Walden University

College of Education

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Cecilia Craig

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Walden University
2014

Abstract

How Robotics Programs Influence Young Women's Career Choices: A Grounded Theory Model

by

Cecilia Dosh-Bluhm Craig

MSE, California State University, Fullerton, 1978

BSME, The Ohio State University, 1974

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

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Abstract

The fields of engineering, computer science, and physics have a paucity of women despite decades of intervention by universities and organizations. Women's graduation rates in these fields continue to stagnate, posing a critical problem for society. This qualitative grounded theory (GT) study sought to understand how robotics programs influenced young women's career decisions and the program's effect on engineering, physics, and computer science career interests. To test this, a study was mounted to explore how the FIRST (For Inspiration and Recognition of Science and Technology) Robotics Competition (FRC) program influenced young women's college major and career choices. Career theories suggested that experiential programs coupled with supportive relationships strongly influence career decisions, especially for science, technology, engineering, and mathematics careers. The study explored how and when young women made career decisions and how the experiential program and its mentors and role models influenced career choice. Online focus groups and interviews (online and face-to-face) with 10 female FRC alumnae and GT processes (inductive analysis, open coding, categorizations using mind maps and content clouds) were used to generate a general systems theory style model of the career decision process for these young women. The study identified gender stereotypes and other career obstacles for women. The study's conclusions include recommendations to foster connections to real-world challenges, to develop training programs for mentors, and to nurture social cohesion, a mostly untapped area. Implementing these recommendations could help grow a critical mass of women in engineering, physics, and computer science careers, a social change worth pursuing

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Dedication

I would not have made this journey without the support of my husband, Tim. We have been married over 40 years, meeting at the Ohio State University where we studied engineering. He has been with me every step of my career and a true partner. Throughout my doctoral pursuit, he has nudged me, shared ideas and counterpoints, and always pushed me to think more deeply. Thank you, my dearest friend and partner—my hero.

Without the influence of two other heroes and an experience, I would not have pursued an engineering career. When I was a high school junior, my chemistry teacher and mentor, Tom Ostertag suggested I apply for a 6-week National Science Foundation summer program exploring engineering. This was the summer the United States landed men on the moon and I came back from that cathartic experience inspired to study engineering. A family friend, Mary Murai, was also an influential role model. She and her husband, a chemist, had been fellow college students with my father. Since my father (who died when I was 9 years old) had been a civil engineer, I assumed that Mary, too, was an engineer. I wrote to her about my plans to pursue engineering and she encouraged me. Only after I graduated as a mechanical engineer in 1974—one of only 66 female recipients of bachelor degrees in mechanical engineering in the United States that year—did she share that her profession was actually nursing, not engineering. She felt that I needed to know a woman could be an engineer, and wisely did not tell me until I was already a working engineer. Although many other people have helped me along the way, these three people (heroes) and that one experience were crucial in inspiring me to become an engineer.

Acknowledgments

First, I must gratefully acknowledge and thank Dr. Norma Mertz, who agreed to let me use her supportive relationships model and understood my modification to it for this study. I appreciate her openness and interest in my work. I would not have successfully made it through this journey without the help of Dr. Sharon Johnson, my advisor and committee chair; Dr. Sigrin Newell, the methodology expert on my committee; and Dr. Asoka Jayasena, the University Research Reviewer. I greatly appreciate and acknowledge their many suggestions and feedback; their support made things happen and I could not have done it without them. Dr. Basil Considine provided substantive writing suggestions for which I am grateful. All errors are of course my own.

Thanks are also due to the Western Region Robotics Forum and ChiefDelphi, who agreed to allow me to send or post messages looking for study participants. Thank you also to For Inspiration and Recognition of Science and Technology (FIRST), for providing data from their studies. Finally, thank you to FIRST mentors and teachers who reviewed the prototype model, and to the researchers from FIRST who helped me hone it.

On a lighter note, I cannot thank enough the people in the service industry who helped me work for hours most afternoons during lunch or a pedicure, earphones in, focused on laptop and my work. Their interest in what I was doing pushed me along.

Last but not least, my sincere thanks go to the young women who shared their stories with me and responded with such openness and sincerity to my questions. Their assistance helped me to build this model, which I hope will eventually help grow the numbers of women in engineering, physics, and computer science.

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Chapter 1: Introduction to the Study

Background

Men have been the primary earners of science and engineering degrees in the United States since American universities first began granting these degrees in the late 1800s. While many women in the United States have since entered certain Science, Technology, Engineering, and Mathematics (STEM) fields, women are still not earning degrees at the same rate as men do in engineering, physics, and computer science. This discrepancy has persisted despite decades of programs aimed at bringing more women into these fields. This study explored what factors influenced young women to choose a career, after being part of one such program.

Today, in a number of historically male dominated fields (e.g., medicine, law) and in certain STEM fields (e.g., biology, chemistry, mathematics), women have achieved parity with men: this is not true in engineering, physics, and computer science fields. Annually, women earn about 20% or less of bachelor degrees in those fields. The situation has not improved in the past decade (NSF, 2013). (See Figure 1 and Figure 2). The percentage of women earning bachelor degrees in computer science, less than 1% in 1966, rose to a 1984 peak of 37.2% and then declined at a (mostly) steady rate to 17.7% in 2008, with a slight increase to 18.2% in 2010. Engineering increased steadily from 1% in 1966 to 14.1% in 1984, grew slowly over the next 16 years to a peak of 20.9% in 2000, and has slowly declined since to 18.4% in 2010. In physics, women earned about 5% of bachelor degrees in 1966, also rising through subsequent decades reaching a peak of

22.6% in 2002, but moving up and down below that peak since then. These low numbers stand in sharp contrast to other STEM fields, where in recent years women graduates earned 44-50% of the bachelor's degrees in fields such as mathematics and chemistry and up to about 60% of the bachelor's degrees in the biological sciences (NSF, 2013).

