4	12.8	31.9	46.8	4.15	1.014
	MD4	1.4	3.5	14.9	32.6	47.5	4.21	.924
	MD5	2.1	8.5	18.4	31.2	39.7	3.98	1.059
	MD6	0.7	7.8	15.6	23.4	52.5	4.19	1.014
	MD7	2.1	7.1	15.6	30.5	44.7	4.09	1.038
	MD8	1.4	1.4	8.5	37.6	51.1	4.35	.812
Teaming and Professional Traits	TP1	0.0	0.7	4.3	34.8	60.3	4.55	.615
	TP2	2.1	0.7	12.1	41.8	43.3	4.23	.851
	TP3	0.0	0.7	8.5	29.1	61.7	4.52	.682
	TP4	0.0	0.0	8.5	37.6	53.9	4.45	.649
	TP5	0.0	0.0	12.1	39.7	48.2	4.36	.689
	TP6	0.0	1.4	12.8	41.8	44.0	4.28	.740
	TP7	0.0	0.7	5.0	39.7	54.6	4.48	.628
	TP8	0.0	2.1	10.6	35.5	51.8	4.37	.760
	TP9	0.7	2.1	5.7	46.1	45.4	4.33	.743
	TP10	0.0	1.4	11.3	31.9	55.3	4.41	.747

Table 12

Confirmatory Factor Analysis Results

Construct 1(programming)		Construct 2 (mechanical and design)		Construct 3 (teaming and professional traits)	
Outcome	Load	Outcome	Load	Outcome	Load
PR1	.891	MD1	.812	TP1	.748
PR2	.713	MD2	.862	TP2	.571
PR3	.832	MD3	.861	TP3	.655
PR4	.832	MD4	.806	TP4	.525
PR5	.854	MD5	.643	TP5	.498
PR6	.928	MD6	.893	TP6	.484
PR7	.889	MD7	.819	TP7	.537
PR8	.873	MD8	.668	TP8	.572
PR9	.765			TP9	.504
				TP10	.555

Note. CFA conducted with maximum likelihood extraction and promax rotation.
PR = Programming, MD = Mechanical and Design, TP = Teaming and Professional Traits.

to the actual results. The fit tests were conducted with LISREL 9.1 (Scientific Software International, 2014). The results of several goodness of fit tests are displayed in Table 17. A correlation matrix was developed for all three constructs; the results can be seen in Table 18. The highest correlation existed between the mechanical and design construct and the teaming and professional traits construct at .562.

Milestone 7—Determine Instrument Bias

During this milestone analyses were made to investigate if any bias was present toward certain groups. Initially the research was going to explore males versus females and participants at various levels of experience (i.e., number of seasons competed). Preliminary chi-square tests were run between males and females. Due to an insufficient

Table 13

Combined Construct Cronbach's Alpha Reliability Estimates

Chronbach alpha	Item	Alpha if deleted
.916	PR1	.910
	PR2	.912
	PR3	.910
	PR4	.909
	PR5	.909
	PR6	.911
	PR7	.910
	PR8	.910
	PR9	.913
	MD1	.913
	MD2	.913
	MD3	.913
	MD4	.913
	MD5	.911
	MD6	.912
	MD7	.912
	MD8	.913
	TP1	.916
	TP2	.916
	TP3	.915
	TP4	.915
	TP5	.915
	TP6	.916
	TP7	.917
	TP8	.916
	TP9	.916
	TP10	.915

Table 14

Programming Construct Individual Cronbach's Alpha Reliability Estimates

Construct alpha	Item	Alpha if deleted
.957	PR1	.950
	PR2	.958
	PR3	.951
	PR4	.951
	PR5	.950
	PR6	.948
	PR7	.949
	PR8	.950
	PR9	.955

Table 15

Mechanical and Design Construct Individual Cronbach's Alpha Reliability Estimates

Construct alpha	Item	Alpha if deleted
.934	MD1	.924
	MD2	.921
	MD3	.921
	MD4	.923
	MD5	.935
	MD6	.921
	MD7	.922
	MD8	.930

Table 16

Teaming and Professional Traits Construct Individual Cronbach's Alpha Reliability Estimates

Construct alpha	Item	Alpha if deleted
.834	TP1	.815
	TP2	.830
	TP3	.812
	TP4	.816
	TP5	.817
	TP6	.823
	TP7	.823
	TP8	.823
	TP9	.822
	TP10	.811

Table 17

Goodness of Fit Indices Calculated on the Instrument

Fit index	Fit score
Normed fit index (NFI)	.920
Goodness of fit index (GFI)	.799
Comparative fit index (CFI)	.968
Root mean square residual (RMS or RMR)	.082
Standardized RMR	.067
Tucker Lewis lndex (TLI) or non-normed fit index (NNFI)	.965

Note. Goodness of fit tests were calculated using LISREL 9.1.

Table 18

Correlations Among Constructs

Construct	Programming	Mechanical and design	Teaming and professional traits
Programming	1.000		
Mechanical and design	.254	1.000	
Teaming and professional traits	.069	.562	1.000

sample size of females, the analysis was unable to be completed. Preliminary chi-square analysis was also completed on participants that were in either their first or second year of competition. These two sets of groups had the largest n sizes of the sample collected. It is recommended to have a minimum of five samples of each response category being analyzed. The frequencies of the 5-point Likert scale responses were insufficient, and therefore proper utilization of the chi square test to detect bias could not be completed.

Summary

During the OTA, 11 experts submitted 586 individual outcomes statements. A review committee combined similar outcomes and reworked statements to be in the desired format. This resulted in 99 outcomes grouped into five constructs. The 99 outcomes were then rated on a 5-point Likert scale by the expert committee. Outcome statements that were rated 2.00 or higher by the expert committee were transformed into efficacy statements to be included on the initial survey instrument. The initial survey instrument was piloted with FRC and VEX IQ participants. Changes were implemented based on feedback from the pilot study. The revised survey instrument was distributed and 203 valid surveys were received. An EFA was conducted on the data. Using the factor loadings from the EFA and the ratings by the expert committee, the number of constructs was reduced from five to three and a total of 27 outcomes statements remained on the final survey instrument. A CFA was conducted on the final survey instrument utilizing 141 valid surveys from VEX participants. Initial survey reliability was calculated using Cronbach's alpha. The initial survey reliability was very high at .916.

Calculation of instrument bias could not be calculated due to low n size in the groups to be compared.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research study was to develop a reliable and valid instrument to measure the self-efficacy of middle and high school students participating in VRC. The procedure followed for this research study was guided by seven milestones. The seven milestones were developed through a combination of two models used for developing similar instruments—the model used by Gentry and Gable (2001) to create the My Class Activities instrument, and the model for developing online surveys by Strachota and colleagues (2006). The seven milestones were as follows.

