RELATIONSHIPS BETWEEN F.I.R.S.T. ROBOTICS PARTICIPANTS' ROLES AND THEIR EDUCATIONAL AND DEGREE CHOICES

by

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The following individuals read and discussed the thesis submitted by student Christine T. Chang, and they evaluated her presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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ABSTRACT

The annual robotics competition that is held by the non-profit organization For Inspiration and Recognition of Science and Technology (better known as FIRST) implicitly requires that the multifaceted teams subdivide in order to ensure that sufficient team resources are committed to all areas of the competition. The self-stated goal of FIRST is to inspire students to pursue careers in science, technology, engineering, and mathematics (STEM) fields. This study examines the relationship between FIRST participants' specific roles on their teams and their subsequent academic and career pursuits. Study participants ($N = 174$) consisting of FIRST Robotics Competition alumni responded to an online survey that asked both Likert-type scale and open-ended questions. Chi-square analysis of the survey results showed statistically significant relationships between participants' majors and their involvement in robot design ($p < .005$), robot build ($p < .003$), and activity documentation ($p < .022$). Chi-square analysis also showed statistically significant relationships between participants who were currently working in a STEM field and their participation in robot build ($p < .002$), award documentation ($p < .026$), and community outreach ($p < .040$). Analysis also compared participants' gender to involvement in particular team roles, and showed some statistically significant results. Implications and suggestions for future research are discussed, and include refining the team structure as well as recruiting more female mentors.

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CHAPTER ONE: INTRODUCTION

Statement of the Question

Robotics competitions are becoming increasingly popular with K-12 students (Johnson & Londt, 2010). One particular competition, the FIRST (For Inspiration and Recognition of Science and Technology) Robotics Competition, or FRC, was created to inspire students to pursue education and careers in science, technology, engineering, and mathematics (STEM) (FIRST, 2012). Multiple studies (Boyer, 2011; Melchior, Cohen, Cutter, & Leavitt, 2005; Welsh & Huffman, 2011) have determined that students who participate in FIRST Robotics are indeed more interested in STEM, and are likely to pursue further education in STEM areas, leading to careers in those fields. But a FIRST Robotics team is multi-faceted, requiring sub-teams for tasks such as designing, building, wiring, programming, animation, outreach, fundraising, recruitment, and real-time competition (FIRST, 2012; Oppliger, 2001). The sub-team structure led me to ask the question, what impact does the role that a student assumes on the team have on the participant's career path? For example, is it possible that a team programmer is more likely to pursue a computer science degree in college? Perhaps she was already interested in programming languages before joining her FIRST team, but participation in FRC reinforced her interest, and informed and guided her degree path.

The studies performed by Boyer (2011) and Melchior et al. (2005) provide a wealth of information on educational and career outcomes from a large sample of the

FIRST Robotics alumni population. But details are missing regarding the roles and specific paths of those alumni. I will attempt to answer the question, “Is a student’s role on a FIRST Robotics team related to his or her choices in educational pursuits or career paths?”

Significance

The results of this research could inform several lines of decision-making. First, if the motivation for choosing certain roles is known, then FIRST teams could improve their recruiting efforts and team effectiveness based on individuals’ motivation. By understanding what roles influence students to become involved, team recruiters can utilize those interests to increase membership, and align roles on the FIRST team with interests and motivation of potential participants.

Second, FIRST Robotics Competition (FRC) teams can build more support for roles that have greater interest. For example, if the role of creating the robot animation shows high student interest, teams can recruit their mentorship base for that area. Conversely, if an essential team role lacks interest, teams can also investigate changing their recruitment, organization, or mentorship accordingly.

Third, it might be important for participants to be exposed to multiple roles on the team. Experience in any particular team role has the potential to discourage a student from pursuing future STEM study altogether, or, conversely, to inspire a student to pursue a path he or she would not otherwise have considered. If team members are required to participate in a variety of roles, the likelihood of finding the right niche is much higher than if the students are not given any guidance regarding their roles on the team.

Fourth, I anticipate that some results of my research could be translated to student activities other than FIRST Robotics Competitions, for example classroom projects and other extracurricular activities. Prior research (Berk & Goebel, 1987; Copeland, Gillespie, James, Turner, & Williams, 2009; Kahler & Valentine, 2011) suggests that extracurricular activities during high school contribute to subsequent educational and career pursuits. The results of this study could further our understanding of how pre-college activities are related to interests and future career paths, more specifically those related to STEM.

Hypothesis

Given the question, “Is a student’s role on a FIRST Robotics team related to his or her choices in educational pursuits or career paths?” I hypothesized that a student’s role on a FIRST team was indeed related to what direction he or she took in future studies and career. I speculate that a positive or a negative experience in a FIRST team role provides information for making decisions about a college major, an internship opportunity, or a career. Additionally, prior experience in any specific area on a FIRST team spurs interest in related opportunities, and provides a sense of confidence surrounding that role and the associated skills and knowledge, thus heightening the likelihood that a former FIRST participant will pursue a related career trajectory.

I also hypothesized that my study data could reveal that FIRST alumni chose their roles based on interests they had prior to joining the team. Some students may join an FRC team for social reasons, while many students may already show interest in and aptitude for STEM content areas (Welsh & Huffman, 2011). I expected that these variations must have an effect on how each student chooses a role on the team.

Definitions of Terms

FIRST: For Inspiration and Recognition of Science and Technology, a non-profit organization.

FRC: FIRST Robotics Competition.

STEM: Science, Technology, Engineering, and Mathematics.

Alumni: Those who have participated in the FIRST Robotics Competition as a high school student.

FLL: FIRST LEGO League.

CHAPTER TWO: LITERATURE REVIEW

What is the FIRST Robotics Competition?

The FIRST organization was founded in 1989 to inspire students in the areas of science and technology (FIRST, 2012). The FIRST Robotics Competition, the initial competition designed by the FIRST organization, is intended for students in 9th through 12th grades, and provides an opportunity for hands-on engineering experience, contact with engineer mentors, and the motivation of a competition (Rudat, 2002). Each year a new game is devised by FIRST, and each team receives a minimal kit of parts that they may use as a starting point for building their competition robot (FIRST, 2012). As Oppliger (2001) explains, the season can be broken down into pre-build, build, competition, and post-competition phases. During the pre-build phase, the team is organized, roles are decided, and funds are raised. The build phase lasts 6 weeks during January and February, and is the time during which the team must design and build their 2.5’ x 3’ x 5’ robot. The competition phase is during March and April, with the World Championship taking place the final weekend of April. In the post-competition phase, the team reviews the recent events and prepares for next season.

Who Is the FIRST Population?

FIRST Robotics Competition Participants

The students who join FIRST Robotics teams are largely academic achievers (Boyer, 2011; Hurner, 2009; Melchior et al., 2005; Rudat, 2002; Welsh & Huffman, 2011). There are differing reasons why they choose to join the team: some are encouraged by scientifically-minded parents (Hurner, 2009; Rudat, 2002), while others are drawn to the glamour of robotics and the hands-on experiences (Melchior et al., 2005). Some students have been part of the FIRST “family” from early on, as FIRST LEGO League (FLL) participants as young as nine years old (McIntyre, 2012). FRC students are predominantly male (Boyer, 2011), and 99% of one survey sample graduated from high school, with 89% going on to college (Melchior et al., 2005). Compared to a national graduation rate of 72-75.5% (Layton, 2012), these numbers clearly show an academically advanced group of male students.

What Does the Population of U.S. College Graduates Look Like?

As a point of reference, per the National Center for Education Statistics (NCES) (2010a), for academic year 2010-11, 1,650,014 Bachelor’s degrees were conferred. Of those degrees, fewer than 1% were in mathematics and statistics. This compares to 6.8% in engineering and computer sciences, 6.6% in the sciences, and 21.6% in business, marketing, and related services (see Figure 1).

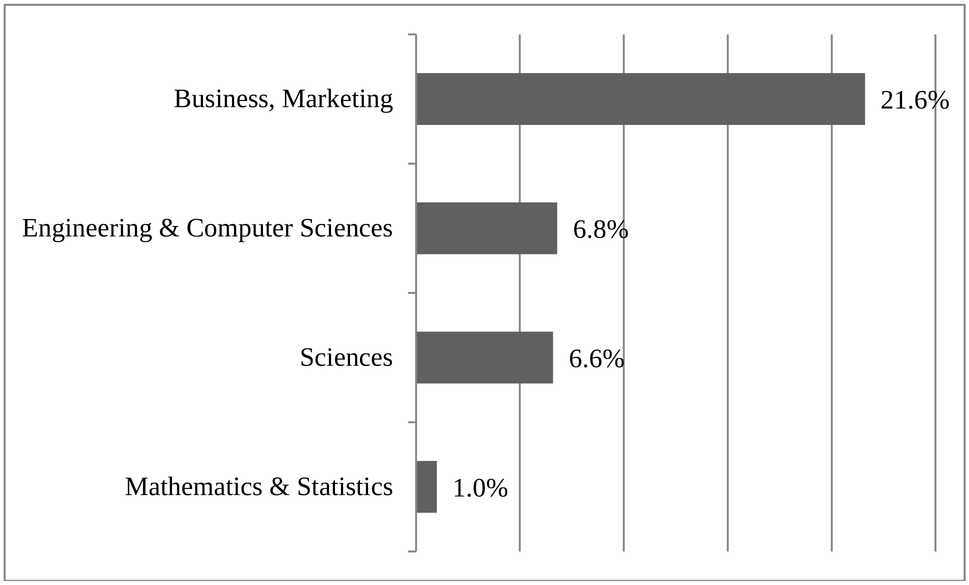

Figure 1 Percentage of Total U.S. Undergraduates in Major Areas (National Center for Education Statistics, 2010a)

Additionally, Fall 2009 undergraduate enrollment for both part-time and full-time students in the U.S. was 10,325,646 for women and 7,778,470 for men (NCES 2010b), which translates to 57% women undergraduates and 43% men undergraduates. Yet according to the National Science Foundation (2011), in 2008, women accounted for only 18.5% of all engineering bachelor's recipients.

A Statistically Different Subset

The data just presented paint a picture of FIRST alumni who are already distinct from the typical secondary school population. FRC participants are high academic achievers in high school. Alumni often pursue STEM degrees in college instead of business or other degrees. Further, males compose a much greater percentage of the students that participate in FIRST Robotics than females do. These differences become even more significant in light of the results from my study.

Starting Young

The recently enacted Next Generation Science Standards and their defining framework (Committee on Conceptual Framework for the New K-12 Science Education Standards, 2012) make it apparent that a need exists to integrate science and mathematics skills from the classroom with technology and engineering applications for the future. The FIRST organization has engaged students as young as kindergarten in competition with others in 33 different countries in varying levels of international robotics competitions (Feather & Aznar, 2011). By starting young, students are provided with early exposure to how engaging and exciting technology and engineering can be. With early and continued experiences in hands-on STEM activities, the likelihood of the students pursuing STEM-related career paths has the potential to increase.

As students move on to high school, they have the opportunity to participate in the FIRST Robotics Competition, which puts them in contact with engineer mentors who help to lead their teams (McIntyre, 2012; Oppliger, 2001; Welsh & Huffman, 2011). These interactions provide chances for students to ask questions about future careers in the mentors' respective fields, and also to experience the engineering design process with those who make a living by following that process in their daily work. Borman and Colson (2011) argue that mentors are an essential part of an individual's development into a professional in any field, regardless of specialty. Similarly, Mau (2003) points out that women have a lack of role models in science and engineering careers, which could partially explain the lack of females in those areas. FRC is an ideal setting for high school students, both male and female, to interact with such mentors in a variety of capacities.

Research (Stoecker & Pascarella, 1991; Tidball, 1980; Tidball & Kistiakowsky, 1976) has shown that women attending women's colleges are more likely to enter male-dominated careers than their coeducational peers. The researchers partially attribute this tendency to the presence of female professors who model leadership and as act as mentors for the female students. Other studies (Platz, 2012; Tyler-Wood, Ellison, Lim, & Periathiruvadi, 2012) have claimed that pre-college extracurricular STEM activities with female mentors have a positive influence on young females' perceptions of science, engineering, and STEM careers. Thus, it is likely that interactions with FIRST Robotics team mentors may be influential on the career trajectories of both female and male participants. The interaction with mentors is one of multiple potential long term influences that engagement in FIRST Robotics may have on the participants.

Additionally, students gain applicable experience working with a team of their peers to accomplish an engineering goal. By participating in the entire season, through all of the aforementioned phases (pre-build to post-competition), skills are gained in the areas of mechanical knowledge, communication, teamwork, and more (Melchior et al., 2005; Oppliger, 2001). Since robotic engineering draws upon fundamental math and science understanding, the applications of classroom knowledge are likely to be more apparent to student participants.

Influence on Career Trajectory

Various other extracurricular programs have been shown to have an impact on students' educational and career pursuits. Raju, Sankar, and Cook (2004) report on an opportunity for students to learn about electricity and engineering using extracurricular hands-on activities. The active engagement showed the students that learning science and engineering could be a fun endeavor, and even encouraged additional learning beyond the planned activity.

Research has also been conducted on which students persist in a STEM major in college, as opposed to those students who switch majors or even drop out. Kokkelenberg and Sinha (2010) determined that those students with STEM experience prior to their freshman year of college are more likely to complete an engineering degree. Similarly, Mau (2003) found that academic proficiency was a significant predictor of persistence in science and engineering paths. Additionally, Mau confirmed that women were less likely than men to persist in science and engineering aspirations. Given the likelihood of FIRST Robotics participants to be academically successful, it is likely that engagement in the teams may be more of an opportunity to refine career goals through the extracurricular interactions.