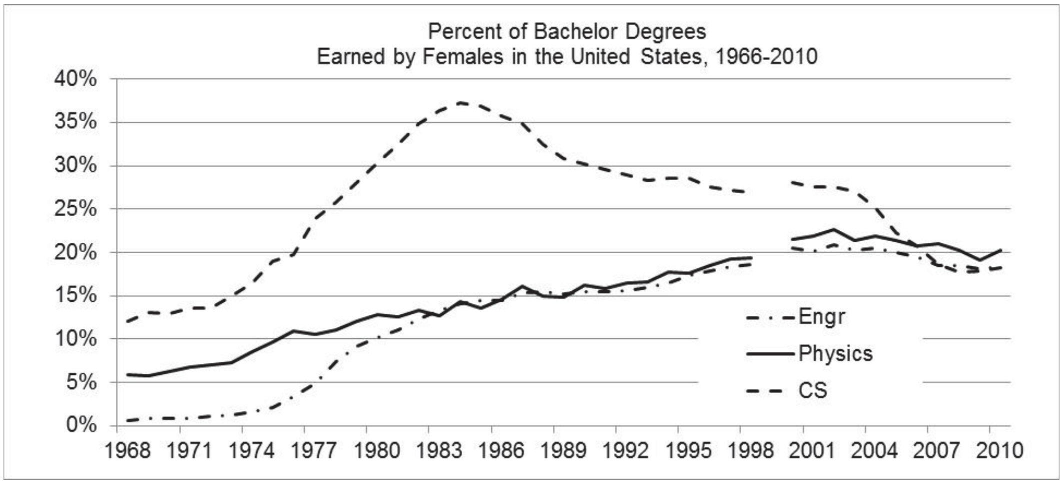

Figure 1. Percent of bachelor degrees in engineering, physics, and computer science earned by women in the United States, 1966-2010. Adapted from Science and Engineering Degrees: 1966-2010. Detailed Statistical Tables (NSF 11-327) by National Center for Science and Engineering Statistics, National Science Foundation, 2013, pp. 52-53, 59, 70. Retrieved from http://www.nsf.gov/statistics/nsf13327. Note: detailed national data were not released for the academic year ending in 1999.

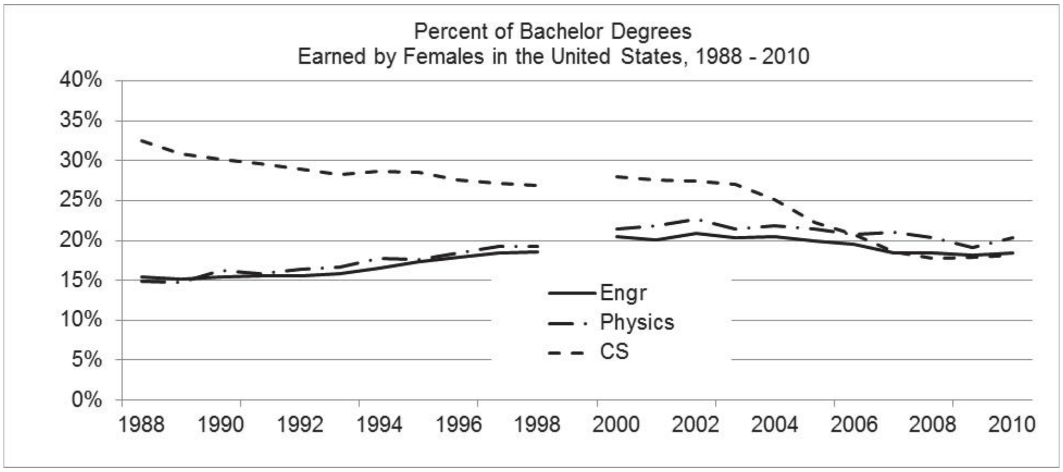

Figure 2. Percent of bachelor degrees in engineering, physics, and computer science earned by women in the United States, 1988-2010. Adapted from Science and Engineering Degrees: 1966-2010. Detailed Statistical Tables (NSF 11-327) by National Center for Science and Engineering Statistics, National Science Foundation, 2013, pp. 52-53, 59, 70. Retrieved from http://www.nsf.gov/statistics/nsf13327. Note: detailed national data were not released for the academic year ending in 1999.

Two problems arise from the lower percentages of women in these fields of engineering, physics, and computer science. First, society loses the innovative ideas and creative solutions that would otherwise have been generated by a large portion of its workforce. Second, fewer women have the opportunity to grow in a lucrative career. STEM occupations generally pay well with average salaries “significantly above the U.S. average” (Cover, Jones, & Watson, 2011, p. 3). Moreover, seven out of the top ten (employment numbers) STEM positions of 2009 (Cover et al., 2011) had computer in their job title (e.g., computer system analyst). If women do not enter these high paying fields, they are closing a door in “a growing job market—and society loses needed mathematicians and scientists” (Huebner, 2009, p. 1). With women earning less than 18% of computer science bachelor degrees (NSF, 2013), the top STEM positions are unlikely to be filled by women.

This ongoing gender gap has severe repercussions. According to the National Academies (2006), women's lack of parity in engineering, physics, and computer science careers hurts the ability of the United States to create and continue technical innovations, a significant economic loss for society. A study by Katehi, Pearson, and Feder (2009) argued that American innovation in technology would be fueled by women's creativity and passion. If women do not enter these typically highly paid professional careers despite having the ability to be successful in them, women are missing out (National Academy of Engineering, 2008; National Academies, 2006).

A body of thought existed in the past asserting that girls had *math fright* or were not as capable in math and science as boys. Research has demonstrated that women are capable of being successful in these traditionally male subjects and fields (e.g., Dedic, Rosenfield, & Jungert, 2010; National Academies, 2006). "They are just as [good], but don't enjoy it" (S. U. R. Rosenfield, personal communication, May 12, 2010). Talent, aptitude, and skills are not the obstacle; the issue is choice (Ceci & Williams, 2010). Young women are not aspiring to those careers (Perez-Falkner, 2010). The problem is why not.