1. Determine the outcomes obtained by students participating in VEX Robotics Competitions (VRC) utilizing an occupational and task analysis (OTA).
2. Develop initial survey instrument using the outcomes determined during milestone one.
3. Conduct an exploratory factor analysis (EFA) on the initial instrument.
4. Reduce the number of items and revise the survey instrument using the results of the EFA and the OTA.
5. Conduct a confirmatory factor analyses (CFA) on the revised survey instrument.
6. Calculate the reliability of the instrument using Cronbach’s alpha.
7. Detect bias of the instrument between various groups based on demographics of survey participants using modeling techniques.

This chapter discusses the conclusions and recommendations for each of the milestones described above. This chapter also provides recommendations for using the instrument in future research.

Milestone 1—Determine the Student Outcomes of Participation in VEX Robotics Competitions

Introduction

The outcomes of student participation in VRCs were determined utilizing a group of experts through an OTA. Initially 23 coaches, mentors, and instructors volunteered to be on the expert committee. During the first round of the OTA, only 11 experts summited completed lists of outcomes. Those 11 experts submitted 586 individual outcomes. A review committee analyzed the lists of outcomes and combined similar outcomes. The review committee also reworded outcome statements to be in the desired format. The review committee was able to reduce the total number of outcomes to 99. The outcomes were also grouped into five naturally occurring constructs. The 99 outcomes were sent to the original expert committee to be rated. The experts were asked to rate how critical each outcome is to the success of a VEX team on a five-point Likert scale. The Likert rating scale used to rate each outcome was as follows:

Not Performed	=	0 points
Not Critical	=	1 point
A Little Critical	=	2 points
Moderately Critical	=	3 points
Extremely Critical	=	4 points

During this round of the OTA, 17 experts rated the outcome statements. After the outcomes were rated they were rank ordered from most critical to least critical in each of the five constructs.

Reflections

The initial response rate of the experts was lower than expected. However, the 11 expert responses were within the recommended range for an OTA. The lower than expected response rate may be attributed to the OTA being conducted in the summer time when teachers are not necessarily focused on their classrooms and educational efforts. When the expert committee submitted their outcome lists, the lists contained the desired substance. As expected, many of the outcomes were repeated by multiple experts. Also, many of the outcome statements were not in the format requested (i.e., an objective statement beginning with a verb, typically used in curriculum development). Therefore, a review committee was necessary. The review committee was able to combine many of the outcomes, and reword the outcomes to be in the desired format. The decisions of the review committee were able to be made quickly because of the size of the committee. The review committee was comprised of three individuals each having their own expertise related to the VRCs. Had the review committee been as large as the expert committee, the revision process would have taken considerable more time. After consensus was reached on the outcome statements, they were grouped in five constructs by the review committee. The five constructs covered all areas of the VRCs that were submitted by the expert committee. The 99 outcomes covered a wide range of skill sets within the five constructs.

During the next round of the OTA, the experts were asked to rate each outcome according to how critical each outcome was to team success. When conducting an OTA, there were a variety of questions that could be asked of the task, or in this case, outcome statements. One of the more popular questions to ask, is how critical is the task to the job being performed. This question was chosen in order to have a rank ordered list of the outcomes. This question was also chosen because it could reliably be rated using a Likert scale. When the 99 outcomes were sent to the original expert committee, 17 coaches, mentors, and instructors responded. This was encouraging to see, and may have been due to this round being conducted during the fall while school was in session. The increase in the number of experts that responded strengthened the already robust information received in round one of the OTA. The ratings provided one of the first organized and rank ordered lists of outcomes achieved by students when participating in VRCs.

Conclusions

The outcome lists determined during the OTA exceeded the expectations of the researcher. The OTA process was natural way to ensure content validity of the outcome statements. The OTA process provided a solid foundation of outcome statements to be used in the self-efficacy survey instrument (see Appendix E). This foundation was more than sufficient to move on to milestone 2 of the research project.

Milestone 2—Develop Initial Survey Instrument

Introduction

During this milestone of the research project, the initial survey instrument was developed from the outcome statements developed through the OTA process. Statements that received a mean rating equal to or less than 2.00 in the OTA were not transformed into efficacy statements. Using this mean cutoff, 88 outcome statements were transformed into efficacy statements. An outcome statement was transformed into an efficacy statement by adding the phrase “I feel confident that I can...” at the beginning of the statement. This question was chosen from statements used in the Motivated Strategies for Learning Questionnaire (MSLQ) to ask about a student’s self-efficacy. To collect demographic data, specific questions regarding sex, grade in school, number of seasons competing, primary and secondary responsibilities on the VEX team, whether the team met as part of school or as a community team, and if the student received a grade for participating in VEX were added. After the initial instrument was developed, it was piloted with students that had previous experience in competitive robotics (i.e., FRC and VEX IQ), but not specifically in VRCs. These groups were selected because they would not take away from the intended population for the study. The purpose of the pilot study was to detect any unanticipated problems with the survey instrument. Based on the feedback received during the pilot study, changes were made to the survey instrument.

Reflections

Not including items that were rated less than 2.00 in the OTA on the initial survey instrument was the correct decision. The researcher did not want the survey instrument to be overwhelming to the participants by having too many items. Dropping the 11 items allowed the research to better meet this goal. The conversion of outcome statements to efficacy statements was a straight forward process. The statement “I feel confident that I can...” was the proper choice to add to the outcome statements. Asking students how confident they are that they can complete certain tasks focuses students on their self-efficacy. Students were not confused by the statement and felt that they could correctly assess their confidence. The changes that were made to the survey instrument based on the pilot study results improved the instrument. There were statements that confused the students. Had these statements been presented to the larger sample in the study, the results would not have been as reliable. Adding the rating scale every five statements throughout the survey instrument, instead of just at the beginning, assisted students in completing the survey quicker, since they were not constantly scrolling up and down the computer screen.

Conclusions

Competing milestone 2 developed an initial instrument that was well constructed for measuring students’ self-efficacy through the efficacy statements. Reducing the number of statements on the instrument made the instrument less overwhelming for the participants. Conducting the pilot study with students who had previous robotics experience proved to be a valuable stage in the development of the initial survey instrument.