Impact for the Future

Experiences on FIRST Robotics teams shape the futures of FIRST alumni. Many decide to go on to study science, technology, engineering, and mathematics (STEM) fields in college (Boyer, 2011; Melchior et al., 2005; Rudat, 2002). Some go even further, wishing to extend their FRC experience to the collegiate level, and mentor or lead teams in their undergraduate careers (Oppliger, 2001). Even those who do not go on to major in STEM fields know that they gained valuable knowledge that will be useful to them in their future careers (Hurner, 2009).

A more complete understanding of the relationship between an alum’s role on the FIRST team and his or her career path can contribute to positive changes in the structure of the FIRST team and the competition as a whole. With knowledge of how a students’ interests relate to a chosen role, teams can improve their recruitment practices, as well as obtain mentors who can guide the team members appropriately. The FIRST organization could also use the results of this study to augment the multi-disciplinary team structure.

The FIRST LEGO League (FLL) challenges are extremely interdisciplinary, and designed to promote the FLL Core Values, including teamwork, learning together, the importance of discovery, and shared experiences (FIRST LEGO League, n.d.). A supplemental goal of FLL is to expose students to potential career paths through that particular season's challenge topic. Thus, with this holistic approach to FLL, different types of students are potentially attracted to the team. Another example of an even more multi-disciplinary team competition is the Solar Decathlon, a college-level event that challenges students to produce an energy-efficient home (Solar Decathlon, 2013). The ten contests that comprise the event include the disciplines of architecture, marketing, engineering, science, communications, design, and business. Solar Decathlon and FLL are only two examples of sparking students' interest in fields in which they may not have been initially inclined to participate. I mention these two examples of interdisciplinary teams because any FRC team could adopt one of these models. The modified team structure could contribute to recruiting more participants and to building stronger and more inspired teams. An understanding of team members' choice of roles would help to build such a team.

Summary

FIRST Robotics Competitions attract students who are strong in academics, and who already have an interest in STEM. Participation in their FRC teams provides opportunities to apply their classroom knowledge to real, hands-on experiences. These experiences translate into increased enthusiasm for STEM, and help to create future advocates for FIRST as well as for STEM learning, as these students go on to pursue STEM degrees and careers. But what interested them specifically about FIRST and STEM? What roles did they play on their respective teams, and did their experiences in those roles provide a platform for their future interests and pursuits?

CHAPTER THREE: RESEARCH DESIGN

Research Question

I used the following question to guide my research: “Is there a relationship between the role a student had on a FIRST Robotics team and his or her choices in educational pursuits or career paths?” In order to form conclusions, I constructed an online survey, distributed it to FIRST Robotics Competition (FRC) alumni, and analyzed the resulting responses. I delineate the details of these activities below.

Instrument Development

I designed the survey instrument to correspond somewhat with two prior studies. The research study conducted by Boyer (2011) was intended “to assess the education and career outcomes of FIRST alumni” with a widely distributed survey, while Melchior and colleagues (2005) evaluated the impact and implementation of FRC by studying a specific schools and those schools’ students. With data from these prior studies, I can compare and contrast the characteristics of my study’s participant population, as well as some of the responses, with those of Boyer and Melchior and colleagues.

As previously mentioned, I gathered data with an online survey, which participants accessed through a specific link. See “Appendix A: Copy of Online Survey Instrument” for a full copy of the administered survey. I grouped my survey questions into four main categories, as detailed below.

Characterization Questions

First, I verified that the respondent was an FRC alum. Next, I presented characterization and demographic items to gather the participant's age, sex, race, high school graduation year, education level, current education status, and job experience. The intent of these items was to gather the data necessary to compare my sample to samples from prior FIRST Robotics studies, in addition to providing various opportunities to compare the participants internal to my study.

Role-Specific Questions

The titles that I used to identify sub-teams are consistent with the FIRST culture and the language of prior studies (Boyer, 2011; FIRST, 2013b; Hurner, 2009; Melchior et al., 2005; Oppliger, 2001). In order to more completely communicate what is involved in being part of the various sub-teams, I list the general responsibilities assumed by the sub-teams in Table 1, consistent with the work of Oppliger (2001) and Melchior et al. (2005).

In my instrument I posed questions about the student's role on his or her team, and the extent of involvement in each particular role. As options for team roles, I provided the list of roles presented in Table 1. I designed my instrument to allow participants to choose multiple roles. I present the specific questions that I posed with regard to participant role in Table 2.

I utilized a two-step questioning process, in which I first asked whether or not the participant played a role. If the participant answered "yes," s/he was then asked to detail how involved he or she was, for two reasons. First, I wanted to encourage the participant to initially consider his or her role as a whole. If he or she was involved at all, and what role did the participant recall playing on the sub-team? Second, this line of questioning prevented accidental answers of involvement in a sub-team, when the participant was not involved at all.

Table 1 Responsibilities Generally Assigned to Sub-Teams

Sub-Team	Responsibilities
Recruitment	Recruiting and retaining students, teachers, and mentors for the team
Fundraising	Obtaining team sponsors to fund competition fees, travel, and costs of robot parts
Community Outreach	Demonstrating robot in community
Robot Design	Designing the robot Designing specific parts of the robot
Robot Build	Building all or part of the robot Using tools, working with hardware
Programming	Coding the robot brain to interface with the electrical and mechanical systems
Award Documentation	Compiling submission materials for awards that are presented during competitions, e.g. Chairman's Award, Woodie Flowers Award, Creativity Award, Entrepreneurship Award
Animation	Creating a short computer animated film on a topic related to the competition
Activity Documentation	Collecting and compiling graphical and written documentation of team activities from throughout the year

Table 2 Survey Questions About Role on FIRST Team

Question	Answer Options
Did you play a role in recruitment of new team members?	Yes No
If yes, how were you involved in recruiting new team members?	Only a little involved Somewhat involved Very involved Leader
Did you play a role in fundraising for your team?	Yes No

If yes, how were you involved in fundraising?	Only a little involved Somewhat involved Very involved Leader
Did you play a role in community outreach for your team?	Yes No
If yes, how were you involved in community outreach?	Only a little involved Somewhat involved Very involved Leader
Did you play a role in robot design?	Yes No
If yes, how were you involved in robot design?	Only a little involved Somewhat involved Very involved Leader
Did you play a role in programming your team's robot?	Yes No
If yes, how were you involved in programming your team's robot?	Only a little involved Somewhat involved Very involved Leader
Did you play a role in preparing documentation for any team awards (for example, Chairman's Award, Woodie Flowers Award, or Entrepreneurship Award?	Yes No
If yes, how were you involved in preparing award materials?	Only a little involved Somewhat involved Very involved Leader
Did you play a role in creating an animation for competition?	Yes No
If yes, how were you involved in creating an animation?	Only a little involved Somewhat involved Very involved Leader
Did you play a role in compiling team activity documentation?	Yes No

If yes, how were you involved in compiling team activity documentation?	Only a little involved Somewhat involved Very involved Leader

Future Impact of Role Questions

I followed the engagement in the sub-teams with items to determine the participant's opinion on whether his or her role on the team impacted his or her course of study in college or career path. I based these questions on the actual college and career choices of FRC alumni (Boyer, 2011). I offered yes or no options instead of a Likert-type scale because I ultimately was interested in even a small degree of influence. I did not design my study to test the degree of influence, but only to assess whether the participants' perceived any influence of their engagement in FIRST Robotics on their career chocies. The questions follow in Table 3.

Table 3 Survey Questions About Impact on College and Career

Question	Answer Options
Do you feel that your particular role(s) on your FRC team impacted your choice of college major?	Yes No
Did your particular role(s) on your FRC team impact any jobs, internships, externships, or other professional activities that you completed during your college experience?	Yes No
Did your particular role(s) on your FRC team impact your career choice(s) after graduating from college?	Yes No

Open-Ended Responses

I also provided two additional questions at the end of the survey to allow the respondent to share what factors influenced the role(s) chosen on the team, as well as how those roles influenced future choices; Table 4 provides the items. I chose these particular questions because I initially guided my research towards the influence of FIRST on the participants' career trajectory, rather than the relationship between the two. Because all survey questions were optional, the participants could choose to answer these open-ended questions if they felt strongly about sharing their experiences.

Table 4 Open-Ended Response Questions

Question
Please share any additional information that you feel would help us to understand what influenced your choice of team roles on your FIRST team.
Please share any additional information that you feel would help us to understand how your choice of role(s) on your FIRST team influenced your educational and career choices.

Study Participant Population

There is no existing data on the actual number of FIRST alumni, the population from which my I drew my sample. The FIRST Robotics competitions began in 1992 with 28 teams (FIRST, 2012); for the 2013 season, FIRST (2013a) reports on their website that there were 50,960 student participants on 2,548 teams. The expansion of the program has resulted in many alumni, whose numbers are unknown. In the study conducted by Boyer (2011), surveys were distributed to 19,076 FIRST alumni, but this number is obviously far fewer than the true number of alumni.

I was unable to obtain assistance in reaching alumni through FIRST headquarters. Therefore, I recruited my research participants through email contact with FIRST Robotics Competition Regional Directors, through posts to participate on the FIRST Alumni Facebook page, and by posting invitations to participate on a well-known online discussion board managed by a prominent FRC team. I will now detail my choices and the process I used as I accessed these three connections to FIRST Robotics alumni to invite individuals to participate in my study.

Regional Directors

Some regional directors keep current contact information for FRC alumni from their regions. I personally contacted 24 of these regional directors, and five responded that they were willing to distribute my survey to their networks. Those who responded were optimistic about the prospective return rate on the surveys and eager to assist with my study. Through interactions with the regional directors, I estimated that approximately 500 alumni received a request to respond to the survey through this mode.

Facebook

FIRST alumni have created a Facebook page to foster social networking among individuals who have participated in FIRST in the past. I posted two requests to take the survey on the group's page. At the time of survey distribution, this page had 3,154 members who potentially viewed the survey requests, although it was unknown how many were actually alumni.

Chief Delphi Forums

Chief Delphi is a legacy FRC team, and one which maintains a discussion forum website with high traffic, particularly during the build season (January and February). There are currently over 30,000 forum members, including, but not limited to, current participants, FIRST alumni, and team mentors. I posted an invitation to participate in my study that included a link to my survey on this site, and refreshed the request twice. The thread received 620 views total.

Final Response Count

Ultimately, I received a total of 174 responses to my survey requests. Due to the anonymous nature of the responses, it is impossible to know which responses originated from which request methods. In Chapter 4, I characterize the demographics of the sample of individuals that responded to the survey request.

Summary

By distributing an online survey to as wide an alumni population as possible with the given constraints, and by performing a quantitative analysis on the responses, I expected to be able to answer the research question, "Is a student's role on a FIRST Robotics team related to his or her choices in educational pursuits or career paths?" Through the survey instrument, I sought data regarding the roles that the participants played on their teams, and the extent of their involvement. By comparing the participants' responses using the personal characteristic data provided by the participants, my goal was to draw conclusions about the particular relationships between roles and college major, and between roles and career paths. Further, the personal characteristic data provided me with the opportunity to determine how consistent my sample was with prior studies.

CHAPTER FOUR: RESULTS AND DISCUSSION

I begin this section by characterizing the participants in my study with respect to their demographic responses. I then present the results of my study's survey questions seeking to determine it there are correlations between the roles that the participants played on a FIRST Robotics team and the perceived influence of those roles on the participants' career trajectories. Next, I present some additional findings that are not directly related to the initial research question, but pose potential for future research. Finally, I discuss the results in detail, elucidating some specific relationships in my analyses.

Characterization of the Study Participants

I initially characterize my study participants by gender, age, and college major. These characterizations are depicted graphically in Figure 2, Figure 4, and Figure 7 below. There were 174 participants total, though not all participants answered every question. As I present the participant characteristics of this study, I compare them to those of Boyer's (2011) study with a total N = 4,666 (Figure 3, Figure 6, and Figure 8). I maintain that the comparison to the Boyer (2011) study is warranted based on a desire to determine if my sample was similar to previous studies of FIRST Robotics alumni. The similarity to previous studies is necessary for considering results of FIRST Robotics studies in aggregate, and for justifying the development of widespread conclusions.

<u>Gender</u>

In my study's participant population, 26.9% were female, while 73.1% identified themselves as male. My study's gender characteristics align somewhat with Boyer's (2011) study on FIRST alumni's career and education outcomes. The gender distribution of her participants was 70.7% male and 29.3% female.