Consider this bold statement by Institute Professor Sheila Widnall (2000) from the Massachusetts Institute of Technology:

> If women don't belong in engineering, then engineering as a profession is irrelevant to the needs of our society. If engineering doesn't make welcome space for them and embrace them for their wonderful qualities, then engineering will

> become marginalized as other fields expand their turf to seek out and make a place for women. (para. 2)

The problem of low numbers of women in engineering, physics, and computer science is not new. Programs to ameliorate the trends and hostile climate have existed at many levels (elementary grades, middle and high school, university, and industry) for decades.

The success of these programs is mixed, however. The American Association of University Women evaluated about a decade's worth—1993 to 2001—of programs (416 in total) aimed at improving gender equity in the sciences (Dyer, 2004). The synthesis report described how "in the last decade alone, [AAUW and NSF] have invested nearly $90 million to fund more than 400 projects specifically aimed at increasing the participation of girls and women in STEM fields" (p. iii). The report highlighted the continued "gender gap…in the physical sciences" (p. 4) and how "adults play a key role in changing…attitudes" (p. 3). These recent efforts have not substantially altered women's presence in these fields, however.

The National Academies examined programs aimed at correcting the gender gap in STEM fields and where losses occurred. Their 2006 report determined that "women who are interested in science and engineering careers are lost at every educational transition" (p. 2): high school, undergraduate school, graduate school, and beyond. The 2006 report echoed an earlier National Academies report (Stage, 1992). This awareness of the importance of educational transition points has driven both program design and analysis.

The multi-level nature of those efforts was highlighted in the National Science Foundation's 2002 report evaluating 10 years (1993 – 2001) of its funding of programs promoting gender equity in STEM fields (National Science Foundation, 2002). During this period, the NSF spent more than $84 million (p. 1) on these initiatives; undergraduate programs received 30% of the funding, high school programs 11%, middle school programs 27%, and elementary schools 10%. The remaining 32% of the funding was spent across segments of different combinations (p. 8). Despite this funding, however, the programs evaluation report concluded that "the overarching need—to better include the female half of the population in the Nation's science and engineering enterprise—remains today" (p. 25).

This lack of success is coupled with a lack of clearly effective strategies for promoting female involvement in STEM fields. This problem can be seen in recent evaluations of *STEM pipeline programs* for young girls and young women. A 2006 evaluation of NSF STEM programs identified a scarcity of qualified STEM evaluators and a lack of the evaluation and testing instruments necessary for effective program evaluations (Katzenmeyer & Lawrenz, 2006, p. 7). Identifying changes necessary to make programs more effective is difficult without sufficient evaluators and appropriate testing instruments.

This dissertation study was designed to address these defects and perform an effective evaluation of a specific STEM pipeline program. The study sought to assess how robotics programs influence young women's career decisions, focusing on the *For*

Inspiration and Recognition of Science and Technology (FIRST®) *Robotics Competition* (FRC®).

How to Explore a Robotics Program

Career theory provided a lens to explore the influence of FRC on young women, investigating reasons for this continuing lack of parity. Many career theorists have noted that both experiential programs and role models/mentors strongly influence teen career selections (Roe, 1952; Roe, 1956: Super, Crites, Hummel, Miser, Overstreet, & Warmath, 1957; Super, 1963; Super & Bachrach, 1957; Super & Hall; 1978). This body of research suggests that experiential intervention programs including supportive relationships can inspire young women in high school to enter engineering and computer science careers and have a strong potential to improve female participation levels in those fields. FRC is a program with that potential, offering to young people, engineering type experiences and heroes in those fields (FIRST, 2010). The term *hero* was used in my study to describe a range of supportive relationships from role model to coach to mentor, as suggested by Mertz (2004).

A key aspect of this study was exploring how being part of an FRC team affected young women's career decisions. Exploring the influence of FRC on young women's college degree selections could enrich the understanding of how these types of experiential and hero based programs influence career decisions. Young female teens have been active participants in many FIRST robotics high school teams. Little research was available to assess the FRC program's influence on young women specifically. This study attempted to fill that gap and potentially demonstrate to society—its schools, companies, and parents—how intervention programs with experiential and hero components might influence young women to study in the male dominated fields of engineering, physics, and computer science.

Key elements of this study's design were guided by several preceding research studies. One study was a mixed methods evaluation of the FRC program performed by Brandeis University researchers at FIRST's behest (Melchior, Cohen, Cutter, & Leavin, 2005). Four doctoral dissertations were also identified that explored the FRC program. Hurner's qualitative ethnographical study (2009) of an all-female FRC robotics team used a "communities of practice" (p. 2) framework exploring gender nuances of social identity and "career trajectories" (p. 12); three dissertations (two quantitative and one qualitative) also considered science interest and learning from different perspectives of FRC. Griffith (2005) studied career interests of South Carolina students in a quasi-experimental study with a problem-based learning framework for FRC; Welch (2007) focused on Midwest teams near St. Louis, MO, investigating improved science understanding after participating in FRC (quantitative study); Webb (2009) explored student learning using a discourse framework, studying an FRC team in the South.

None of these earlier studies used a career theory framework and non-proprietary research on FRC influences and impacts was limited. As a result, my new study was designed to expand on prior work (Hurner, 2009; Melchior et al., 2005; Webb, 2009; Welch, 2007) by filling in the knowledge gap about FRC program female alumnae. An important contribution of this study was to explore FRC alumnae's post-FRC decision making processes after they made a career choice and entered college. Further details on career theory, its applicability to this population and program, how the prevailing literature informs the research problem, along with gaps and weaknesses in that literature are in Chapter 2. An overview of the conceptual framework used as scaffolding for a proposed theoretical model is found later in this chapter; the study model is found in Chapter 4.