Milestone 3—Exploratory Factor Analysis

Introduction

The survey instrument was developed using Qualtrics, an online data collection package. A video was added to the beginning of the survey to explain the directions for completing the survey. The video also explained the Letter of Information that was required to be distributed to survey participants by the Institutional Review Board (IRB). Using Qualtrics allowed the initial survey instrument to be sent to coaches, mentors, and instructors that participated in the OTA, coaches, mentors, and instructors in Utah, and other coaches, mentors, and instructors across the U.S. that volunteered to assist in the data collection process. The number of surveys collected through this process did not meet the minimum sample size necessary for completing an EFA. Therefore student participants were sought out at the 2014 VEX Robotics World Championship. A minimum rolling sample of 200 was recommended for the EFA based on the number of items on the survey instrument. There were 257 surveys completed by students. After removing 54 invalid responses, 203 surveys were analyzed in the EFA.

Reflections

The item loadings from the EFA were above acceptable levels, ranging from .403 to .920. Because the item loadings were acceptable with a sample of 203, a larger rolling sample was not necessary. Developing the survey online using Qualtrics made the data collection more manageable. Because the survey was online and not traditional pencil and paper, it could be sent to multiple recipients at the same time. The location of the recipients did not disrupt data collection either. Data were also able to be collected at a computer station while at the world championship. This eased the burden of having to solicit student participation in the research study. By adding a video to the beginning of the survey, IRB guidelines were easily met and retained. Having the rights of the participants explained by the researcher ensured that all participants were thoroughly explained their rights before participating in the research study. The video also relieved the burden of explaining the directions for the survey from the teacher. The focus statements that were added to each construct allowed for easy validation of the survey responses. Students that quickly answered questions by simple clicking on responses, and therefore incorrectly answering one or more focus statements, did not have their data included in the analysis. This allowed for a more dependable data analysis process.

Conclusions

The research process was completed in an efficient manner because the survey instrument was developed and distributed online. Creating a video to explain directions and participant rights ensured that all participants received sufficient information prior to completing the survey. The data collected was confidently and efficiently validated prior to analysis because of the focus statements built into the survey instrument.

Milestone 4—Revisions to Survey Instrument

Introduction

The EFA conducted in milestone 3 produced 94% of the item loadings above an acceptable level of .4. Acceptable item loadings ranged from .403 to .920. The acceptable items loaded on three constructs and not the five original established in milestone 1. Based on the loadings of each statement in the three constructs, mechanical outcomes and design outcomes became one construct, teaming outcomes and professional trait outcomes became one construct, and programming remained a single construct. The review committee aimed to have a minimum of five statements and a maximum of ten in each construct. Each qualified statement was analyzed by the review committee to determine if it should remain on the revised instrument or if it should be removed. The review committee kept statements in each construct that measured both entry level and advanced level outcomes for each construct. For example, in the programming construct, programming a bumper switch (PR7) is usually one of the first tasks students learn when beginning to programming. While programming automated routines to assist in driver control mode (PR8) may not be learned until a student's second or third season. The EFA results for the mechanical and design outcomes were especially interesting because outcomes that were highly related in terms of what they were asking students to perform (e.g., M8—Construct various lift systems—linear, single arm, parallel arm [4-bar], and 6-bar, versus D2—Design various lift systems—linear, single arm, parallel arm [4-bar], and 6-bar) loaded at nearly the exact weight and were ranked very close to each other. This was the case for four pairs of mechanical and design outcome statements, M8 and D2, M2 and D9, M13 and D10, M10 and D1. After combining statements, the mechanical and design construct contained eight efficacy statements, the programming construct contained nine efficacy statements, and the teaming and professional trait construct contained 10 items.

Reflections

The item loading results from the EFA were higher than expected. This gave the review committee a variety of options of items to retain. More importantly, it enabled the review committee to have an ample number of well-developed items in each construct. With the number of constructs reduced from five to three, this enabled the committee to use between eight and ten items under each construct and still keep the overall length of the survey to a manageable size. With a manageable size survey, student participants were able to complete the survey without losing focus. The researcher was extremely pleased to see related mechanical and design statements receive similar loadings in the EFA. The fact that related items loaded similarly instilled confidence in the research process being utilized.

Conclusions

The revisions implemented on the survey instrument as a result of the EFA created a strong and efficient instrument. The researcher was confident that the revised survey instrument was ready to be tested on a new sample of student participants.

Milestone 5—Conduct Confirmatory Factor Analysis

Introduction

Once the instrument was revised, the changes were implemented in Qualtrics. One focus statement was again included in each of the three constructs. The survey contained the same video used in the EFA to explain student rights and survey directions. The survey was administered to students at the 2014 VEX Robotics World

Championship. To obtain more survey responses the Qualtrics link was sent to teachers and event partners from around the country. These teachers volunteered at the world championships to assist in the research study after the world championship was finished. Event partners were selected from the list of past tournaments available online. When the survey was closed there were 141 valid surveys. Fifty-nine invalid surveys were removed prior to analysis. The CFA was conducted using maximum likelihood extraction and promax rotation. The results of the CFA indeed confirmed the factors and high item loadings of the EFA.

Reflections

The sample size of 141 met the 1:5 item to participant ratio minimum, acceptable to conduct a CFA. A rolling sample to collect additional data was not necessary. The focus statements included in the survey produced valid survey responses from the participants. The item loadings were higher than expected when calculated for each of the three constructs.

Conclusions

The item loading results from the CFA showed that the instrument developed from the OTA, pilot study, and EFA processes was constructed properly and proficiently. Once again the item loading results instilled confidence in the procedure that was followed to develop the self-efficacy survey instrument.

Milestone 6—Instrument Reliability

Introduction

Initial reliability of the instrument was calculated using Cronbach's alpha. Reliability was calculated on the instrument using all three constructs. The Cronbach's alpha reliability score for the overall instrument was .916. To further test the reliability of the instrument, Cronbach's alpha was calculated for each individual construct. The alpha reliability for programming was .957. The alpha reliability for mechanical and design was .934. The alpha reliability for the teaming and professional traits construct was .834. Reliability of the instrument was also measured using goodness of fit tests to compare the theorized model to the actual results. A correlation matrix was also developed for all three constructs.