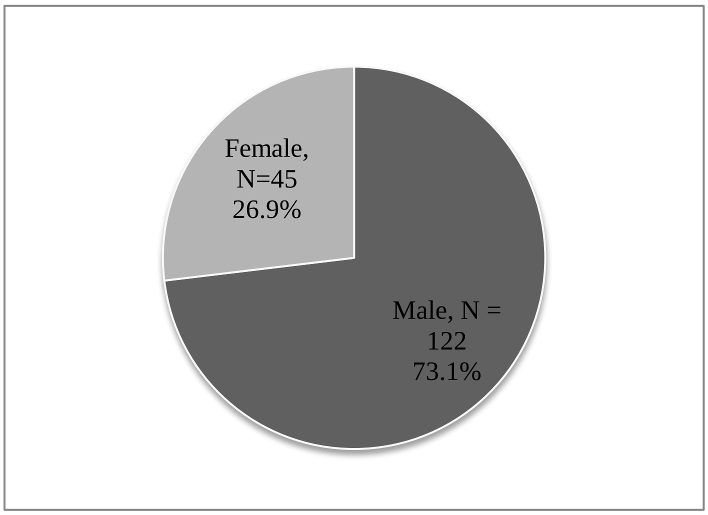

Figure 2 Gender Distribution of Participants, N = 167

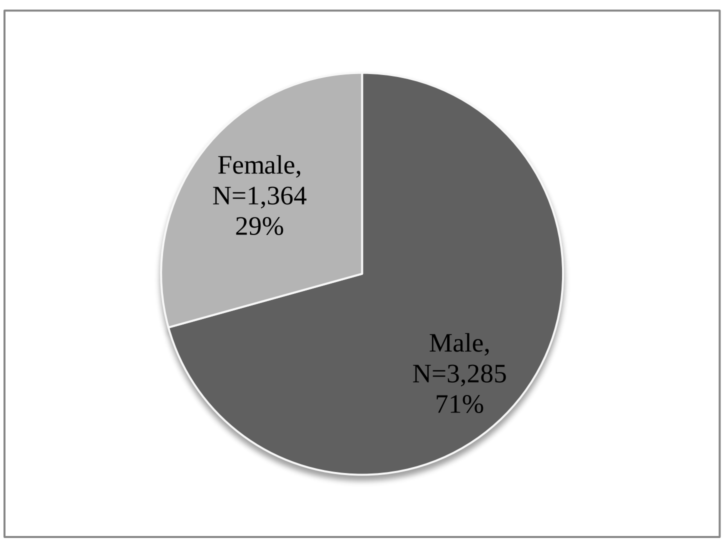

Figure 3 Boyer (2011) Study Gender Distribution

<u>Major</u>

The majors chosen by the study participants are represented in Figure 4. If a participant chose more than one major, then all selections have been reported in the figure. Mechanical Engineering majors account for the highest total, with n = 60. Also notable is the number of Business major participants (n = 12).

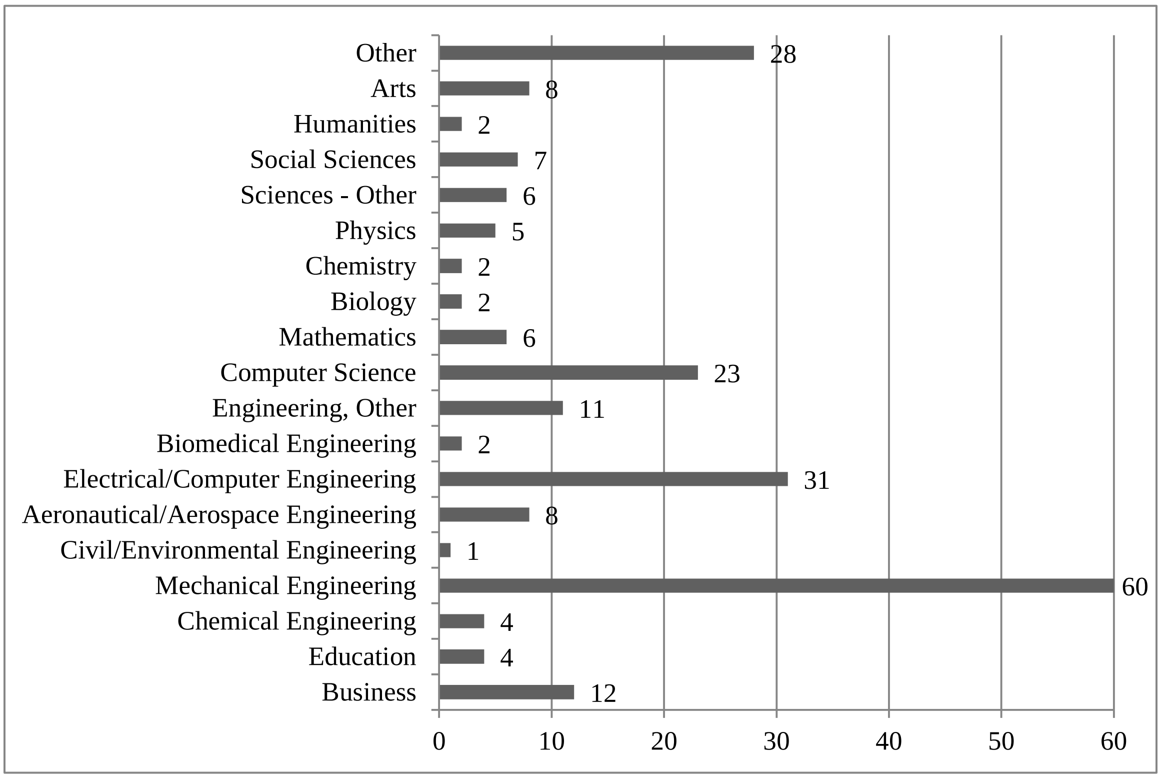

Figure 4 College Major Distribution, Including Multiple-Major Participants

In Figure 5, I graphically represent the distribution of my study participants' majors with certain STEM fields grouped together. The Engineering/Technology category includes all engineering majors, as well as computer science and other computer-related majors. Participants who majored in more than one engineering area, or in both engineering and computer science, are included in the Engineering/Technology category as well, but only counted once. My basis for this combination is that the majority of top engineering programs in the country, as ranked by U.S. News & World Report (2012), include computer science as part of their schools or colleges of engineering. The Humanities category consists of arts, English, history, social sciences, and all other non-STEM majors. Mathematics includes participants who chose Mathematics as their major, and Sciences accounts for participants who chose Biology, Chemistry, Physics, or Sciences–Other. In order to more explicitly distinguish the separate majors and to conduct accurate analyses, I excluded participants who chose two or more majors that did not fall into the same category. In all further analyses involving major, I utilized these particular single major respondent sub-groups.

There are differences in the college major distribution between my study and the study conducted by Boyer (2011). The Boyer (2011) study had a higher percentage of science majors (9.6% compared to 3%), and a lower percentage of business majors (3.6% compared to 7%). The mathematics and humanities distributions are relatively similar in both studies. These comparisons are tentative, since Boyer did not explain if or how double-majors were accounted for.

Age

The age distribution of my study participants was heavily weighted towards those who are still in college, pursuing their undergraduate degrees. A total of 61% (n = 106) of my participants were under the age of 22 (see Figure 7 for full results). Boyer's study had a much larger distribution of college-age participants with only 11% of participants age 22 or older. I account for this difference based on my sampling method that relied heavily on Internet-based interactions, in which college students are more likely to engage.

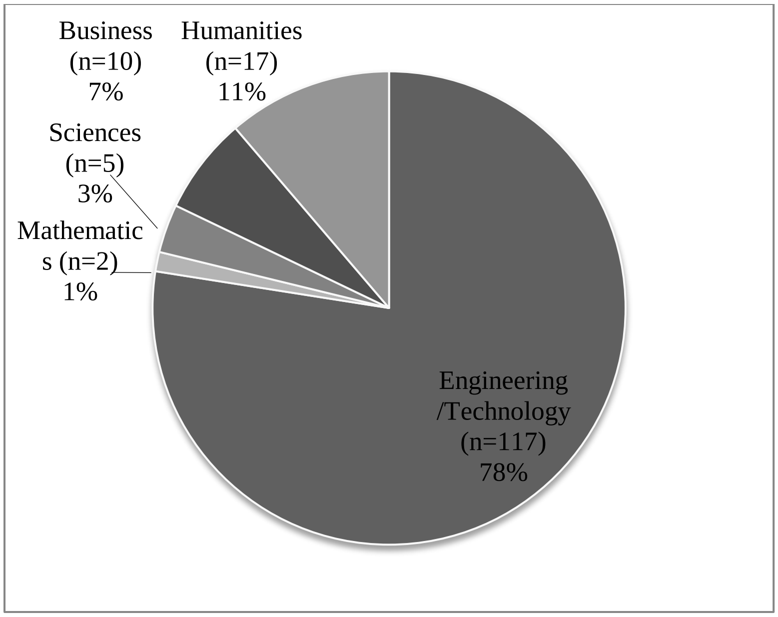

Figure 5 College Major Distribution of Study Participants, Sorted By STEM

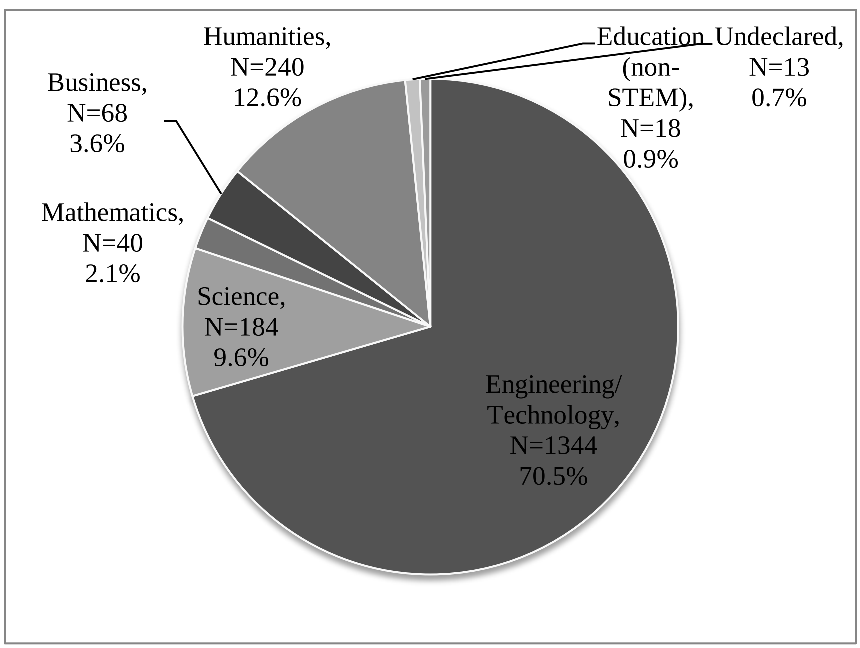

Figure 6 College Major Distribution of Boyer (2011) Study Participants

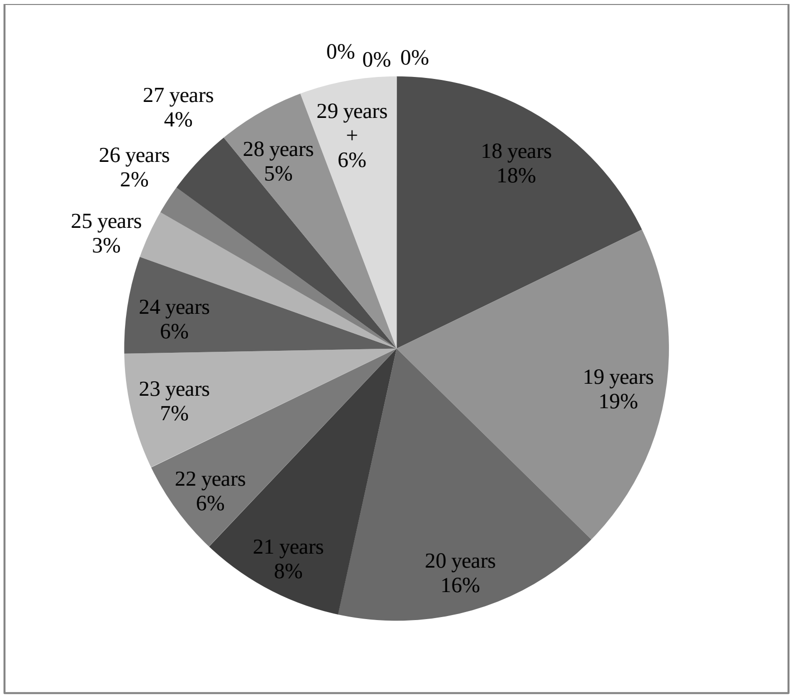

Figure 7 Age Distribution of Study Participants

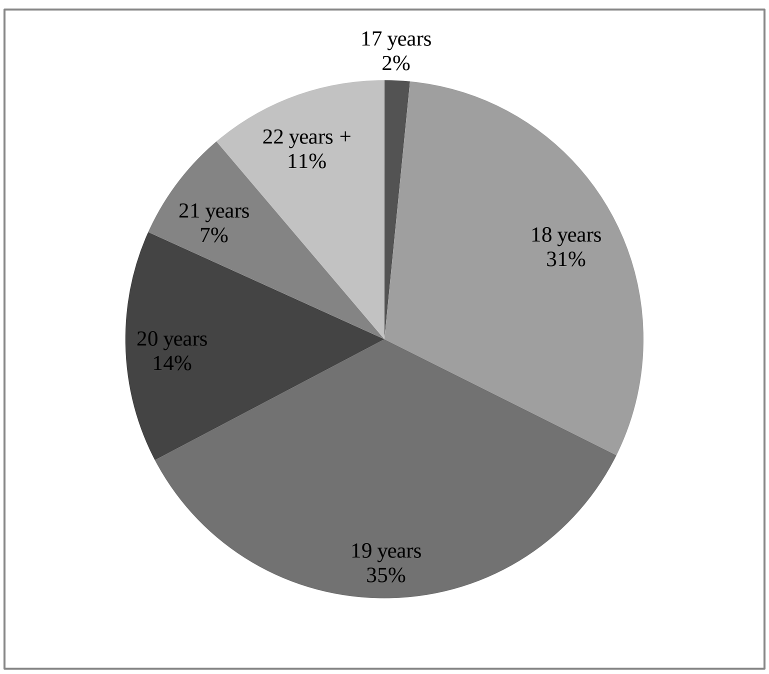

Figure 8 Age Distribution of Boyer (2011) Study Participants

Average Number of Years of Participation in FIRST

Another point of comparison is the average number of years of participation as a high school student. Participants in my study had an average participation of 3.16 years. In Boyer's (2011) study, the average years of participation was 3.04 years, but this is ultimately not a meaningful number for comparison, since Boyer included FIRST LEGO League (FLL) and FIRST Tech Challenge (FTC) participation as well, and I did not. Both FLL and FTC are part of the FIRST family of programs (FIRST, 2012), but are separate from FRC. In contrast, Melchior and colleagues (2005) found that their FIRST Robotics study's participants had a mean participation of 2.1 years. However, the racial, gender, and socioeconomic characteristics demographics of their sample were a subset of the FIRST participant population: the majority were non-white (55.6%), 59.4% male, and from Title I schools. Thus the results of the Melchior et al. (2005) study are not necessarily applicable across the populations of my study or Boyer's study.