Problem Statement

The continued low percentage of women earning engineering, physics, or computer science degrees in the United States is an overarching problem for American society. The significance of this problem was underscored by Recio and Gable (2007), who asserted "for the U.S. to remain competitive and to succeed in a global market, we must educate students from all demographic backgrounds and encourage more to consider STEM careers" (p. 13). Career theory suggests that experiential programs and heroes influence career decisions, in particular for STEM careers (Roe, 1952; Super et al., 1957; Super, 1969; Super & Bachrach, 1957; Super & Hall; 1978), though follow-up studies to validate this assertion for young women are limited. I chose to explore this by examining a sample high school intervention program, the FRC, that has provided those two influences—experiences and heroes—for over 20 years (Bolin, 2007).

How do robotics programs influence, positively or negatively, a young woman's long-term career decisions and do these programs grow interests in engineering, physics, and computer science careers is the core problem. Without an answer, it is difficult to implement changes addressing the continued gender gap in those fields. Prior research on the FRC program with a gender filter has been limited to a few dissertations and overview research articles. One qualitative dissertation (Hurner, 2009) explored female social identity and career paths for young women in an all-female FRC team. The few other studies have considered other outcomes (e.g., improved science understanding; Webb, 2009; Welch, 2007) or were proprietary, large-scale program evaluations (Melchior et al., 2005). None have focused on the influences of FRC on young women's career decisions. This problem is not well understood, has not been explored for young women specifically, and was the subject of this dissertation study.

Conceptual Framework and Study Overview

Purpose of the Study

The main purpose of this qualitative study was to explore how a high school robotics program (i.e., FRC) influenced young women's college major (career) choices. One of the study outcomes was specific recommendations for improving this and other such programs to better inspire young women so as to enter careers in engineering, physics, or computer science (see Chapter 5).

Conceptual Framework

The career theories developed by Super and Roe describe how both experiential programs and role models influence teen career selections (Roe, 1952; Super et al., 1957; Super, 1969; Super & Bachrach, 1957; Super & Hall; 1978). This conceptual framework was the support structure for this dissertation study's exploration of how FRC programs influence young women's career decisions. Remaining open to alternative influences and differences beyond heroes and the experience itself was important for grounded theory processes (Charmaz, 2006).

Research by Super (1957, 1969, 1963) and Roe (1952) supported a notion of role models and mentors (i.e., heroes) inspiring young people to pursue certain careers, if the young person had matching skills and aptitudes (Hartung & Niles, 2000). This dissertation study explored what young women thought about the FRC program experiences and heroes they met in it; and, how it related or did not relate to what they experienced and learned from participating in the program, not whether their abilities matched those roles. These conceptual framework connections will be explained in detail in Chapter 2.

This exploration was designed using the Super (Super et al., 1957) and Roe (1952) frameworks. Holland's RIASEC theory (1963) and Social Cognitive Career Theory (SCCT) as defined by Lent and Brown (Lent & Brown, 1996; Lent & Brown, 2006) were not considered appropriate. The decision making phases outlined by Tiedemann in 1961 were groups of activities collected into "two aspects, *anticipation* and *accommodation* [emphasis added]" (Dudley & Tiedeman, 1977, pp. 290-291). Though similar to Super's lifecycle phases, Tiedeman's models did not specifically mention hero or experience influences in any depth. The exploration of influences by role models and experiential activities comes directly from specific aspects in theories by Super and Roe, putting this proposed study at the right of the research continuum described by Lynn (Laureate, 2010), exploring a theory for explanations to a problem that remains unresolved. Beginning with a foundational framework on which to explore and build was consistent with grounded theory (Charmaz, 2006, p. 16). The use of grounded theory with its focus on processes and “making the study of action central” (p. 9) kept the influence of FRC on career decisions at the forefront. In the next section, I will show the research questions and outline connections with the conceptual framework.

Research Questions

This study searched for what young women thought about their prior experiences in FRC robotics teams, what influence FRC had on their career choice (if any), explored when and how their degree program became of interest to them, and how their robotics experiences and heroes affected those choices (if they did). Two other perspectives help weave a richly textured understanding of these women’s experiences. Young women’s experiences in either single- or mixed-gender teams were one of these perspectives. The second thread was young women who made non-technical (i.e., business and liberal arts) curriculum choices. These women provided another perspective: FRC alumnae who did not choose a STEM field for college study.

The conceptual framework scaffolding was career theory and thus the primary question and first sub-question related to the young women’s career decisions and the influences of FRC on those. The next two questions considered each of the two factors, experiences and heroes. The final question captured stories about the perspective of single- or mixed-gender team influences. This one main research question with four sub-questions was the result:

1. How did the FRC program influence young women's career choices?
    a. How and when did young women make their career decisions and college program selections?
    b. How did the experiential part of the FRC program influence career choice?
    c. What FRC heroes affected the young women and how?
    d. How does a team's gender composition, that is, a single-sex versus mixed gender team, make a difference, if any?

Nature of the Study

Using grounded theory processes for data collection and analysis to hear the stories and ideas from female FRC alumnae helped develop a richly textured view of career influences, enhancing or going beyond the career theory constructs that served as a foundation. Grounded theory supported connecting the young women's stories with my own prior experience in FRC and engineering. "We construct our grounded theories through our past and present involvements and interactions with people, perspectives, and research practices" (Charmaz, 2006, p. 11). Career theory constructs—influence of experiences and heroes—were the scaffolding nodes with emergent concept nodes added as they arose in the data gathering and analysis. The young women's stories about these constructs added connections among the nodes (p. 16). Grounded theory emphasized both comparisons and researcher involvement (p. 178) making it a suitable approach to explore the research questions.