Reflections

The initial alpha reliability of the survey instrument was high. The alpha levels calculated were well above the acceptable level for use in educational research. If items were deleted from the instrument, the reliability of the instrument would drop; with the exception of item TP7. However, if item TP7 was deleted from the survey, the reliability would only be increased by .001. This item was kept because it was both rated high in the OTA, and loaded high in both rounds of factor analysis. The reliability not becoming lower if items were to be deleted indicates that all of the items contribute valuable information to the results of the survey. The results of the goodness of fit tests were mixed. The results of the normed fit index (IFI) of .920 and root mean square residual

(RMS or RMR) of .082 are acceptable to some researchers, but are also considered slightly lower than acceptable by others. When the standardize RMR was calculated, a value of .067 was obtained, placing the RMR within the acceptable region. Other goodness of fit test results were well above the acceptable fit value. This included the comparative fit index (FCI) at .968 and the non-normed fit index (NNFI) or Tucker Lewis index (TLI) at .965. The correlation matrix results indicate that the constructs are somewhat related. The highest correlation was between the mechanical and design construct and the teaming and professional traits construct at .562. This is higher than the researcher would like, but is still within the acceptable range. The correlations are not so high as to indicate the constructs are measuring the same information, but that the constructs are obtaining separate and useful information.

Conclusions

The initial alpha reliability of the survey instrument indicates that the instrument is reliable for measuring the self-efficacy of students competing in competitive VEX robotics. In fact, the reliability is well above the acceptable level for instruments to be utilized in educational research. The goodness-of-fit test results indicate acceptable fit to the theorized model. The correlations indicate three constructs that will separately obtain valuable information to completely measure a student's self-efficacy.

Milestone 7—Instrument Bias

Introduction

Preliminary chi-square tests were conducted between males and females, and between samples with one and two seasons of competing. Due to an insufficient sample size of females, the male/female analysis was unable to be completed. Also, the frequencies of the 5-point Likert scale responses from the first and second year participants did not meet the chi square distribution recommendations of a minimum of five samples in each category being analyzed. Due to insufficient sample sizes, proper utilization of the chi square test to detect bias could not be completed.

Reflections

Although the sample sizes were not large enough, preliminary chi square analyses were run on certain groups. Based on the preliminary results, there does not appear to be bias in the instrument. However, bias does need to be fully explored with larger sample sizes. Analysis of bias may be able to be calculated with a sample size of at least 200 females and 200 participants in each of the number of seasons students compete.

Conclusion

Analysis of bias could not be fully conducted with the sample size collected in this study. It is recommended that future study be conducted with larger sample sizes acceptable for calculating chi square analysis.

Recommendations for Administering the Survey Instrument

The survey instrument developed for this research study was shown to be a valid and reliable instrument for measuring the self-efficacy of students participating in VRCs based on initial data. The survey instrument can be utilized to track a student’s level of self-efficacy throughout several years of the student competing in competitive VEX robotics. However, a baseline of a student's self-efficacy should be established before tracking the student overtime. The ideal time to establish this baseline has not been determined. Establishing the baseline may be done before the student ever participates in VEX robotics. This could lead to an inflation of the student's self-efficacy because the student may be over confident and not fully understand the magnitude of being successful in VRCs. The next possible time to establish a baseline measure would be after the student has competed in his or her first competition. Measuring the student's self-efficacy after a competition may be a more realist baseline because the student should have a better understanding of what it takes to be successful in VRCs. It seems logical to take yearly measurements after a student's state tournament (after qualification for the world championship has ended) and before or during the world championship.

The survey should continue to be administered to students as an online survey through Qualtrics. Collecting data online will allow for a diverse population from around the U.S. Collecting data from around the U.S. will allow for a more generalizable understanding of how participating in VEX robotics can increase a student's self-efficacy. Administering the instrument via Qualtrics will allow the investigator to fully explain the survey directions and participant rights through an instructive video.

To gather larger samples from all 50 United States, it may be beneficial to partner with the Robotics Education and Competition Foundation (RECF). A partnership with the RECF might allow the researcher to have a readily available sample to collect data. Having a more consistent source of participants will help create a more efficient data collection process.

Limitations and Constraints of the Survey Instrument

Selection of the students for the development of the survey instrument was limit to specific criteria. Therefore, future use of the survey instrument should be limited to students that meet the same specific criteria. The specific criteria are as follows

- middle and high school students
- students from the United States
- students that participate in competitive VEX robotics

The survey instrument was designed to measure the self-efficacy of students and result interpretations should be limited to self-efficacy. Other cognitive traits e.g., motivation and self-regulated learning should not be measured or inferred from the results of this survey instrument. In summary, the utilization of this instrument is limited to measuring the self-efficacy of middle and high school students that participate in competitive VEX robotics.

Recommendations for Further Study

The research process of this study produced a valid and reliable instrument to measure the self-efficacy of students participating in VRCs based on initial data. The survey instrument should now be used in a longitudinal study. A longitudinal study could explore:

- How the self-efficacy of student’s changes overtime with participation in

VRCs.

- How self-efficacy changes based on formal or informal meeting environments for VEX teams.
- How the self-efficacy of females changes versus males.
- If participation in VRCs influences a student's decision to attend college or post-secondary education.
- How participation in VRCs affects a student's choice in a college major.
- If there is any impact of VRCs on completion rates of STEM majors in college.

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.

Further study needs to be conducted to fully evaluate if the instrument is biased towards certain groups, and to confirm the instrument alpha reliability estimates. Larger sample sizes of the groups to be explored need to be collected. Various groups to be explored could be male versus female, first year verses second year versus third year etc., and various minority students. In order to compare data on minority students, a question regarding ethnicity would need to be added to the survey. Knowing a student's ethnicity was not necessary to develop a valid and reliable instrument, and therefore was not included in this research study.

Similar instruments could be developed for other robotics competitions, because there are numerous robotics competitions available throughout the U.S. These competitions could include but are in no way limited to:

- VEX IQ
- SeaPerch
- FIRST Robotics Competition
- FIRST Tech Challenge
- FIRST Lego League
- BEST

It is important to remember that each robotics competition has unique benefits for the students participating. To look at one competition and say it is the best would be unfair without fully investigating all of the potential options.

Conclusion

The overall process utilized in this research study produced a survey instrument that is to be highly reliable and valid based on initial data. The survey instrument should now be utilized to conduct further research on the outcomes of student participation in competitive VEX robotics. 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 student participation in competitive VEX robotics. The VEX community can use this information to determine the future direction of VEX Robotics Competitions. Financial supporters and school administrators can also use the information to make informed decisions regarding their future support of competitive VEX robotics.

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APPENDICES

Appendix A

Initial E-mail Sent to Expert Committee

Hello VEX Delphi participants,

Most of you I met at the recent VEX World Championship in Anaheim, California, and received your approval to include you as experts in the Delphi Study we are conducting to determine student outcomes as a result of participating in VEX robotics. Others I talked to more recently and gained your approval over the phone. I am very pleased to have such an experienced and diverse panel.

For the first round, I would like you to list the outcomes you believe students gain through participating in VEX robotics. List outcomes as task statements, preferably starting with a verb. Both hard and soft skills should be listed. In addition outcomes may reflect cognitive, psychomotor, or affective domains of learning.