Comparison of Demographic Results

Both my study's participants as well as Boyer's (2011) participants are only a subset of the larger FIRST alumni population. The similarities and differences between Boyer's (2011) study and my study suggest that the results of my study can be applied appropriately to the greater FIRST Robotics alumni population.

Results of Survey Questions Regarding Role on Team and Personal Characteristics

Next, I conducted chi-square analyses on the data from the participants' responses to the survey questions regarding specific roles that were available on their FIRST Robotics teams. I wanted to see if there were differences between the role played on a

FIRST Robotics team and the career trajectory of the different sub-groups of participants in my study. I used major as the grouping classification for my analyses. I chose chi-square to determine if the roles played were dependent or independent of the major. Participant responses to sub-team roles are summarized in Table 5.

In my chi-square comparisons for sub-team role versus major, I included the five major categories described previously: Engineering/Technology, Sciences, Mathematics, Business, and Humanities. I performed individual comparisons between the participants' majors and their response for extent of involvement in each sub-team. Thus, I had 25 degrees of freedom for the sub-team roles versus major comparisons.

Table 5 Participant Responses to Survey Questions Regarding Team Roles

Did you play a role in…[r]	Yes	No	Extent[#] (1/2/3/4)[*]
…recruitment?	144	26	20 / 55 / 44 / 27
…fundraising?	136	32	23 / 40 / 44 / 33
…community outreach?	141	28	13 / 49 / 37 / 44
…robot design?	153	14	17 /22 / 47 / 68
…building the robot?	156	14	20 / 21 / 44 / 73
…programming the robot?	78	91	29 / 21 / 11 / 20
…documentation for awards?	115	55	17 / 24 / 33 / 44
…animation?	20	148	13 / 4 / 3 / 3
…activity documentation?	80	88	7 / 26 / 22 / 26

[r] Questions paraphrased from actual wording. See APPENDIX A for actual verbiage.

[#] Extent of involvement. Totals may not equal number in "Yes" column, as participants were not required to answer both questions.

[*] 1 = Only a little involved, 2 = Somewhat involved, 3 = Very involved, 4 = Leader.

Comparison Between Extent of Sub-Team Involvement and College Major

I found statistically significant results when I conducted chi-square tests comparing college major to involvement in roles in three areas: robot design, robot building, and activity documentation. The particularly significant relationships are delineated below in Figure 9, Figure 10, and Figure 11.

Although I conducted chi-square comparisons on all majors, of particular interest with regard to involvement in robot design and robot build were the Business majors as compared to the Engineering/Technology majors. When compared to the expected values, the Engineering/Technology majors were skewed towards greater involvement in both design and build, as opposed to the Business majors, who were skewed towards lesser involvement in robot design and build (Figure 9 and Figure 10). My analysis revealed no Business majors who responded that they were leaders in robot design, and only one Business major who was a leader in robot build, whereas much higher than expected numbers of Engineering/Technology majors were leaders in both design and build sub-teams. My results indicate that role played is not independent of major.

Conversely, Humanities, Business, and Sciences majors were skewed towards high involvement and leadership in Activity Documentation, while Engineering/Technology majors tended to be less involved (Figure 11). Sciences majors in particular were more heavily involved in Activity Documentation. Sciences majors responded with higher than statistically expected numbers in involvement, prompting interesting possibilities for further research, such as what specifically attracted those participants to that sub-team. No other data regarding involvement in specific roles produced statistically significant results when compared to college major. However, my analysis again revealed that role played is dependent on major.

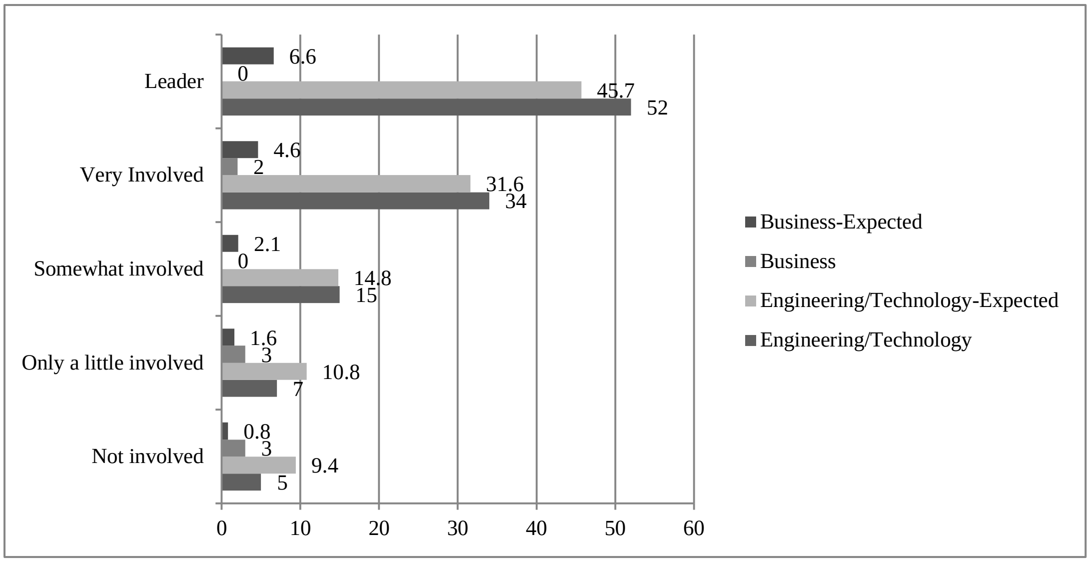

Figure 9 Expected vs Actual Values of Engineering/Technology and Business Majors' Involvement in Robot Design, χ^2(25,174)=[46.933], *p*<0.005

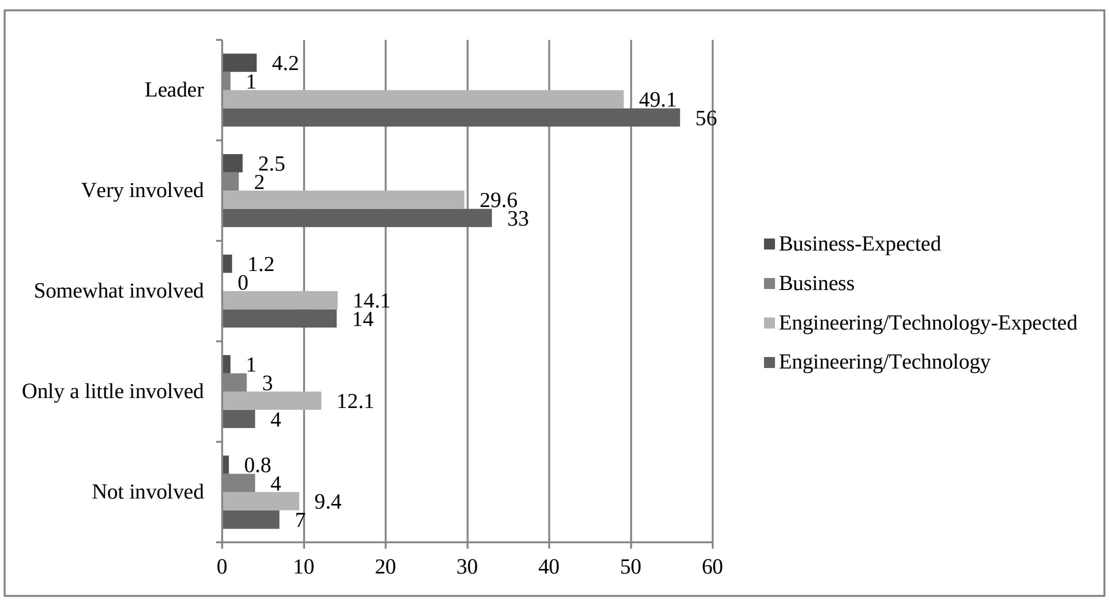

Figure 10 Expected vs Actual Values of Engineering/Technology and Business Majors' Involvement in Robot Build, χ^2(25,174)=[48.726], *p*<0.003

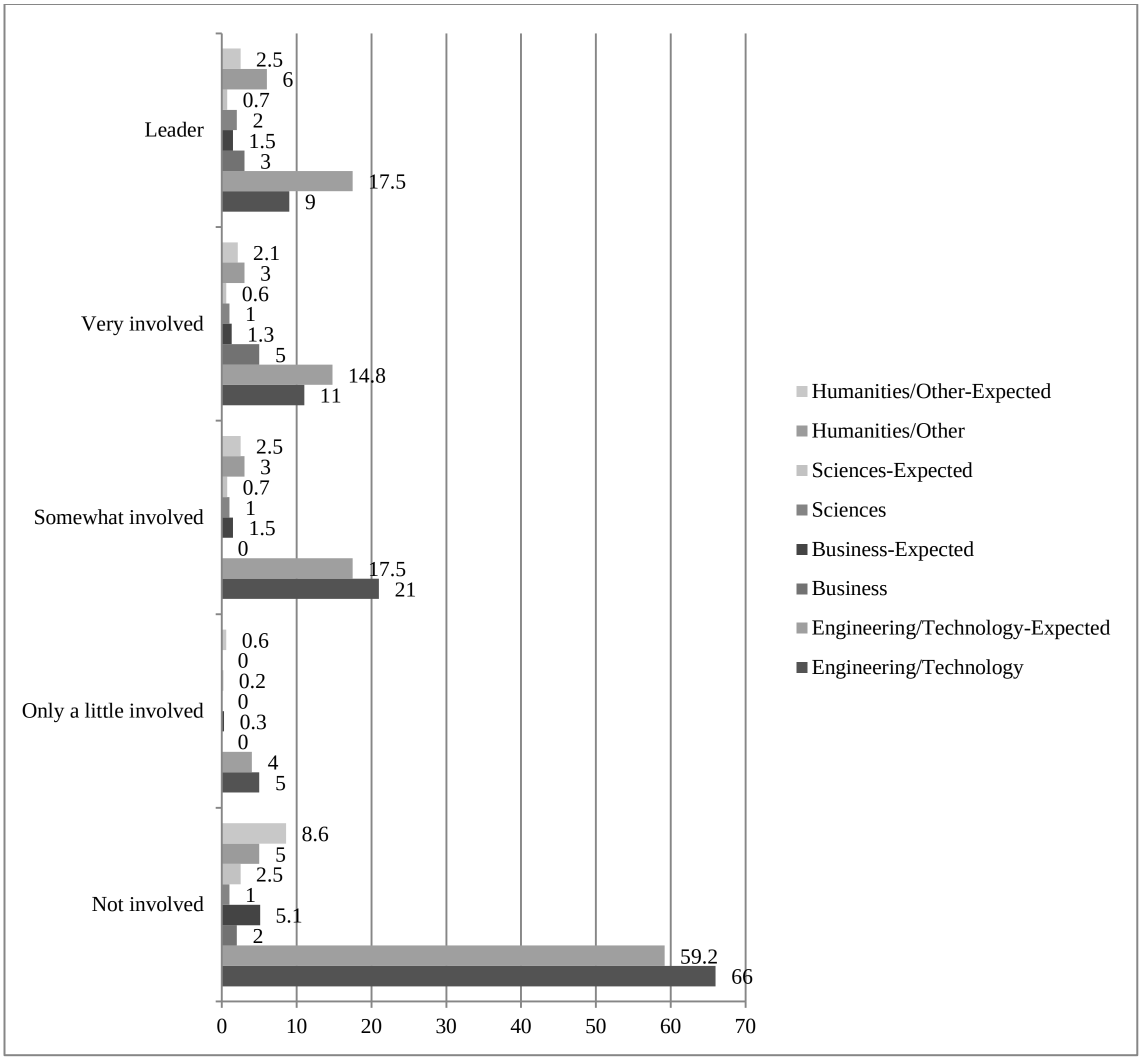

Figure 11 Expected vs Actual Values of Involvement in Activity Documentation Based on Major, $\chi^2(25,174)=[41.109]$, $p<0.022$

<u>Comparison Between Extent of Sub-Team Involvement and Work in a STEM Field</u>

Then I compared the role on the team to whether the participant is currently working in a STEM field. Statistically significant results were found for the sub-teams of robot build, award documentation, and community outreach, as displayed below in Figure 12, Figure 13, and Figure 14.