The grounded theory study participants included female alumnae from northern California FRC teams, with young women from both single- and mixed-gender teams. By including alumnae currently in engineering, physics, and computer science degree programs as well as those in other college programs, the study explored young women's alternative career choices and what can be learned from those decisions.

Participants were obtained through multiple paths: (a) emails sent to FRC alumnae using the Western Region Robotics Forum (WRRF) community; (b) outreach to teams directly through faculty and mentors known to me; and (c) outreach at *Chief Delphi*, an online, established website bulletin board for FIRST robotics teams.

In this study, the conceptual framework was laid first with initial sampling (Charmaz, 2006) feeding an online Yahoo Group using threaded conversations around discussion questions with female FRC alumnae now in college. Theoretical sampling led to intensive interviews with selected participants informed by the focus group discussion and analysis. A form of elicited text data gathering was also used: photographs, descriptions of photographs, and other images provided by the young women as exemplars of their FRC memories. Charmaz asserted that elicited texts are effective when participants view the activity as worthwhile and relevant. Participant demographics included basic information: university name, location, and what year, initial and current degree program, how many years spent in FRC teams, and what type of team (single- or mixed-gender). I use Mindjet mind mapping, content clouds (see Chapter 3) and tools in QDA Miner from Provalis Research to analyze these conversations, observations, and electronic communications for themes and ideas that informed the research questions described herein.

Definitions

Definitions and acronyms used throughout are found below with acronyms listed in Table 1 and robotics programs mentioned throughout briefly described in Table 2.

Competition phase. This phase varies in length and timing depending on the team. Some teams pay to compete in more than one regional or state event. The three-day regional (some district) events occur over the following weekends after the Stop Build date until the Championship event is held in late April. Only a portion of the total teams competing go to that final event.

Content clouds. Content clouds count the occurrence of words or phrases in a file and depending on the frequency show the word in larger or bolded font. (Cidell, 2010; McNaught & Lam, 2010). These visual images provide a relatively nuanced view of themes found in text (see Figure 7) and were principally developed from the study's codes and categories using QDA Miner features.

Coopertition®. This FIRST trademarked word represents a significant FIRST value. "Coopertition is founded on the concept and a philosophy that teams can and should help and cooperate with each other even as they compete" (FIRST, n.d.b, para. 5).

Design and build phase. For FIRST Robotics Competition (FRC), for each team, the design and build phase begins the morning of the kickoff day and lasts six weeks and two days until the Stop Build day. Kickoff is held commonly on the first Saturday in January, televised from Manchester, NH. Teams generally begin brainstorming ideas for that year's game immediately after kickoff. Once a team has selected their design, the robot is built. Software is written. Team buy materials to supplement the Kit of Parts (KOP) obtained at kickoff. Teams sometimes build game elements for practice; some teams build a second robot to practice with after the Stop Build day. Otherwise, all work stops on Stop Build day to ensure a level playing field among teams competing at the regional events across the world (e.g., Canada, United States, Mexico, Brazil, and Israel).

Experiential activities. Hands-on activities are one kind of experiential activities. FRC activities include designing, building, testing, repairing a robot, software development, and driving in competitions.

Heroes. Using Mertz's model (2004), as modified by me (see Figure 5), heroes can range from role models to mentors, including coaches, parents, and teachers.

Mind map images. As demonstrated in Figure 3, mind map images are visual representations of connections and links that are easily expanded and collapsed. Several software applications are available that accomplish this task. The mind maps developed herein and planned for the study are from Mindjet.

Table 1

Acronyms Frequently Used

Acronym	Explanation
NSF	National Science Foundation
RIASEC	Realistic, Investigative, Artistic, Social, Enterprising, and Conventional (Holland, 1963)
SCCT	social cognitive career theory (Lent & Brown, 1996)
SES	socioeconomic level
STEM	Science, Technology, Engineering, and Mathematics
SWE	Society of Women Engineers
WRRF	Western Region Robotics Forum

Table 2

Robotics Programs Overview

Acronym	Explanation
BEST™	Since 1993, as a not-for-profit, *Boosting Engineering, Science, and Technology*™ has offered a robotics competition using a standard kits of parts and requiring no entrance or kit purchase fees. The robots are built by middle- and high-school extracurricular teams over a six week period in the fall. Teams compete at regional events where the hub planning group raises money for the event and team kits. (BRI, 2011).
Botball®	Botball provides an educational robotics program where robots are built from iRobot® Create and LEGO® parts, with entrance fees of $2,500 per team (2013). (KIPR, 2012).
FIRST®	*For Inspiration and Recognition of Science and Technology* (FIRST)® founded in 1992 as a not-for-profit by Dean Kamen as a "Sport for the Mind™" (FIRST, 2012a, p. 3) initially with FRC, followed by FLL, then FTC, and Jr.FLL. (See below).
FRC®	FIRST Robotics Competition (FRC)® is a high school program. Robots are built by teams (in robotics classes or after school clubs) using a foundational kit of parts, adding others (up to a dollar limit), over a six week design and build period (January-February), then competing in regional events (March – April), and potentially in a championship event. (FIRST, 2012a). Teams pay entrance fees (~$7,000) for a kit of parts and a regional competition billet, and an opportunity win a place at the championship (additional fee if attended).
FTC®	Begun in 2006, FIRST Tech Challenge (FTC) aimed at making a competition more accessible for teams is also aimed at high school students, with lower fees, smaller robots, and a different timeline. (FIRST, 2012b; FIRST, n.d.a).
FLL®	Since 1998, FIRST LEGO® League (FLL) has involved grades 4-8 in LEGO based robots, competing in the fall and winter. (FIRST, 2012c).
Jr.FLL®	In 2004, Junior FIRST LEGO® League (Jr.FLL) opened for grade K-3, using LEGO parts to build a robot. (FIRST, 2012a)
SeaPerch	Developed by NAVSEA (U.S. Navy) as an outreach program to inspire young people to enter STEM careers. Their vision is *Teach, Build, Become* by building underwater robots out of plastic pipe and other readily available and inexpensive materials (AUVSI, 2012).
VEX	VEX competitions are aimed at middle- and high-school teams, for both in-class and club oriented teams. The competition year is relatively long with competitions from September to March, mostly locally organized, with an entrance fee of $75 (2012/13). VEX is also a platform for other robotics competitions; it was the hardware platform used by FIRST for its first years of FTC. Many schools invested in the product components. VEX's parent company, Innovation FIRST International, has maintained a relationship with FIRST. (IFI, 2012)