For example:
-- Program analog inputs for autonomous operation
-- Calculate gear ratios
-- Present robot designs to judges
-- Maintain a design notebook

The difficult aspect of identifying outcomes is determining the size of the outcome. An outcome written too general will not enable us to develop a self-efficacy instrument for VEX robotics participants, the next step in our research project.

For example:
-- Program a VEX robot—too general
-- Program a potentiometer for autonomous operation—perhaps the right size chunk
-- Work in a team—too general
-- Learn to resolve team conflicts—perhaps the right size chunk

We will exercise our editorial rights to size and combine outcomes of similar meaning.

As I mentioned to everyone when asking if they would be willing to participate as an expert in the Delphi study, the first round will represent the greatest time commitment. Additional rounds will list the outcomes previously identified and ask you to rate each outcome on a seven point Likert scale (e.g., disagree, agree, strongly agree, etc.). We will also use SurveyMonkey® to administer addition rounds. This should make the rounds designed to gain consensus among the panel of experts less time consuming and more efficient. Please persevere through to the second round.

For this round, please reply to this email with an attached list of outcomes you believe students who participate in VEX robotic competitions gain over the course of their VEX experience. Include your name on your list. We would like to receive your list of student outcomes within two weeks of receiving this email.

If you have any questions, please feel free to contact me at your convenience.

Thank you again for your time and effort, Gary

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Appendix B

Participants on the Expert Committee

Table B1

List of Coaches, Mentors, and Instructors that Served on the Expert Committee in the Occupational and Task Analysis of VEX Robotics Competitions

Name	State
Kevin Bradley	California
Lance Rush	California
Nancy McIntyre	California
Randy Moehnke	California
Liz Rayment	Colorado
Jodie Marshall	Georgia
Kevin Lupton	Idaho
Doug Tipton	Indiana
Jed Wandland	Indiana
David Franc	Maryland
Betsy Lamb	Michigan
Marc Taylor	Michigan
Jeremy Weimer	Nebraska
Joe Pouliot	New Hampshire
Andrew Lynch	Texas
Stephen Williams	Utah
Bill Wiley	Virginia
Rick Tyler	Washington
Greg Cheslock	Wisconsin

Appendix C

Participants on the Review Committee

Table C1

List of Content Experts Who Served on the Review Committee in the Occupational and Task Analysis of VEX Robotics Competitions

Name	Expertise
Dr. Gary A Stewardson, PhD (Mechanical and Design)	25 years as a professor of Technology and Engineering Education (TEE) 30 years of teaching and conducting Occupational and Task Analyses 6 years as a VRC mentor and coach
Mr. Raymond Boyles, MS (Programming)	B.S. in Information Technology 20 plus years of computer programming 3 years as Utah VRC Head Referee Computer programming curriculum developer
Mr. Trevor P. Robinson, MS (General Competitive Robotics)	15 plus years of competitive robotics experience 5 years as a VRC coach Educational robotics curriculum developer

Note. VRC=VEX Robotics Competition.

Appendix D

Data Frequencies of Participants in the Exploratory Factor Analysis

Table D1

Frequency of Students for the U.S. Who Participated in the EFA

State	*n*	Percent
AK	3	1.5
AZ	1	0.5
CA	25	12.3
CO	3	1.5
CT	10	4.9
FL	5	2.5
GA	9	4.4
IA	1	0.5
ID	4	2.0
IL	5	2.5
IN	13	6.4
MA	5	2.5
MD	4	2.0
MI	2	1.0
NE	5	2.5
NH	12	5.9
NJ	1	0.5
NY	6	3.0
OH	12	5.9
OK	3	1.5
OR	2	1.0
PA	5	2.5
SD	2	1.0
TX	9	4.4
UT	43	21.2
VA	2	1.0
WA	6	3.0
WI	4	2.0
Not listed	1	0.5
Total	203	100.0

Table D2

Frequency of Males and Females Who Participated in the EFA

Gender	*N*	Percent
Male	165	81.3
Female	38	18.7
Total	203	100.0

Table D3

Frequency of Participants in the EFA by Grade Level

Grade	*n*	Percent
6th grade	2	1.0
7th grade	8	3.9
8th grade	13	6.4
9th grade	33	16.3
10th grade	49	24.1
11th grade	51	25.1
12th grade	47	23.2
Total	203	100.0

Table D4

Frequency of Participants in the EFA by Number of Seasons Participated in Competitive VEX Robotics

Number of seasons participated	*n*	Percent
1 or less	93	45.8
2	52	25.6
3	35	17.2
4	14	6.9
5	9	4.4
6	0	0.0
7	0	0.0
8 or more	0	0.0
Total	203	100.0

Table D5

Frequency of Participants in the EFA by Primary and Secondary Responsibilities on Team

Responsibility	Primary	Percent	Secondary	Percent
Builder	70	34.5	51	25.1
Designer	25	12.3	46	22.7
Driver	22	10.8	30	14.8
Programmer	32	15.8	30	14.8
Team Leader	29	14.3	8	3.9
Team Promotion	9	4.4	12	5.9
Fundraising	2	1.0	7	3.4
Other	14	6.9	19	9.4
Total	203	100.0	203	100.0

Table D6

Frequency of Participants in the EFA by Team Affiliation

Team affiliation	*n*	Percent
School team	174	85.7
Community team	22	10.8
4-H	5	2.5
Scouting (e.g., Boy Scouts or Girl Scouts)	2	1.0
Total	203	100.0

Table D7

Frequency of Participants in the EFA by Formal and Informal Classroom Setting

Classroom setting	*n*	Percent
Formal	46	22.7
Informal	128	63.1
Nonschool team	29	14.3
Total	174	85.7

Appendix E

Self-Confidence Survey for VEX Robotics Participants

The survey instrument presented below is a print version. The actual survey instrument was delivered online utilizing Qualtrics: Online Survey Solutions. By collecting data online the three constructs were randomly presented to the participants. Some students would receive the programming statements first, while others may have received the mechanical and design statements first. Also, within each construct, the efficacy statements were presented at random.

Self-Confidence Survey for VEX Robotics Participants © 2014

Trevor Robinson, MS and Dr. Gary Stewardson, PhD

Directions: Answer the following questions about yourself. The first two questions, name and team number, will be used to determine the history of you completing the survey. Your name and team number will be removed and replaced with an identifying code to keep your responses confidential.