Figure 12 Expected vs Actual Values of Involvement in Robot Build Based on Current Work in STEM, $\chi^2(10,174)=[27.987]$, $p<0.002$

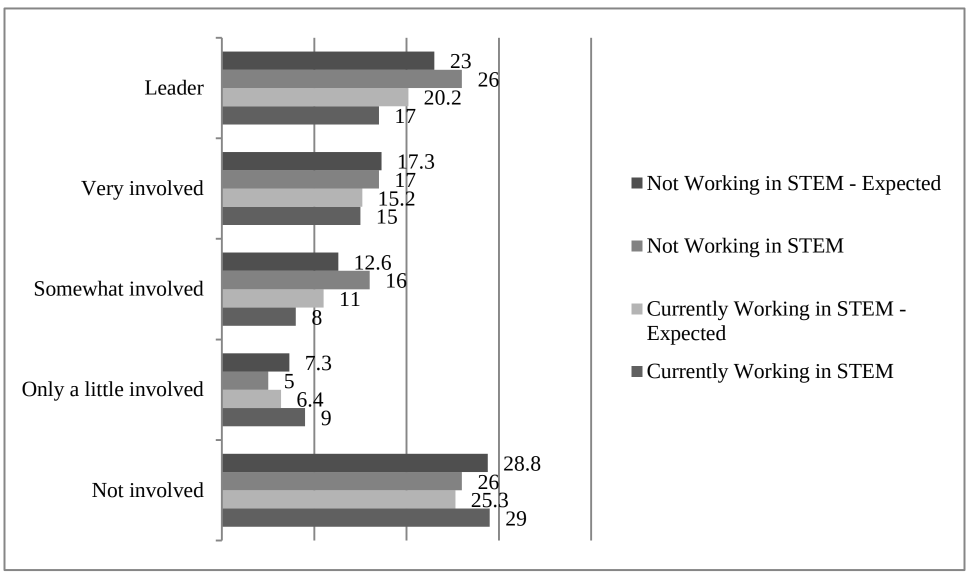

Figure 13 Expected vs Actual Values of Involvement in Award Documentation Based on Current Work in STEM, $\chi^2(10,174)=[20.419]$, $p<0.026$

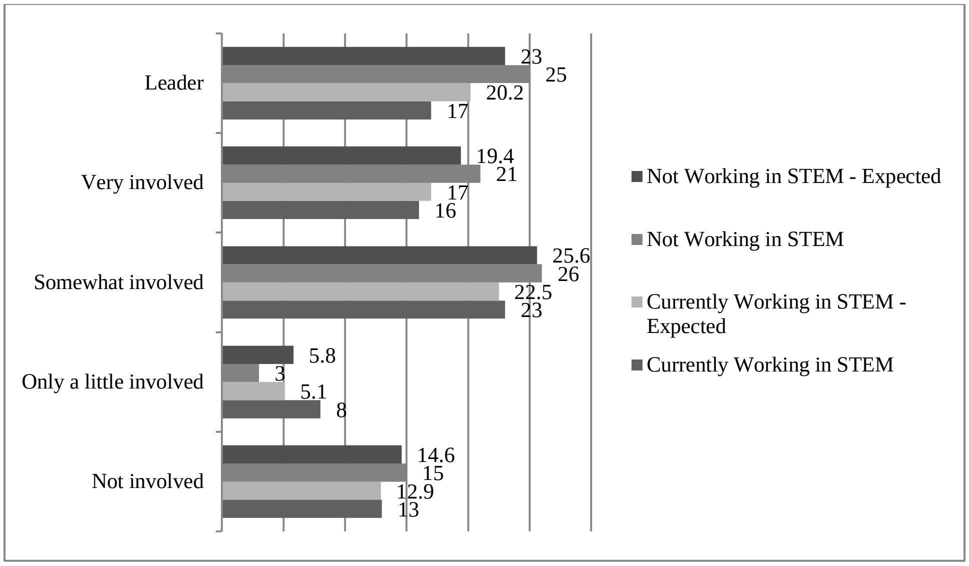

Figure 14 Expected vs Actual Values of Involvement in Community Outreach Based on Current Work in STEM, $\chi^2(10,174)=[19.027]$, $p<0.040$

The results in Figure 12, Figure 13, and Figure 14 show that, in general, the participants who are currently working in STEM fields tended towards the robot build aspect of their FRC teams, while they shied away from less technical tasks such as award documentation and community outreach. As for the participants who are not currently working in STEM fields, there were a number of different reasons why that was the case. Many of the participants who were not working in a STEM field stated that they were still in school, and intended to pursue a STEM career after obtaining their degree. Some participants stated that they had no intent to work in a STEM field. Thus, my chi-square test again indicated that role is associated with major.

Analysis of Open-Ended Survey Questions

Table 6 and Table 7 summarize the responses to the open-ended questions. These two questions were, "Please share any additional information that you feel would help us to understand what influenced your choice of team role(s) on your FIRST team," and, “Please share any additional information that you feel would help us to understand how your choice of role(s) on your FIRST team influenced your educational and career choices.” After becoming familiar with the data, I coded the responses using the descriptors delineated in the tables. A large number of participants (n = 24) claimed that their choice of role on their team was guided by interests they had before joining FIRST Robotics. Further, 16 participants said that involvement in FIRST Robotics helped them to realize that they wanted to pursue a career in STEM, and another 16 participants indicated that FIRST involvement helped them confirm or specify their career aspirations. One trend I noticed during the analysis was that 15 of the 16 participants claiming that FIRST confirmed or helped to specify their career trajectory were Engineering/Technology majors. Additionally, three Business majors responded that FIRST helped them to realize a career trajectory towards STEM that they otherwise would not have. One of those Business major participants specified that, “I am hoping to work for FIRST someday and am hoping to start my master’s degree in the fall for Youth Development. FIRST has helped me shoot for my dreams and I want to help kids realize and achieve theirs.”

Table 6 Factors Influencing the Choice of Role on the Team, N = 46

Coding	Count	Sample Responses (Gender, Major)
(a) Tried everything/different areas on team	5	"I was on a small team so we were encouraged to try everything." (F, Biomedical Engineering) "I was eager to try out everything on the team, and ended up as a student team leader for all three years while I was in high school." (F, Electrical/Computer Engineering)
(b) Guided by prior interests/skills	24	"My interests led me to pursue different activities, from web team to mechanical." (M, Aerospace/Aeronautical Engineering)
(c) Mentor(s) guided to specific role(s)	5	"My mentor placed me in what he thought were my talents and he helped me find what I was good at." (F, Mechanical Engineering)
(d) Didn't fit anywhere else	1	"Even though I grew up knowing how to use [tools], building was never something I was interested in, so I started working on the business side of our team…it was where I was meant to be for the team." (F, Business)
(e) Worked where needed	6	"I wanted to bring to my team what the great teams had and we didn't. Which meant shifting gearboxes and six wheel drives, as well as fundraising, presentation, style, outreach, FIRST community participation." (M, Visual & Performing Arts)
(f) Role evolved over tenure with team	3	"I wanted to just build the robot early on, which I did, then my senior year I got very interested in modeling the robot and the aesthetics of the design." (M, Industrial Design)
(g) Pushed into role due to gender	2	"I got pushed onto the business side of things because that's where all the girls went to." (F, Interactive Multimedia)

Table 7 Factors Influencing Educational and Career Choices, N = 49

Coding	Count	Sample Responses
(h) Still involved in FIRST	1	"I actually now work for FIRST while going to grad school." (F, Social Sciences)
(i) FIRST helped me realize a career trajectory I otherwise would not have (towards STEM)	16	"I went into civil engineering to pursue a project management career path, which I never would have realized I was suited for if I hadn't been in FIRST." (F, Civil Engineering) "After participating in robotics, I was less intimidated by STEM courses, and in college I found a niche in the sciences!" (F, Nursing & English)
(j) FIRST helped me realize a career trajectory I otherwise would not have (away from STEM)	1	"I think being involved with Chairman's and the other essay/documentation awards helped me realize that my passion existed in writing, not STEM." (F, Journalism)
(k) FIRST confirmed and/or helped me to specify my career trajectory/interests	16	"FIRST sharpened my interest for technology at the intersection of hardware and software. I enjoy a bit of web programming and software development, but I keep coming back to things where software interacts with the 'real world'." (M, Electrical/Computer Engineering) "My time in FIRST definitely helped cement that I wanted to be a mechanical engineer." (M, Mechanical Engineering) "Programming the robot showed me that I like embedded computing much more than desktop programming. So, now I am studying computer engineering." (M, Computer Engineering)
(l) FIRST taught me applicable life skills	9	"I followed my heart into filmmaking. Everything I did except build the robot helps me in my career and education every day." (M, Visual & Performing Arts) "I think my role on my FRC team helped me to gain valuable leadership and business skills. I have used these skills in my current retail position and am being promoted to a lead position in the coming months. FRC gave me time management skills that are very helpful in balancing college classes, community service activities, and a job." (F, Biology)
(m) FIRST somewhat influenced my career trajectory	4	"received full tuition scholarship through FIRST" (F, Robotics Engineering) "The fact that my university hosted a regional event and one of my former teammates attended it were the reasons I learned of the school." (M, Mechanical Engineering)
(n) FIRST had no influence on my educational or career choices	2	"FIRST didn't really change my educational and career choices." (F, Library Sciences)

<u>Gender Distribution Comparison</u>

Because of the availability of the data and the attention paid to gender in STEM fields (Farmer, Wardrop, Anderson, & Risinger, 1995; Luo, 2013; Mau, 2003; Oakes, 1990; Wang, Eccles, & Kenny, 2013), it seemed prudent to conduct chi-square analysis on specific roles and involvement as compared to gender to determine if role and gender were dependent. I did this analysis despite gender not being an explicit factor in my hypothesis. The results were statistically significant in the five areas of community outreach, robot design, robot build, award documentation, and activity documentation, and are summarized in Figure 15 through Figure 24. Table 8, Table 9, Table 10, Table 11, and Table 12 show the calculated percentage of involvement by male and female STEM and non-STEM majors for the same five sub-team areas of community outreach, robot design, robot build, award documentation, and activity documentation. My analysis indicates that there is a relationship between gender and FIRST Robotics sub-team role.

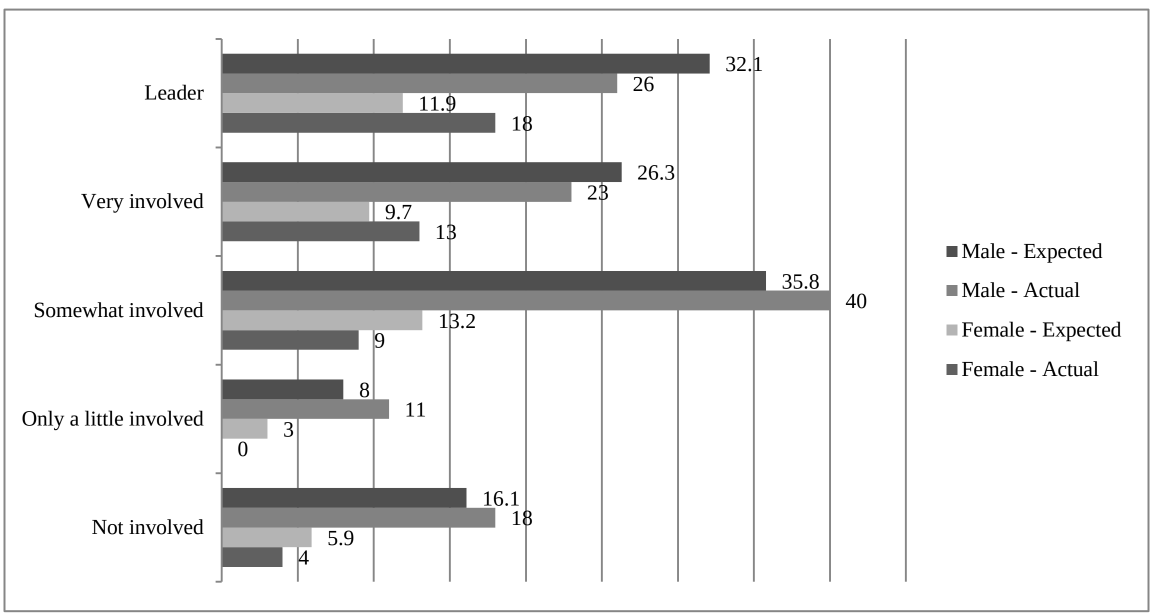

Figure 15 Expected vs Actual Values of Involvement in Community Outreach Based on Gender, χ^2(5,167)=[12.764], *p*<0.026

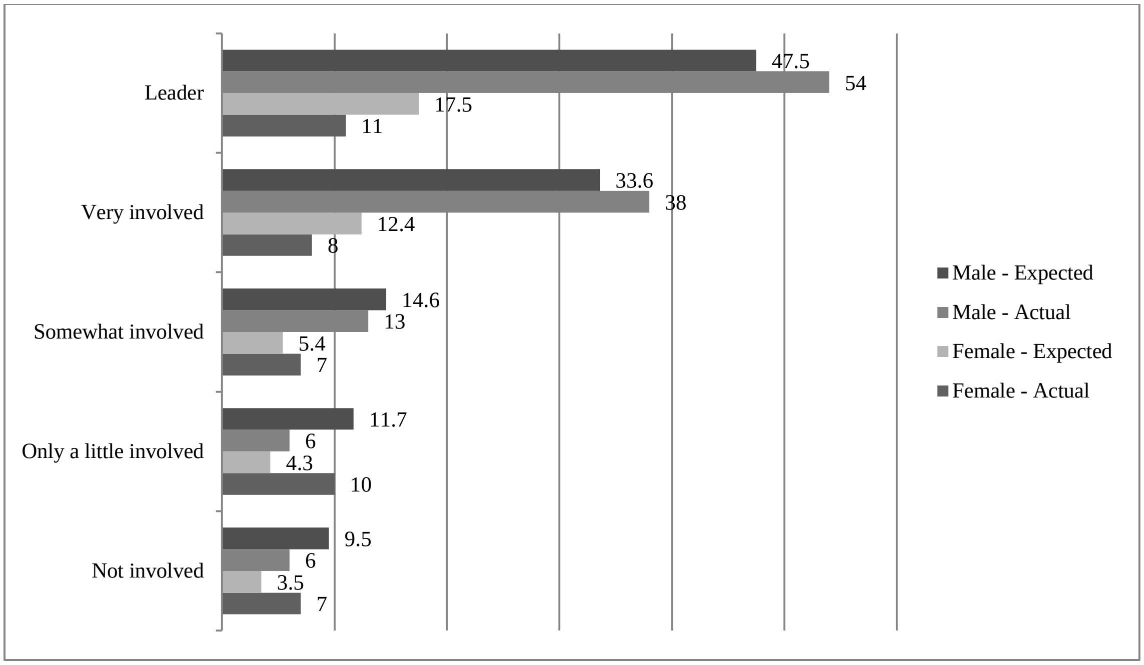

Figure 16 Expected vs Actual Values of Involvement in Robot Design Based on Gender, $\chi^2(5,167)=[21.172]$, $p<0.001$