Assumptions

Two underlying assumptions were made for this study:

1. Participants replied honestly and openly as much as possible.
2. Northern California, the home of the young women who participated in FRC, did not represent all young women from the United States. However, this region is highly diverse and provided a reasonable scope of stories for future studies of female FRC alumnae. It was selected because it is where I am located and had ready access to finding participants, even though they might be in college in other states.

Scope and Delimitations

Other experience-based programs for high school students exist, many aimed specifically at females. Some are robotics programs, but many are not. Also, numerous programs exist that provide mentors for young women or bring role models to inspire young women about STEM fields. Only a few intervention programs were found that included both elements as a foundation. FRC is one such program. Its longevity (20 plus years) and breadth (multiple countries) made it a worthwhile program to study. Most research found on this particular program had explored or investigated students while in high school, not several years later during their college experiences. Working with college-age alumnae of FRC brought a new perspective to the research problem and intervention program.

When developing the conceptual framework for this study, I did not use RIASEC theory (Holland, 1963) or SCCT theory (Lent & Brown, 1996) that dominate career theories today. The theories of Super (Super et al., 1957) and Roe (1956) have not been as studied in recent years. However, Super's and Roe's theories probed the reasons for how career interests developed and match well with two FRC program elements: experiences and heroes. The grounded theory approach (e.g., Charmaz, 2006) supported explorations of nuances and differences in the conceptual framework leading to a construct describing this program's influence on young women's career decisions.

This study plan could be replicated in other geographic areas where FRC teams are found, or could focus instead on alumnae from FTC (high school teams, but smaller robots and less technically challenging). Alternatively, studies could focus on Jr.FLL or FLL teams involving elementary age students (see Table 2) for details on those programs). My study plan could also be used with other robotics programs, like VEX, BEST, or SeaPerch; these will be discussed briefly in Chapter 2 and are explained in Table 2

Limitations

The study included young women from only one area (California) and thus the women in this study do not represent all areas of the United States. The study could be replicated in other geographies to expand coverage. The study does not focus on the roles played by race or ethnicity; racial and ethnic factors could potentially cause differences in career influences that transcend gender, as described by Margolis, Estrella, Goode, Holme, and Nao in their seminal work, *Stuck in the Shallow End, Education, Race, and Computing* (2008) and in the earlier work of Hackett, Betz, Casas and Rocha-Singh (1992). When participants mentioned racial or ethnicity issues, though few in number, I recorded them. This remains a gap for a future, more focused study.

Throughout the study, I was aware of two biases where I strove to maintain an objective focus and first and foremost be an effective listener. As a female engineer, influenced long ago by a high school experiential program and certain heroes, I bring my own story to this narrative, though that was not relevant to this work per se. As an 11-year volunteer for FIRST and an FRC team mentor for 8 years, my own history and experiences could color what I hear. On counterpoint, these two biases provided me a level of experience somewhat different than the prior FRC program researchers and were compatible with grounded theory approaches. By hearing a variety of voices and focusing on the young women's stories, I maintained an awareness of those possible biases and worked to prevent them from having significant influence.

Significance

My study results provide recommendations for improving the effectiveness of the FRC program, especially for young women. If used, these recommendations could help FRC inspire more young women to explore the fields of engineering, physics, and computer science. Inspiring more young women to join FRC teams, helping them have a positive experience, and raising their interest in engineering, physics, and computer science careers would be true social change for the United States and young women.

These action items and findings have a strong potential to benefit four groups: (a) young women (by expanding their career choices); (b) corporations looking for more engineers, physicists, and computer scientists, as well as a more diverse pool of candidates; (c) the United States (by helping to grow a more diverse STEM workforce); and (d) the FIRST organization (enabling them to improve female participation in FRC).

Three out of four women between 25 and 54 years of age are in the workforce today; this ratio is projected to continue into 2050 (Tossi, 2006). Young women studying engineering can expect high paying careers and to earn more when starting engineering careers versus recipients of other types of bachelor’s degrees. According to a 2007 study by Terrel, women in engineering earn “70 percent more than the national average [was] in 2005” (p. 29) and the highest average starting salary for a bachelor’s degree. An ability to earn a higher salary could be an advantage to those large numbers of women in the workforce.

Bringing more women into STEM fields is also necessary to meet labor trends. Several studies point to industry needs for more graduates in engineering, physics, and computer science fields (National Academies, 2007; Terrell, 2007) because a “growing demand for technological advances means more jobs for STEM workers” (Terrell, 2007, p. 32). Companies such as Google, IBM, Boston Scientific, and Medtronic have demonstrated that they recognize this need for more engineers and scientists by providing significant support to FIRST. FRC in particular has attracted continuous interest from government agencies such as NASA that need more engineers, physicists, and computer scientists (FIRST, 2012a; FIRST, 2010). The continued lower graduation rates of women in engineering, physics, and computer science curriculums represent a problem for companies in the United States (National Academies, 2007). Social change is needed to inspire more women to enter these fields.