1. Please write your name: Last name, First name (for example, Smith, John).

   ____

2. What is your team number?

   ____

3. Are you a male or female?
   - ❍ Male (boy)
   - ❍ Female (girl)
4. During this year's VEX robotics season, what grade in school were you in?
   - ❍ 5th grade or younger
   - ❍ 6th grade
   - ❍ 7th grade
   - ❍ 8th grade
   - ❍ 9th grade
   - ❍ 10th grade
   - ❍ 11th grade
   - ❍ 12th grade
   - ❍ Post secondary or higher

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

5. How many seasons have you been competing in VEX Robotics Competitions?
   - ❍ 1 or less
   - ❍ 2
   - ❍ 3
   - ❍ 4
   - ❍ 5
   - ❍ 6
   - ❍ 7
   - ❍ 8 or more
6. What is your primary responsibility on your VEX team, your most important role? (Please check only one.)
   - ❍ Builder
   - ❍ Designer
   - ❍ Driver
   - ❍ Programmer
   - ❍ Team Leader
   - ❍ Team Promotion
   - ❍ Fundraising
   - ❍ Other
7. What is your secondary responsibility on your VEX team, your second most important roll? (Please check only one.)
   - ❍ Builder
   - ❍ Designer
   - ❍ Driver
   - ❍ Programmer
   - ❍ Team Leader
   - ❍ Team Promotion
   - ❍ Fundraising
   - ❍ Other

8. Select the choice that best describes your team affiliation. ❍ School team ❍ Community team ❍ 4-H ❍ Scouting (e.g. Boy Scouts or Girl Scouts)	
9. If you selected that you are on a school team; does your team primarily meet as a scheduled class in which you receive a grade and credit? ❍ Yes ❍ No	
The following question(s) ask you about your future college plans.	
10. At this point do you plan on continuing your education after high school? ❍ Yes ❍ No	
11. If you indicated that you plan on continuing your education after high school, what do you plan on studying? At this time, if you are unsure of what you plan to study, write "unsure." ____	

Directions: In the following 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 in your confidence to complete each task stated. 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	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
I feel confident that I can design and construct a structurally sound and stable robot—chassis, lift, end-effectors	❍	❍	❍	❍	❍
I feel confident that I can explain the design tradeoffs between various lift systems—linear, single arm, parallel arm (4-bar), or six-bar	❍	❍	❍	❍	❍
I feel confident that I can design and construct various lift systems—linear, single arm, parallel arm (4-bar), and six-bar	❍	❍	❍	❍	❍
I feel confident that I can design and construct various end-effectors (for example, conveyor, scoop, rollers, and gripper)	❍	❍	❍	❍	❍
I feel confident that I can calculate the ratios for simple and compound drive trains—gears; chain & sprocket	❍	❍	❍	❍	❍
I feel confident that I can design and construct a drivetrain that increases rpm or torque	❍	❍	❍	❍	❍
I feel confident that I can explain the design tradeoffs between regular and high strength VEX components (for example, motors, gears, and chain & sprocket)	❍	❍	❍	❍	❍
I feel confident that I can work through several design iterations of a robot	❍	❍	❍	❍	❍
To demonstrate you are still focused on the survey, select the "strongly agree" circle	❍	❍	❍	❍	❍

Programming Outcomes	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
I feel confident that I can program conditional statements (for example, if statements and while loops)	❍	❍	❍	❍	❍
I feel confident that I can update the master code (firmware) on the Cortex microcontroller and joystick	❍	❍	❍	❍	❍
I feel confident that I can troubleshoot programming error messages	❍	❍	❍	❍	❍
I feel confident that I can install and write a program to utilize an optical shaft encoder	❍	❍	❍	❍	❍
I feel confident that I can install and write a program to utilize a potentiometer	❍	❍	❍	❍	❍
I feel confident that I can program user functions to accept and return values	❍	❍	❍	❍	❍
I feel confident that I can install and write a program to utilize a bumper/limit switch	❍	❍	❍	❍	❍
I feel confident that I can program automated routines to assist in driver control mode	❍	❍	❍	❍	❍
I feel confident that I can program a PID control loop to change outputs based on an input(s)	❍	❍	❍	❍	❍
To demonstrate you are still focused on the survey, select the "Strongly disagree" circle	❍	❍	❍	❍	❍
Teaming and Professional Traits Outcomes	**Strongly Disagree (1)**	**Disagree (2)**	**Neither Agree nor Disagree (3)**	**Agree (4)**	**Strongly Agree (5)**
I feel confident that I can collaborate with other team members to accomplish tasks	❍	❍	❍	❍	❍
I feel confident that I can resolve conflicts among team members	❍	❍	❍	❍	❍
I feel confident that I can approach and work with other alliances	❍	❍	❍	❍	❍
I feel confident that I can make decisions for the good of the group versus personal gain	❍	❍	❍	❍	❍
I feel confident that I can receive constructive feedback from others without taking it personally (for example, team members, alliances, and judges)	❍	❍	❍	❍	❍
I feel confident that I can structure my team to best use individual strengths and mitigate weaknesses	❍	❍	❍	❍	❍
I feel confident that I can provide constructive feedback about other's designs and strategies	❍	❍	❍	❍	❍
I feel confident that I can manage time to complete qualifying matches, skill challenges, and judging	❍	❍	❍	❍	❍
I feel confident that I can follow assigned tasks and responsibilities (follower)	❍	❍	❍	❍	❍
I feel confident that I can maintain a professional behavior when negative and positive circumstances occur	❍	❍	❍	❍	❍
To demonstrate you are still focused on the survey, select the "Neither Agree or Disagree" circle	❍	❍	❍	❍	❍

Appendix F

Data Frequencies of Participants in the Confirmatory Factor Analysis

Table F1

Frequency of Students per U.S. State Who Participated in the CFA

State	*n*	Percentage
AL	7	5.0
AR	1	0.7
CA	9	6.4
CO	7	5.0
CT	20	14.2
FL	1	0.7
GA	6	4.3
ID	9	6.4
IN	2	1.4
MD	1	0.7
MO	11	7.8
NE	3	2.1
NJ	10	7.1
NY	1	0.7
OH	10	7.1
OR	1	0.7
PA	4	2.8
TN	5	3.5
TX	6	4.3
UT	11	7.8
VA	7	5.0
WA	5	3.5
Not listed	4	2.8
Total	141	100.0

Table F2

Frequency of Males and Females Who Participated in the CFA

Gender	*n*	Percent
Male	115	81.6
Female	26	18.4
Total	141	100.0

Table F3

Frequency of Participants in the CFA by Grade Level

Grade	*n*	Percent
6th grade	11	7.8
7th grade	24	17.0
8th grade	27	19.1
9th grade	18	12.8
10th grade	15	10.6
11th grade	30	21.3
12th grade	16	11.3
Total	141	100.0