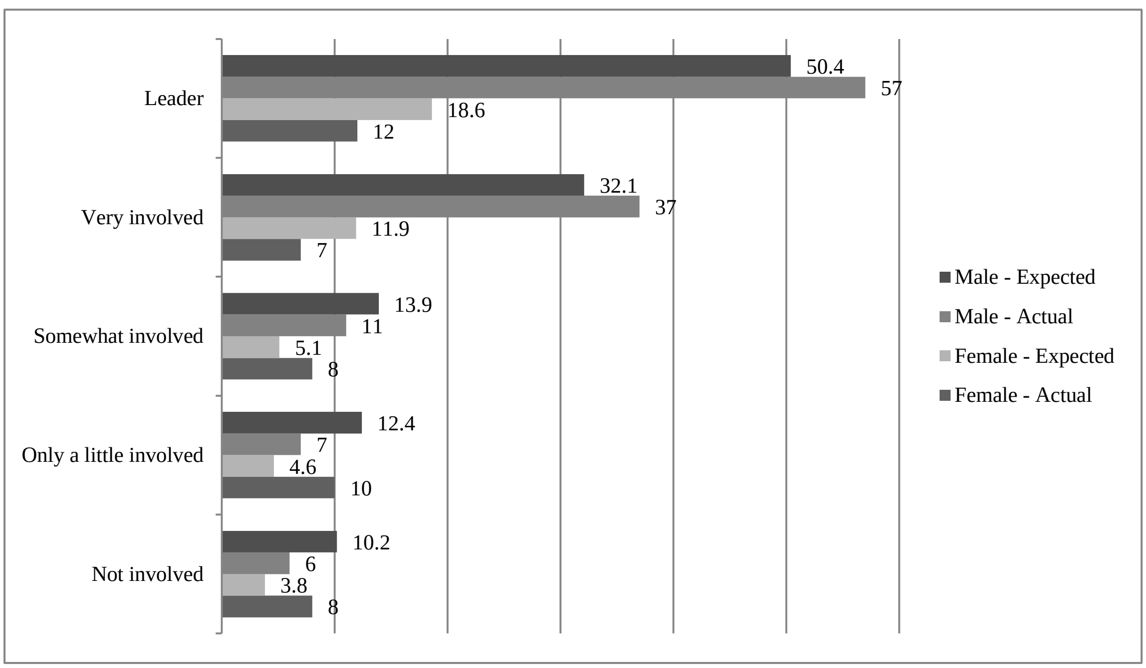

Figure 17 Expected vs Actual Values of Involvement in Robot Build Based on Gender, $\chi^2(5,167)=[24.877]$, $p<0.001$

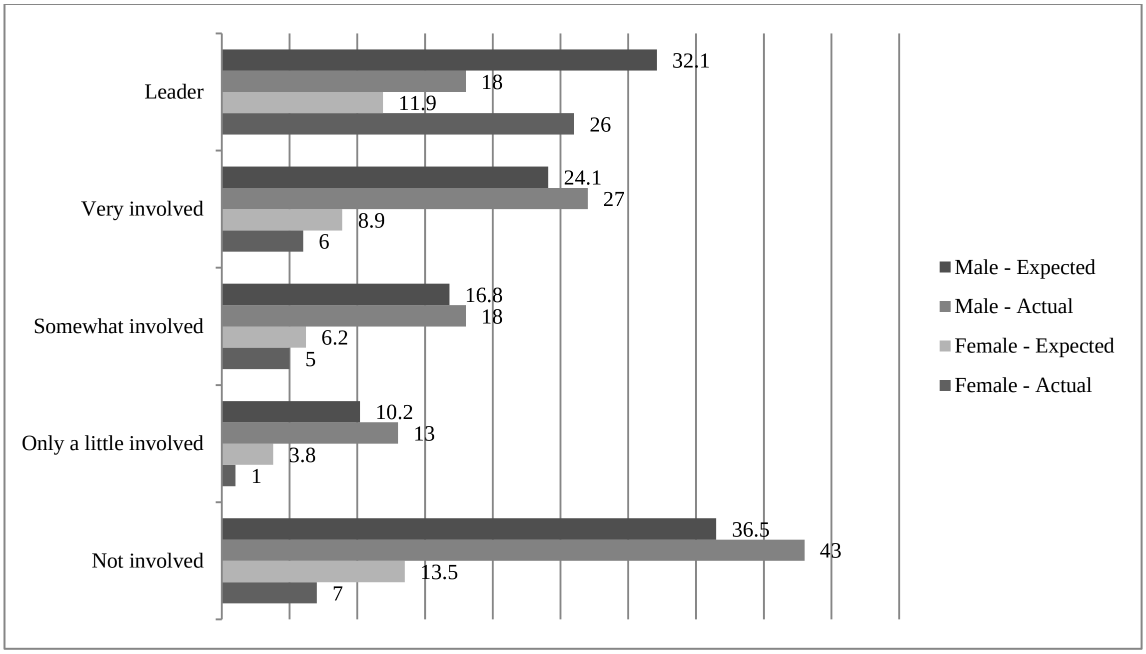

Figure 18 **Expected vs Actual Values of Involvement in Award Documentation Based on Gender, $\chi^2(5,167)=[32.853]$, $p<0.0005$**

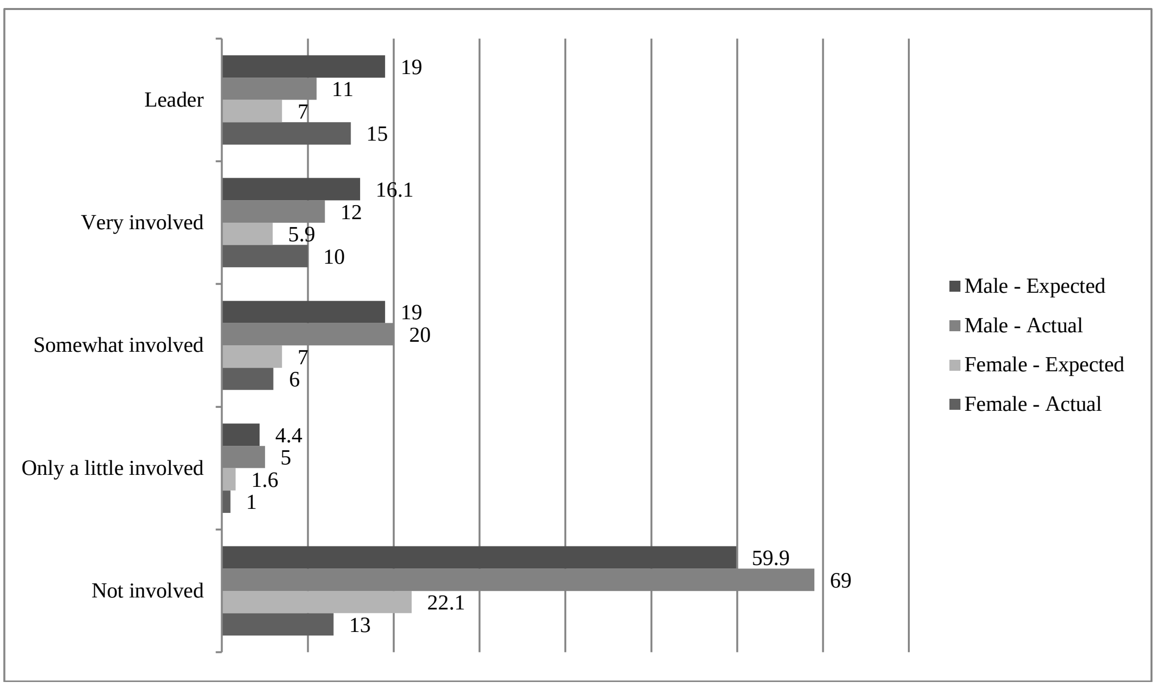

Figure 19 **Expected vs Actual Values of Involvement in Activity Documentation Based on Gender, $\chi^2(5,167)=[23.804]$, $p<0.0005$**

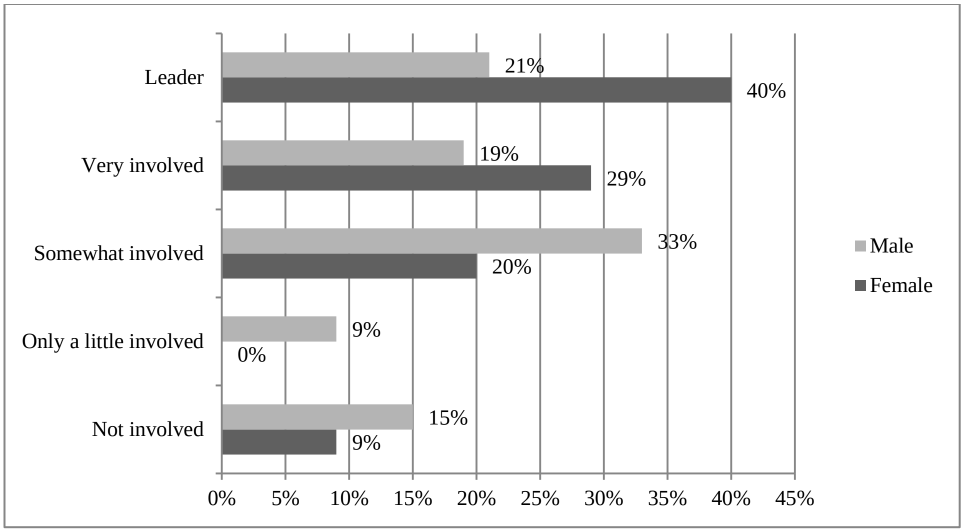

Figure 20 Involvement of Male and Female Participants in Community Outreach by Percentage Within Gender

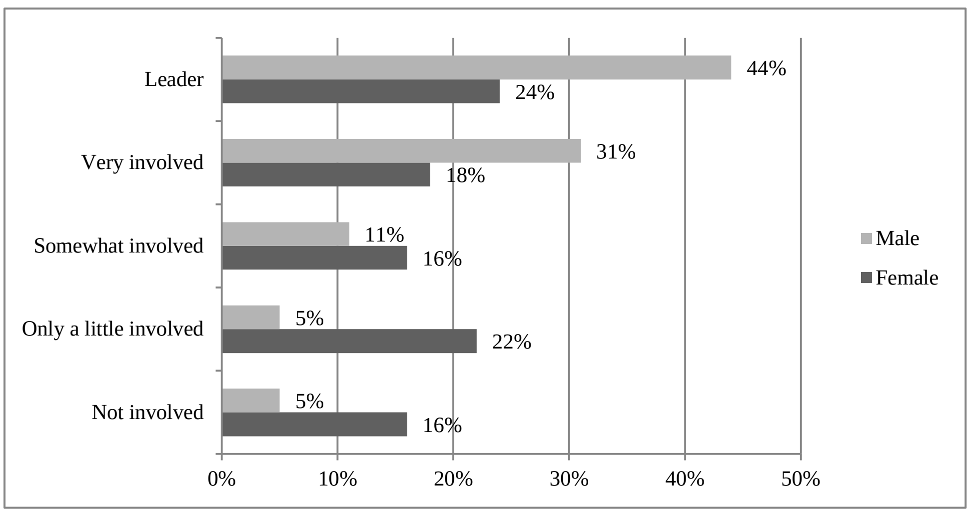

Figure 21 Involvement of Male and Female Participants in Robot Design by Percentage Within Gender

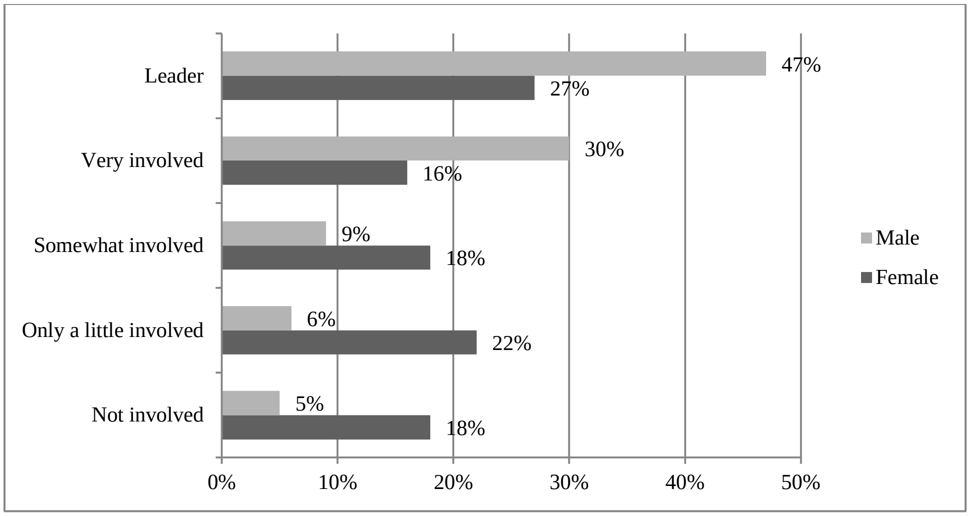

Figure 22 Involvement of Male and Female Participants in Robot Design by Percentage Within Gender