FIRST could help the above problems by increasing the ratios of female participants in its programs. Females have comprised 30% of FRC team members (Brandeis, 2011), 23% of FTC (Brandeis, 2011) and 30% of FLL team members (FIRST, 2012a).While the numbers of high school females active in FRC seems to be larger than in prior years to the casual observer (examining photographs from various years), it was possible that young women were being excluded from FRC teams for reasons that I explored in this study. As Betz stated in 1994 when guiding career counselors how to counsel women about a career in engineering, an "environment may be nonsupportive…we need to know more about the women who didn't make it, not just about those who did" (p. 248). Learning more about the FRC program from all perspectives could help it be more welcoming and supportive of female participants. Potential negative factors from FRC participation have not been much explored in prior studies. In summary, these young women's stories could guide FIRST and other experience and competition-based STEM programs on ways to make the programs more attractive and positive for young women.

Chapter Summary

Female graduation rates, as a percentage of total graduates in engineering, physics, and computer science, are stagnant or declining in the United States. This outcome is of grave concern (National Academies, 2006) to the United States. High school intervention programs—for this study, a 20-year old robotics program: FRC—are one factor that might change this picture for young women. Understanding why and how programs of this type are effective and identifying ways to improve them can effect social change and improve female graduation rates in these fields. The voices of the young women in these programs have not been heard in previous studies. Instead, attention has focused on analyzing outcomes such as the number of females entering STEM careers or attitude changes towards STEM following intervention programs. Considering how young women make career decisions, especially career choices through a STEM filter, has not occurred. The influence of FRC on young women's career decisions was not well understood in previous studies. This grounded theory study addressed these gaps by involving young college women who were FRC alumnae. It explored two influential factors, experiences and heroes, using a career theory based conceptual framework.

Chapter 2: Literature Review

The For Inspiration and Recognition of Science and Technology (FIRST) Robotics Competition (FRC) program and the career theories of Roe and Super share two factors in common: *heroes* (role models and mentors) and *experiences*. Experiential programs and heroes (mentors, teachers, parents, and role models) strongly influence teen career selections (Roe, 1952; Super, Crites, Hummel, Miser, Overstreet, & Warmath, 1957; Super, 1969; Super & Bachrach, 1957; Super & Hall; 1978), though little research had explored these influences from a gender filter or specifically for engineering, physics, and computer science careers. This section outlines research involving these two factors, using a gender filter, identifying what gaps existed that this grounded theory explored.

Robotics programs such as those provided by FIRST offer both heroes and experiences to teens (Melchior, Cohen, Cutter, & Leavin, 2005). The importance of using such programs to lead women into STEM fields is underscored by the continued low percentage of women earning engineering, physics, or computer science degrees in the United States. The low percentage was described as an overarching social problem for the United States in a 2006 report by the National Academies, which noted, “The consequences of *not* acting [to improve this percentage] will be detrimental to the nation’s competitiveness” (p. 4). The study that I designed addressed this problem by exploring the influences of heroes and experiences on female teen career decisions and their college experiences. The purpose of this qualitative grounded theory study was to explore how FRC, a well-established high school robotics program, influenced young women’s college major (career) choices. My aim was to provide program improvement insights that can help FRC and other such robotics programs inspire more young women to pursue engineering, physics, or computer science careers.

What inspires or drives young persons, more particularly females, to pursue a specific career has been investigated in many studies (Stage, 1992). Over the last decades, intervention programs developed by universities (some funded by the National Science Foundation or NSF), companies, professional organizations, and other not-for-profit organizations have been successful to some degree, helping graduation rates rise above the very low numbers found before the mid-1980s. (National Academies, 2006; Stage, 1992). However, data from recent years continues to show that less than 20% of bachelor degrees in engineering, physics, and computer science fields are earned by women. (NSF, 2011).

Innovative ideas grow in a diverse environment. With a continued lack of labor diversity in engineering, physics, and computer science, innovation levels are less than would be possible otherwise. (National Academies, 2006; National Academies, 2007). Women themselves are not seeking entry into what is typically a lucrative profession (Terrell, 2007) and thus are not able to take advantage of the financial possibilities found in many of these positions. These two problems are worth solving.

Robotics programs offer a multidisciplinary intervention approach to educators and other program sponsors. They have the potential to reach many and have a history of positive influences on young women. These programs characteristically have an experiential component. Some robotics programs employed a problem-based learning (PBL) theoretical framework (e.g., Hademenos, Russell, Birch, & Wosczyna-Birch, 2010). Other non-robotics programs focused on mentoring relationships for young women and had a positive impact. Very few studies have explored the combination of these two elements—heroes and experiences—within a career theory framework for an intervention program, let alone a robotics program.

The first section in this chapter will outline the literature search strategy that informed my conceptual framework. In the next section, the key constructs of the conceptual framework are defined from a literature review foundation, followed by a synthesis of the current literature. Research gap descriptions close the chapter.

Literature Search Strategy

Using the keywords outlined in this section, my search was principally online within the Walden Library system and to a lesser extent in the online California libraries for journals not available in Walden's library, as well as my own book collection on these subjects. Other online sites used included the National Academies Press, American Educational Research Association, Google Scholar, Microsoft Research, National Science Foundation research, Women Engineer's ProActive Network Knowledge Center (WEPAN KC), and Society of Women Engineers (SWE). See Figure 3 for an overview of the literature search process that was conducted over the past several years. Most searches were for peer-reviewed articles, though in some cases this was expanded to non-peer reviewed sites providing a more textured and deeper view.