Table F4

Frequency of Participants in the CFA by Number of Seasons Participated in Competitive VEX Robotics

No. of seasons participated	*n*	Percent
1 or less	59	41.8
2	56	39.7
3	17	12.1
4	5	3.5
5	1	0.7
6	1	0.7
7	0	0.0
8 or more	2	1.4
Total	141	100.0

Table F5

Frequency of Participants in the EFA by Primary and Secondary Responsibilities on Team

Responsibility	Primary	Percent	Secondary	Percent
Builder	41	29.1	37	26.2
Designer	11	7.8	32	22.7
Driver	15	10.6	20	14.2
Programmer	27	19.1	23	16.3
Team Leader	24	17.0	8	5.7
Team Promotion	4	2.8	5	3.5
Fundraising	0	0.0	2	1.4
Other	19	13.5	14	9.9
Total	141	100.0	141	100.0

Table F6

Frequency of Participants in the CFA by Team Affiliation

Team affiliation	*n*	Percent
School team	132	93.6
Community team	8	5.7
4-H	1	0.7
Scouting (e.g., Boy Scouts or Girl Scouts)	0	0.0
Total	141	100.0

Table F7

Frequency of Participants in the CFA by Formal and Informal Classroom Setting

Classroom setting	*n*	Percent
Formal	47	33.3
Informal	85	6.3
Nonschool team	9	6.4
Total	141	100.0

Appendix G

Letter of Information

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

Full AAHRPP Accreditation

USU IRB Approval: March 25, 2014
Approval Terminates: 03/24/2015
Protocol #5812
IRB Passwowrd Protected per IRB Administrator

LETTER OF INFORMATION

The Development of an Instrument to Measure the Self-efficacy of Students Participating in the VEX Robotics Competition

Introduction/ Purpose Dr. Gary A. Stewardson, PhD and Trevor P. Robinson, MS (current doctoral candidate) in the Department of Agricultural Systems 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 the VEX Robotics Competitions (VRC). You have been asked to take part because of your participation in competitive VEX Robotics. There will be approximately 400 total participants in this research.

Procedures If you agree to be in this research study, you will be asked to complete a onetime online survey that should take between 40-50 minutes to complete if in the exploratory round, and 20-30 minutes to complete if in the confirmatory round. The survey will ask you to rate how confident you are that you would be able to perform certain tasks related to the VEX Robotics Competition.

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 Trevor Robinson 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.

Payment/Compensation There will be no compensation given to you for your participation in this research study.

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, simply discontinue answering any survey questions. You may be withdrawn from this study without your consent by the investigator if your survey is incomplete or missing data.

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. 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

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

Full AAHRPP Accreditation

USU IRB Approval: March 25, 2014
Approval Terminates: 03/24/2015
Protocol #5812
IRB Passwowrd Protected per IRB Administrator

LETTER OF INFORMATION

The Development of an Instrument to Measure the Self-efficacy of Students Participating in the VEX Robotics Competition

information will be stored separately from data and will be kept until the conclusion of the study on August 15, 2014.

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 Administrator 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)

Dr. Gary A. Stewardson, PhD	Trevor P. Robinson
Principal Investigator	Student Researcher
(435-797-1802)	(740-361-7763)
(gary.stewardson@usu.edu)	(trevor.robinson@aggiemail.usu.edu)

CURRICULUM VITAE

TREVOR P. ROBINSON

Utah State University (USU)
Department of Agricultural Systems Technology and Education (ASTE)
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EDUCATION:

2014 ***Doctor of Philosophy***. Utah State University (USU), Logan, Utah 84322
Major: Education—Curriculum and Instruction
Emphasis: Technology and Engineering Education
Specialization: Robotics Curriculum Development, Robotics Competitions
Dissertation: *The Development of an Instrument to Measure the Self-efficacy of Students Participating in VEX Robotics Competitions.*

2010 ***Master of Science***. Utah State University, Logan, Utah 84332
Major: Engineering and Technology Education
Project: *Development of a Secondary School Curriculum for Competitive VEX Robotic Teams Meeting in Formal and Informal Learning Environments.*

2009 ***Bachelor of Science***. Ohio Northern University (ONU), Ada, Ohio 45810
Major: Technology Education

Educational Work Experience:

2009-Current **Graduate Teaching Assistant/Instructor**, USU, Logan, UT 84322
Responsibilities included teaching undergraduate courses in computer aided drafting and design utilizing Autodesk AutoCAD, Autodesk Inventor and Autodesk Revit. Head instructor for the Design Academy, an after school robotics team for middle and high school students utilizing the VEX Robotics Design System. Team captain of the Utah State University VEX Robotics Team. Managed and maintained the Dimension SST 1200 3-D printer. Developed a proposal to purchase a laser engraver, then

installed, managed, and maintained the Universal Laser Systems VLS4.6 laser engraver. Webmaster for etcurr.com, a site dedicated to disseminating engineering and technology curricula. Produced videos for departmental project promotion.

2009 **Substitute Teacher**
Ada High School, Ada, Ohio 45810
Allen East High School, Harrod, Ohio 45850
Spencerville High School, Spencerville, Ohio 45877

2009 **Student Teacher**, Ada High School, Ada, Ohio 45810.
Responsibilities included teaching courses in computer applications, computer aided drafting, and graphic design. Non-teaching responsibilities included hallway monitoring, lunch room monitoring, and study hall monitoring.

RELATED WORK EXPERIENCE:

2008 **Robotics Camp Counselor/Instructor**, ONU Summer Honors Institute, Ada, Ohio, 45810.
Responsibilities included instructing high school students in building and programming robots for competition.

2007-2008 **Senior Resident Assistant**, ONU, Ada, Ohio 45810.
Responsibilities included leading programs for residents of the university and helped them with any problems during the year. Supervised Resident Assistants in their programming efforts. In charge of running the front desk and hiring students to work at the desk.

2007 **Robotics Camp Counselor/Instructor**, ONU Summer Honors Institute, Ada, Ohio, 45810.
Responsibilities included instructing high school students in building and programming robots for competition.

2006-2007 **Resident Assistant**, ONU, Ada, Ohio 45810.
Responsibilities included leading programs for residents of the university and helped them with any problems during the year.

2003-2006 **Boy Scout Camp Counselor**, Heart of Ohio Council, Ashland, Ohio 44805. Responsibilities included teaching younger scouts working on merit badges: rifle shooting, archery, swimming, lifesaving, canoeing, small boat sailing, rowing, and motor boating.