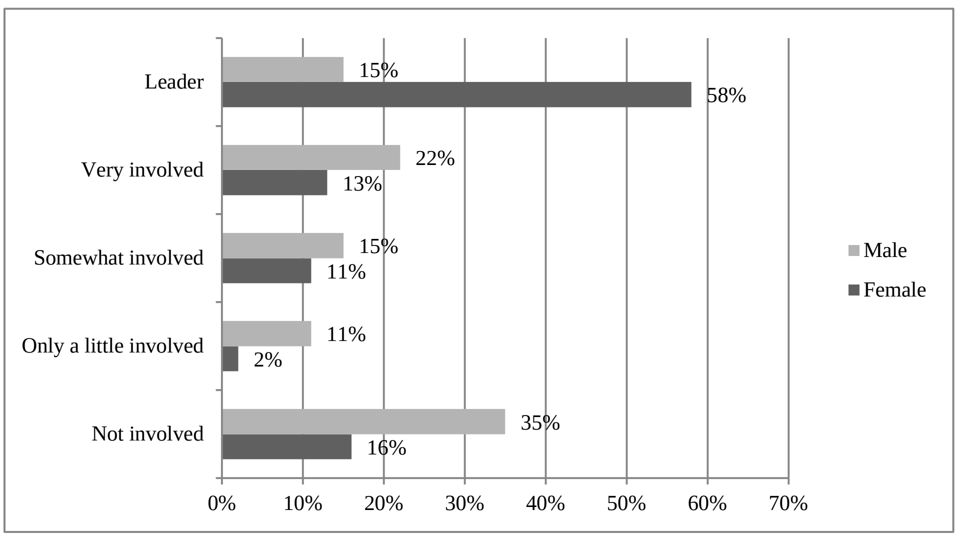

Figure 23 Involvement of Male and Female Participants in Award Documentation by Percentage Within Gender

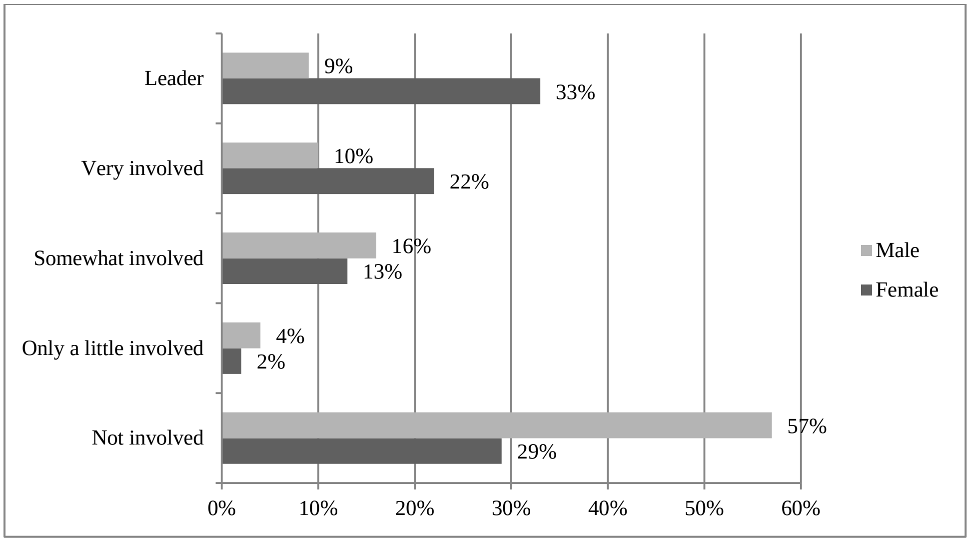

Figure 24 Involvement of Male and Female Participants in Activity Documentation by Percentage Within Gender

Table 8 Percent of STEM Majors and Non-STEM Majors By Gender in Community Outreach Roles

Gender/Major	Leader	Very involved	Somewhat involved	Only a little involved	Not involved
Female/STEM	40%	20%	32%	0%	8%
Female/Non-STEM	42%	42%	5%	0%	11%
Male/STEM	20%	20%	35%	10%	15%
Male/Non-STEM	57%	14%	14%	0%	14%

Table 9 Percent of STEM Majors and Non-STEM Majors By Gender in Robot Design Roles

Gender/Major	Leader	Very Involved	Somewhat Involved	Only a Little Involved	Not Involved
Female/STEM	32%	24%	16%	16%	12%
Female/Non-STEM	17%	11%	17%	33%	22%
Male/STEM	47%	32%	12%	5%	5%
Male/Non-STEM	33%	50%	0%	0%	17%

Table 10 Percent of STEM Majors and Non-STEM Majors By Gender in Robot Build Roles

Gender/Major	Leader	Very Involved	Somewhat Involved	Only a Little Involved	Not Involved
Female/STEM	35%	23%	23%	12%	8%
Female/Non-STEM	16%	5%	11%	37%	32%
Male/STEM	48%	31%	10%	6%	5%
Male/Non-STEM	57%	43%	0%	0%	0%

Table 11 Percent of STEM Majors and Non-STEM Majors By Gender in Award Documentation Roles

Gender/Major	Leader	Very Involved	Somewhat Involved	Only a Little Involved	Not Involved
Female/STEM	65%	4%	15%	4%	12%
Female/Non-STEM	47%	26%	5%	0%	21%
Male/STEM	14%	22%	16%	12%	36%
Male/Non-STEM	29%	29%	0%	0%	43%

Table 12 Percent of STEM Majors and Non-STEM Majors By Gender In Activity Documentation Roles

Gender/Major	Leader	Very Involved	Somewhat Involved	Only a Little Involved	Not Involved
Female/STEM	31%	15%	12%	4%	38%
Female/Non-STEM	37%	32%	16%	0%	16%
Male/STEM	8%	9%	18%	5%	60%
Male/Non-STEM	29%	29%	0%	0%	43%

The results displayed graphically in Figure 15 through Figure 24, and more explicitly illuminated in Table 8. Table 9, Table 10, Table 11, and Table 12, tell a story where females are disproportionately involved in tasks and responsibilities that do not require hands-on work with the robot itself, in a team competition where the robot itself could easily be viewed as the ultimate goal. Of those female participants who eventually went on to major in a STEM field, 32% took on leadership roles in robot design and 35% took lead positions in robot build. For comparison, their male STEM major counterparts were leaders at much higher rates (47% in robot design and 48% in robot build). Conversely, in the award documentation sub-team, female STEM (65%) and non-STEM (47%) majors surpassed males in leadership roles (14% and 29%, respectively). Additionally, the male STEM majors took on leadership roles in activity documentation at extremely low rates; only 8% of male STEM majors responded that they were leaders on their sub-teams.

A cautious conclusion, in conjunction with the results from Boyer's (2011) study, would be that the rate of female participants in FIRST is higher than in engineering in general. I use the word "cautious" because special attention must be paid to those roles in which females tend to be more involved, specifically those less directly related to STEM. It is possible that those female participants who were more involved in activities such as community outreach and award documentation had little interest in STEM from the outset. On the other hand, perhaps those participants in particular are a perfect target for FIRST's mission to inspire students to pursue STEM careers. Regardless, my analysis does indicate that gender and role played on a FIRST Robotics team are not independent.

Discussion

My research question asked whether there was a relationship between the role that FRC participants had on their teams and their subsequent academic and career trajectories. The goals of my study were to evaluate the roles that alumni had played on their teams, and compare their involvement to the personal characteristics of major, career path, and gender. I conducted chi-square analysis to determine if role played and major or career path and gender were independent from or if role was associated with career path or gender.

Relationship Between College Major and Role on FRC Team

From the chi-square comparisons, a statistically significant relationship exists between certain college majors and some of the roles those alumni played on their FRC teams, indicating dependence. The Engineering/Technology majors tended towards the hands-on activities with the robot (design and build), while the Business majors were less involved in those activities. One possible explanation for this association is that those team members who were drawn to the hands-on engineering aspects of the team were also those who were predisposed to an interest in engineering and technology. Alternately, though, team members who were not given a chance to take on larger roles in robot design and build might have gained an affinity for those kinds of activities if they were encouraged towards those sub-teams. Yet, the data I present in Table 5 show that a majority of the study participants were involved to at least a small extent in almost all of the sub-teams, which prompts the question of why some participants were not involved to a greater extent. Was it because they disliked the responsibilities of those roles, or because they were not allowed (either by teammates or mentors) to continue their involvement, or because they simply decided to pursue further involvement in other sub-teams instead? Determining the relationship between role extent and persistence in the role is an excellent direction for future research. The nature of my sample could also have contributed to these results, since the more involved FRC alumni were likely to continue to be involved in the FIRST community through modes such as email contact with their regional directors and membership on the FIRST Alumni Facebook page.

For team responsibilities related to activity documentation, the Humanities, Sciences, and Business majors were all skewed towards greater involvement, whereas Engineering/Technology majors were skewed towards lesser involvement. Since work in the sciences can tend to be very documentation-based, specifically documenting work in the lab or in the field, I find it fitting that the Sciences majors deviated most from the expected values in Activity Documentation. Because the activities that were being documented were STEM activities and were more directly related to science than to business or humanities, potentially explains why Sciences majors were more involved than Business or Humanities majors in documentation activities. I propose that the Sciences majors were aware of their affinity for STEM while in high school, yet were not as fascinated with the engineering aspects of the team such as robot design and build; so a logical progression is that, in order to be somewhat involved in the scientific reasoning aspects of the team, they tended to choose to play a greater role in Activity Documentation.

Relationship Between STEM Career and Role on FRC Team

As displayed in Figure 12, the participants who were currently working STEM fields tended to have been more involved in the robot build on their FRC teams than expected. They also were less involved in award documentation and community outreach. Because of the engineering focus of building the robot, I would expect that this would be the case, as the build is an application of STEM knowledge. I also believe that so much time and energy may have been put towards the robot build that little was left for any other activities, particularly those that may have seemed far from anything having to do with the actual robot. Thus, it is possible that the build consumed the STEM majors' time, leaving no time for other team activities. Additionally, award documentation and community outreach are arguably the least engineering-oriented sub-teams of all the options included in the instrument. Award documentation is less of a scientific or engineering endeavor, and relies heavily on the verbal abilities of the applicants to depict the activities of the team, mentor, or team member who is being nominated (FIRST, 2013b; Oppliger, 2001). Thus, the students who were leaders in award documentation and community outreach likely had an affinity for community building and communication, areas that I speculate are not typically attractive to students who have an affinity for STEM learning.

Qualitative Analysis of Open-Ended Responses

The qualitative information provided by the open-ended responses provides interesting perspectives on the influence of FIRST on participants' choice of major or career trajectory, as well as what influenced their choice of team roles in the first place. Of those who responded, over half (52%) chose their roles according to prior interests or skills. The data supports my prior argument that many of the participants who played a large role in robot design and build were already inclined to pursue engineering and technology majors.

The qualitative data on the influence of the participants' roles on their educational and career choices showed positive results with regard to FIRST's mission to inspire students in STEM. Of the 49 responses, 39% claimed that their involvement helped them to realize a career towards STEM that they otherwise would not have. Another 39% of responding participants were coded as having felt confirmation that they were pursuing the right field for them. With the current deficit in high school graduates interested in pursuing STEM degrees (BHEF, 2011), it would be productive to determine ways to recruit more students onto FIRST teams for the purpose of inspiring students in career paths they had not previously considered, such as the Business major who now wants to inspire youth in STEM careers, in addition to retaining those students who already have a STEM career path in mind. A number of possibilities exist for how the structure of

FIRST inspires students in STEM careers. For the participants who were already certain of their general interests, FIRST Robotics provides a platform for experimenting with the various engineering, technology, and scientific topics involved in the team. For those who join their FRC team unsure of their career path, FIRST presents a world of new opportunities for these participants to experience. Good mentorship and teacher advisors provide role models and subject matter experts for participants to consult about possible college and career options. Although my results may not hold enough weight to deem FIRST's mission a success, they certainly bode well for a positive trajectory towards inspiring students to pursue STEM careers

Relationship Between Gender and Role on FRC Team

My final analysis compared participants' gender to their roles on the team. A comparison to their expected values shows that females tended more towards community outreach, award documentation, and activity documentation, while males tended towards robot design and build. I also calculated the percentage among female participants and percentage among male participants who responded with their level of involvement in those particular sub-teams, and the results are in Figure 20, Figure 21, Figure 22, Figure 23, and Figure 24. When examined this way, the data show how much more involved the females are than the males in the activities of community outreach, award documentation, and activity documentation. Likewise, the graphs present an obvious disparity between the percentage of male participants in leadership roles on the robot design and build sub-teams and the percentage of female participants on those same teams. Table 8, Table 9, Table 10, Table 11, and Table 12 further detail the results, showing that even the female participants who went on to major in STEM specialties did not lead the robot design and build sub-teams at rates as high as those of the males who majored in STEM areas. In STEM fields that continue to be male-dominated, females could easily feel hesitant or even discouraged from taking on leadership roles. Additionally, depending on the composition of the mentorship base, females could feel either motivated towards or discouraged from greater involvement in leadership on specific sub-teams.

An interesting trend that I noticed was in Figure 23, regarding award documentation. While 58% of the female participants responded that they were leaders in award documentation, relatively high numbers of male participants responded that they were very involved or somewhat involved (22% and 15%, respectively). What I gather from this data is that while the females on the team were drawn to the non-engineering activity of writing content for award nominations, those same female leaders received substantial input from the males on the team who were actually involved in the hands-on activities required to create the robot itself in order to compile thorough award submissions. Thus, there was a sizable percentage of males who had significant involvement in award documentation.