PROFESSIONAL AWARDS/RECOGNITION:

2014	Robins Award Finalist for Graduate Teaching Assistant of the Year, Utah State University
2014	North American Colleges and Teachers of Agriculture Graduate Student Teaching Award of Merit
2013-2014	Utah NASA Space Grant Consortium Fellow
2013	College of Agriculture and Applied Sciences Graduate Student Teacher of the Year, Utah State University
2012-2013	27th People's Attitude Towards Technology Conference, Christchurch, New Zealand, December 2-7, 2013. Participant sponsored by the Technical Foundation of America, *Technology Education for the 21st Century Initiatives*.
2010-2013	Rocky Mountain NASA Space Grant Consortium Fellow
2009	Outstanding Senior in Technology Education, Ohio Northern University

PROFESSIONAL SERVICE ACTIVITIES:

2014	Robotics Challenge event author for the national conference of the Technology and Engineering Education Collegiate Association (TEECA)
2010-2013	Assisted with organization and running of the Utah Technology Student Association State VEX Tournament for middle school and high school
2008-2009	President for the Ohio Northern student chapter of the Society of Manufacturing Engineers (SME)
2008-2009	President for the Ohio Northern student chapter of The Association of Technology, Management, and Applied Engineering (ATMAE), formally NAIT
2007-2009	Secretary for the Gamma Lambda Chapter of Epsilon Pi Tau (EPT) at Ohio Northern University

PROFESSIONAL/HONORARY ORGANIZATIONS:

International Technology and Engineering Educators Association (ITEEA)

Epsilon Pi Tau, Technology Professionals Honorary Fraternity, Gamma Lambda Chapter (ONU)

Kappa Delta Pi, International Honor Society in Education (ONU)

Omicron Delta Kappa, National Leadership Honor Society (ONU)

Mortar Board, National College Senior Honor Society (ONU)

Society of Manufacturing Engineers (SME)

Association of Technology, Management, and Applied Engineering (ATMAE)

REFEREED PRESENTATIONS WITH PAPER:

Robinson, T. P. (2013). *Investigating the Self-Efficacy of Students Participating in VEX Robotics Competitions*. Conference Proceedings of the 27th People's Attitude Towards Technology Conference, Christchurch, New Zealand, December 2-7, 2013. Paper can be retrieved from: http://tinyurl.com/lo2q7o4.

Robinson, T. P., Stienecker, A. (2008). *2D Edge Detection Through Manipulation of Non-cooperative Featureless Payloads*. International Association of Journals and Conferences-International Journal of Modern Engineering Conference, Nashville, Tennessee, November 17-19, 2008. Paper can be retrieved from: http://tinyurl.com/ltzv3nf.

Rankin, J., Robinson, T., Vorhees, D., Kinney J., Frank, H., Miller, C., Wambo, R. (2008) *An Experiment in Vision Driven Robotic Table Hockey*. Proceedings of the 2008 ASEE North Central Section Conference, Wright State University, Dayton, Ohio, March 28-29, 2008. Paper can be retrieved from: http://tinyurl.com/nhf8nh5.

REFEREED PUBLICATIONS:

Robinson, T. P., & Stewardson, G. A. (2012). *Exciting students through VEX robotic competitions.* Technology and Engineering Teacher, 72(2) 15-21. Paper can be retrieved from: http://tinyurl.com/khpms6m.

Robinson, T. P. (2014). *The Development of Judging Rubrics for Utah VEX Robotics Competitions*. Proceedings of the 20th Annual Fellowship Symposium. Sponsored by the Utah NASA Space Grant Consortium, Hill Aerospace Museum, Roy, Utah, May 6, 2014. (invited). Paper can be retrieved from: http://tinyurl.com/ljtghpj..

Robinson, T. P. (2013). *Longitudinal Growth of VEX Robotics Competitions in the Rocky Mountain Region.* Proceedings of the 19th Annual Fellowship Symposium. Sponsored by the Utah NASA Space Grant Consortium, Salt Lake Community College, Salt Lake City, Utah, May 6, 2013. (invited). Paper can be retrieved from: http://tinyurl.com/ojqd2g8.

Robinson, T. P. (2012). *The Growth of VEX Robotics Competitions in the Rocky Mountain Region.* Proceedings of the 18th Annual Fellowship Symposium. Sponsored by the Rocky Mountain NASA Space Grant Consortium, Utah State University, Logan, Utah, May 9, 2012. (invited). Paper can be retrieved from: http://tinyurl.com/l5tsrs2.

Robinson, T. P. (2011). *Implementing VEX Robotic Competitions in the Rocky Mountain Region.* Proceedings of the 17th Annual Fellowship Symposium. Sponsored by the Rocky Mountain NASA Space Grant Consortium, Utah State University, Logan, Utah, May 11, 2011. (invited).

PROFESSIONAL PRESENTATIONS:

Robinson, T.P. & Stewardson, G. (2014). *Establishing VEX Robotics through Partnerships.* ITEEA Interest Session, 76th Annual International Technology and Engineering Educators Association Conference, Orlando, Florida, March 27-29, 2014.

Stewardson, G. & Robinson, T.P. (2014). *Outcomes of Participation in VEX Robotics Competitions*. Council on Technology and Engineering Teacher Education special interest session, 76th Annual International Technology and Engineering Educators Association Conference, Orlando, Florida, March 27-29, 2014.

Robinson T.P. & Stewardson G. (2014). *VEX Robotics: How Utah is Leading the Way.* Utah Association for Career and Technical Education Annual Conference, Westlake High School, Saratoga Springs, Utah, January 31- February 1, 2014.

Robinson, T. (2011). *VEX Robotics Demonstration*. TSA Fall Leadership Conference, Jordan Applied Technology Center, West Jordan, Utah, October 15, 2011.

Stewardson, G. & Robinson T. (2011). *Utah State University Curriculum resources: Robotics, Energy, and Manufacturing*. Utah Technology and Engineering Summer Conference, Orem High School, Orem, Utah, June 15-16, 2011.

Stewardson, G. & Robinson, T. (2011). *Exciting the Next Generation through Robotic Competitions*. ITEA Interest Session, 73rd Annual International Technology and Engineering Educators Association Conference, Minneapolis, Minnesota, March 24-26, 2011.

Robinson, T. & Helm, B. (2010). *Hands on VEX Demonstration*. TSA Fall Leadership Conference, Jordan Applied Technology Center, West Jordan, Utah, October 9, 2010.

Robinson, T. & Miller, C. (2008). *Scholarship Fundraising for the Department of Technological Studies at Ohio Northern University*. Society of Manufacturing Engineers Annual Meeting, Detroit, Michigan, June 2008.