Limitations of the Study

Foremost, the results of this study are limited by the sample of the alumni population. Because FIRST headquarters is unable to share personal contact information for any participants, nor does FIRST maintain extensive alumni records, the participants were a self-selected sample. I also assumed that each participant provided honest answers, and was indeed an FRC alum.

Additionally, the majority of the questions were limited by the choices provided. Open-ended responses were included, and some participants provided insightful details in that way. But these could not compensate for the limitations of the questions themselves.

Another limitation of the data were the participants who chose more than one major, especially those whose majors differed from each other, such as Humanities and Engineering. I eliminated those participants from my analyses regarding major, in order to maintain a segregated data set. Future studies could either require participants to rank the priority of their majors, or ask deeper questions, such as the area with which they feel the most connection.

A less obvious limitation is that in my comparison of participants currently working in a STEM field and those not currently working in a STEM field, many of those not working in STEM only responded in that way because they were still in school or seeking work in STEM. Still others did not desire a career in a STEM field. Providing more options for response, or expanding the survey population, could eliminate this limitation.

Suggestions for Further Study

Larger Participant Population

It would be worthwhile to repeat this study with a larger population of alumni. The results could be compared and correlated to those of the Boyer (2011) and Melchior et al. (2005) studies. There is also the possibility that a larger participant population would provide more statistically significant results. Additionally, a larger population could generate more participants of different demographics, which would provide additional points of comparison.

Additional Sub-Team Options

In the open-ended responses, four other sub-teams emerged that could have been included in a future instrument as options: the electrical/wiring team, the pit crew, the scouting team, and the drive team. The pit crew consists of students who work on the robot at the competitions. Scouting is an essential part of the competition as well, where team members observe other teams to determine what their strengths and weaknesses are. The drive team is the group of students that actually remotely operate the robot during the matches in competition. It is possible that the inclusion of these other sub-teams would produce further correlations between role and career trajectory.

Female Involvement in FIRST

Pursuing additional study regarding the involvement of females in FIRST seems essential. Investigations on what motivates females to join, particularly where the motivation is different from males, as well as the outcomes of female as opposed to male participation could produce interesting results. Since there exist at least a few all-girl FRC teams (Fe Maidens Team #2265, Girls of Steel Team #3504, and The Fighting Unicorns Team #2399), some thought-provoking studies could be conducted utilizing the unique team compositions as a control.

More Community Outreach

This study found that FRC alumni who were currently working in a STEM field were less inclined to be involved in community outreach activities on their respective teams. It would be interesting to study whether those same participants currently participate in community outreach associated with STEM. In order to recruit more students to study STEM in college, and thus work in associated fields post-graduation, exposure to STEM is essential (DeJarnette, 2012). When FRC teams visit local elementary and middle schools to demonstrate their robots, chances of sparking children's interest in STEM increase. Additionally, those who are doing the hands-on work on the robot (designing and building) have insights that others on the team do not. Encouraging those team members to be more involved in community outreach would possibly increase future team interest, as well as promote STEM in general. And FRC alumni could potentially be the best mentors possible for a current FIRST Robotics team, so studying how to encourage alumni to participate in outreach is a logical research path.

Personal Interviews

In order to supplement my data, interviews could be conducted, through email, telephone, or face-to-face. More in-depth questions could be answered regarding motivation for choosing certain sub-team roles and persistence in the pursuit of a STEM career. Additionally, anecdotal stories could provide insight into personal experiences on FIRST teams around the world.

Longitudinal Study

Perhaps the ultimate data source, a longitudinal study could provide accurate information regarding FRC participants’ team experiences, educational pursuits, and career paths. By documenting their behavior over time, alumni would be able to continually inform FIRST teams and the FIRST organization regarding the impact of FIRST and other outside factors.

CHAPTER FIVE: IMPLICATIONS AND CONCLUSION

Implications

There are a number of potential implications for my study. Most of the implications are programmatic, indicating that the structure or processes of FIRST Robotics may need to be considered to address some of the issues that my research has exposed. Further, there may also be implications for who is involved and the ways that they interact with teams. My detailed exploration of these implications follows.

Provide a Wide Variety of Experiences

My study provides additional data to support Boyer's (2011) conclusion that FIRST is inspiring high school students to pursue career paths in STEM fields. Yet my research also revealed not all participants decided to pursue STEM careers, and some participants were even turned away from STEM careers by their experiences. By providing an opportunity for participants to engage in a wide variety of sub-team roles, FIRST teams can help ensure that students understand what is truly involved in such a multi-faceted event and explore roles that can help bring clarity to their career choices. The current limitation of role engagement should be examined to determine how students can experience a wider range of roles that provide experience that is associated with a wider range of career trajectories.

Encourage Leaders to Take on Other Roles

I also proposed that because leaders of sub-teams become so engrossed in one or two specific areas, they are less likely to experience other parts of the team. Although these leaders are necessary, perhaps encouraging them to try areas outside their comfort zones would inspire students in ways they had not anticipated. For example, engaging in all of the aspects of a STEM-based project, not only the building, affords a team member the opportunity to more fully appreciate what is involved in a successful team.

Additionally, all team members would benefit from learning what is involved in being a good follower, not just a good leader. Table 5 shows a distribution of involvement in each of the sub-teams in which participants are taking on multiple roles. By ensuring that team members know how to both lead and follow, FIRST alumni will be able to contribute fully in any capacity that they find themselves, particularly those requiring collaboration.

Encourage Females to Lead in Robot Design and Build

The percentage of females in STEM fields is still significantly smaller than males. In order to overcome this, we must enhance high school girls' perceptions of the abilities, thus increasing their competence, capabilities, and success as leaders in areas where boys have historically dominated. Providing female mentors and advisors, recruiting more female team members, and encouraging those team members to take on leadership roles will help overcome this historical barrier. Research (Platz, 2012; Tyler-Wood et al., 2012) has already shown that females are influenced to pursue STEM careers when mentored by females in those fields. Increasing the number of female mentors on FIRST Robotics teams would be a logical step. These female mentors would be able to encourage more girls to join FIRST Robotics, as well as provide role models for future career paths.

My data also revealed that female participants who went on to major in STEM areas were not as likely as male STEM majors to take leadership positions in robot design and build on their teams. Wittmer (2001) has reported on perceptions of female leadership styles in outdoor education settings, where women are historically subordinate to men, much like in STEM careers. In experiential education, females who lead with more masculine methods and qualities are perceived as less appealing than males who have the same leadership style. Simply by understanding the differences in male and female leadership, and by being aware of the cultural preconceptions, FIRST teams can empower their female members to step up to roles as leaders.

A New Team Order

The implications I have discussed could revolutionize the FIRST Robotics team structure on many teams. At certain points throughout the season, sub-team roles could become more fluid, allowing, or perhaps even strongly encouraging, participants to try different areas of the team. During these more fluid periods, ideally once at the beginning of the school year, and at least one more time near the build season kickoff, mentors or teachers could offer specific leadership training. The training would explain and demonstrate different, yet appropriate and effective, leadership styles, as well as the characteristics of a successful team player, to all team members. Throughout these phases, mentors would be present, providing input whenever necessary, guiding the students, acting as subject matter experts, and providing copious opportunities for learning and inspiration.

Conclusion

The survey instrument I designed for my study was intended to test the hypothesis that FIRST Robotics alumni educational and career paths were related to the role(s) in which team members were involved as students. According to my research findings, there are three main conclusions. First, greater involvement in designing and building the robot was related to pursuit of an engineering or technology degree. Second, majors in the sciences tended to be more involved in activity documentation. Finally, those who obtain business-related degrees are less involved than statistically expected in robot design and build.

The data also led me to conclude that those alumni who were currently working in a STEM field were more likely to participate in the robot build sub-team, while they were less likely than expected to be involved in award documentation and community outreach. The lack of experience that these participants in STEM careers have with documentation and outreach could have very real implications for the future of employable STEM graduates, as well as the FIRST mentor base.

The data available to compare male and female participation and career choice show many paths for further research. Females led robot design and build at much lower rates than males, while males participated to a much lesser extent than females in community outreach, award documentation, and activity documentation. When I expanded my analysis to examine role by STEM and non-STEM majors, I found that female STEM majors were less likely to lead than male STEM majors in robot design and build.

The open-ended responses reveal that there is more to an FRC team experience than that which can be easily quantified. Although further study, both quantitative and qualitative, is necessary to continue to learn more about how to successfully inspire students through activities such as the FIRST Robotics Competition to pursue careers in science, technology, engineering, and mathematics, immediate opportunities exist to improve upon the already-successful program.

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APPENDIX A

Copy of Online Survey Instrument

Influence of FIRST Robotics Participant Roles on College and Career

INFORMED CONSENT
Boise State University
College of Education

TITLE OF STUDY: Influence of FIRST Robotics on Alumni College and Career Choices
INVESTIGATOR(S): Christine Chang, Dr. Louis Nadelson
CONTACT PHONE NUMBER: (208) 426-2856
CONTACT EMAIL(S): christinechang@u.boisestate.edu, louisnadelson@boisestate.edu

The purpose of this study is to determine whether participation in FIRST Robotics has an influence on the educational and career choices of alumni. The survey is designed to assess your experiences and motivations while participating in the FIRST Robotics Competition.

By completing the survey you are agreeing to allow us to use your responses. You may withdraw from the study at any time. You are encouraged to ask questions about this study at any time via the contact information described above. You may refuse to participate in this study or to give us permission to use your data.

Research at Boise State is conducted under the oversight of the BSU Institutional Review Board. Questions or concerns about research participants' rights may be directed to the BSU IRB office, telephone: (208) 426-5401.

All information gathered in this study will be kept completely confidential. Your privacy will be safeguarded and all information gathered will remain confidential.

By completing the following survey I am consenting to participate and allowing my data to be used in research. I am at least 18 years of age.

*1. Did you participate in the FIRST Robotics Competition as a high school student?

- Yes
- No (If not, please exit the survey.)

2. Please choose your AGE:

3. Gender:

Female	Male
○	○

4. Ethnicity:

- African American
- Native American
- Asian
- Latino/a
- Caucasian
- Other, please specify

Influence of FIRST Robotics Participant Roles on College and Career

5. Year of high school graduation:

6. Highest level of education

7. What is your current education status?

8. What is/was your major?

- ☐ Business
- ☐ Education
- ☐ Chemical Engineering
- ☐ Mechanical Engineering
- ☐ Civil/Environmental Engineering
- ☐ Aerospace/Aeronautical Engineering
- ☐ Electrical/Computer Engineering
- ☐ Biomedical Engineering
- ☐ Engineering - Other
- ☐ Computer Science
- ☐ Mathematics
- ☐ Science - Biology
- ☐ Science - Chemistry
- ☐ Science - Physics
- ☐ Science - Other
- ☐ Social Sciences
- ☐ English, History, or other humanities
- ☐ Visual or Performing Arts

Other (please specify)

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9. Have you worked full-time in a STEM (science, technology, engineering, or mathematics) field?

- Yes
- No

10. If so, for how many years (round to the nearest year)?

11. Are you CURRENTLY working in a STEM (science, technology, engineering, and mathematics) field?

- Yes
- No

12. If not, why not?

13. For how many years were you a student participant in the FIRST Robotics Competition?

- 1
- 2
- 3
- 4

Other (please specify)

The following questions regard YOUR ROLE on your FIRST Robotics Competition team.

14. Did you play a role in RECRUITMENT of new team members?

- Yes
- No

15. If yes, HOW were you involved in recruiting new team members?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

Influence of FIRST Robotics Participant Roles on College and Career

16. Did you play a role in FUNDRAISING for your team?

- ○ Yes
- ○ No

17. If yes, HOW were you involved in fundraising?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

18. Did you play a role in COMMUNITY OUTREACH for your team?

- ○ Yes
- ○ No

19. If yes, HOW were you involved in community outreach?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

20. Did you play a role in ROBOT DESIGN?

- ○ Yes
- ○ No

21. If yes, HOW were you involved in robot design?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

22. Did you play a role in BUILDING your team's robot?

- ○ Yes
- ○ No

23. If yes, HOW were you involved in building your team's robot?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

24. Did you play a role in PROGRAMMING your team's robot?

- ○ Yes
- ○ No

25. If yes, HOW were you involved in programming your team's robot?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

Influence of FIRST Robotics Participant Roles on College and Career

26. Did you play a role in preparing DOCUMENTATION for any team AWARDS (for example, the Chairman's Award, Woodie Flowers Award, or Entrepreneurship Award)?

- Yes
- No

27. If yes, HOW were you involved in preparing award materials?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

28. Did you play a role in creating an ANIMATION for competition?

- Yes
- No

29. If yes, HOW were you involved in creating an animation?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

30. Did you play a role in compiling team ACTIVITY DOCUMENTATION?

- Yes
- No

31. If yes, HOW were you involved in compiling team activity documentation?

Only a little involved	Somewhat involved	Very involved	Leader
○	○	○	○

The following questions regard the influence of your team role(s) on your educational and career choices.

32. Do you feel that your particular role(s) on your FRC team impacted your choice of college major?

- Yes
- No

33. Did your particular role(s) on your FRC team impact any jobs, internships, externships, or other professional activities that you completed DURING your college experience?

- Yes
- No

Influence of FIRST Robotics Participant Roles on College and Career

34. Did your particular role(s) on your FRC team impact your career choice(s) after graduating from college?

- Yes
- No

35. Please share any additional information that you feel would help us to understand what influenced your choice of team role(s) on your FIRST team.

36. Please share any additional information that you feel would help us to understand how your choice of role(s) on your FIRST team influenced your educational and career choices.