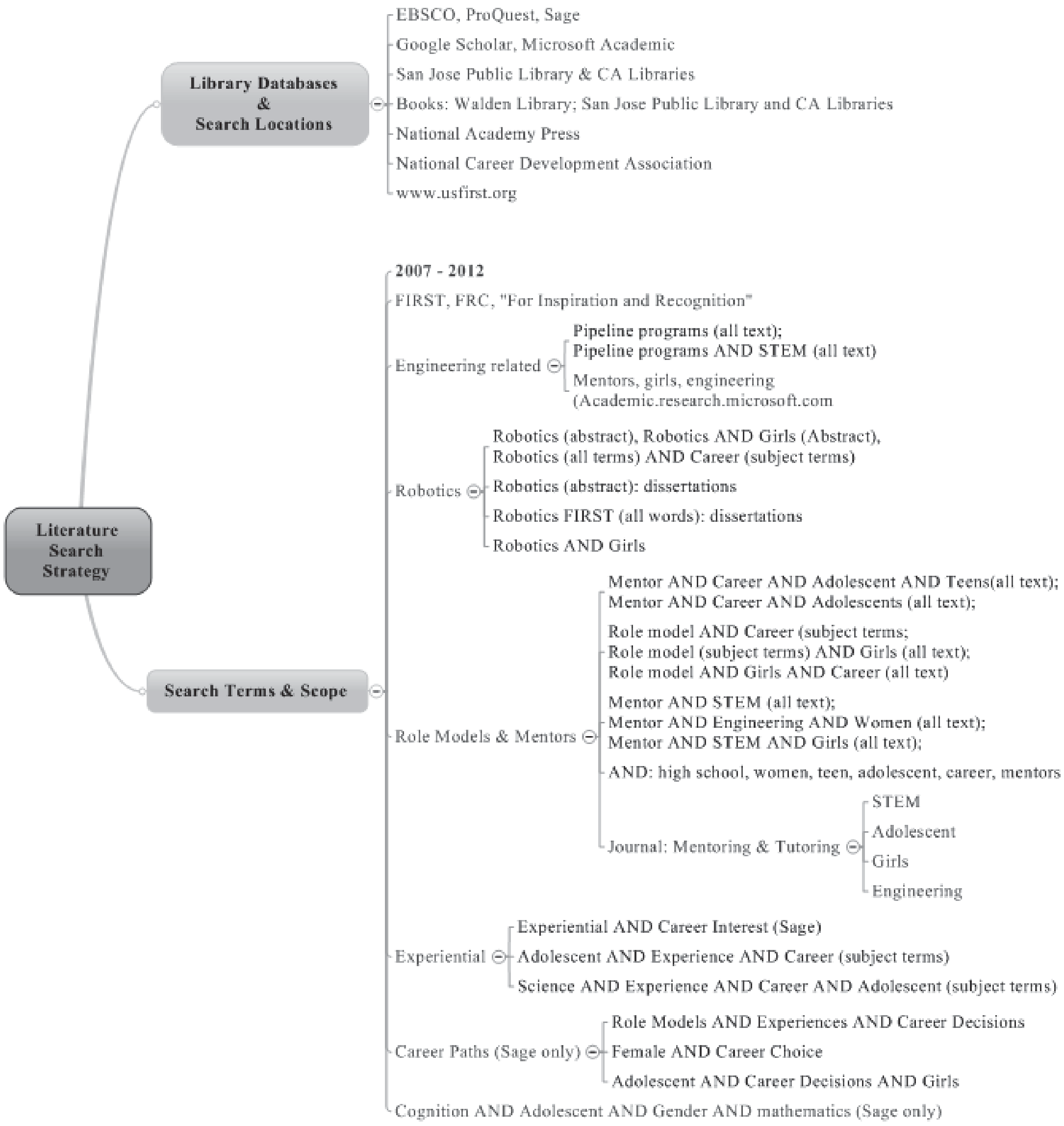

Figure 3. Overview of the literature search.

Searching for *FIRST* as a keyword proved difficult, but searching for *FRC* in all-text was more productive to find literature on FIRST and FRC. Only a few dissertations were found that studied the FRC program. Little other research in journals or peer-reviewed literature specific to the FRC program was available beyond those few. To provide context and orthogonal viewpoints, I expanded the search to include other robotics programs for high school students. In addition, searching for mentor, role model, and experiential all provided fruitful and necessary. After a time, the results began to repeat.

The next section highlights relevant pathways, ideas, and gaps from the searches, reading of specific articles, and analysis of them that lead to the final conceptual framework details.

Conceptual Framework

Career theories from Super (Super et al., 1957) and Roe (1952) were the foundation for this grounded theory study. Two elements within these, specifically experiences and heroes, were the main exploration themes. The logic behind this framework is described in the seminal research section followed by descriptions of other key career development theories that were found not to fit the research questions. Relevant applications of the conceptual framework and specific FRC research are next described, concluding with study definitions and a summary.

Defining Heroes: The Influence of Heroes on Career Selections

Career theorists (Roe, 1952; Super et al., 1957; Super, 1969; Super & Bachrach, 1957) described the role of influential persons on young people's career decisions. These heroes and their influence on young women was the first conceptual framework element for this study. To be successful, Cullen and Crowson (2010) asserted that intervention programs must address psychosocial aspects, specifically via role models, or heroes. A single encounter can make a difference for some young people, as found by Roe in her study of eminent scientists (1952, p. 104). Heroes inspire. Heroes help young people learn and see the places where they themselves might fit, considering culture and society (Holub, Tisak, & Mullins, 2008). Heroes include role models, coaches, teachers, parents, and mentors.

Role models and mentors in the FRC program have the potential to provide these contextual factors to young women. Buck, Plano Clark, Leslie-Pelecky, Lu, and Cerda-Lizarraga (2008) suggested that research did not effectively explain why and how young women identified a role model (p. 705). My dissertation study explored the impact of the FRC program heroes; and how those supportive relationships influenced or informed young women's career decisions filling in literature gaps outlined in the next sections.

Types of heroes. The words role model and mentor (and many other words in-between) mean different things. The relationships they characterize are different. Mertz (2004) suggested a model connecting two salient relationship variables—intent and involvement—using a layered triangle to show levels of supportive relationships, ranging from role model to teacher to advisor to sponsor to patron to mentor. This visual model (Figure 4) allows a range of supportive relationships to be clearly classified, described, and studied.

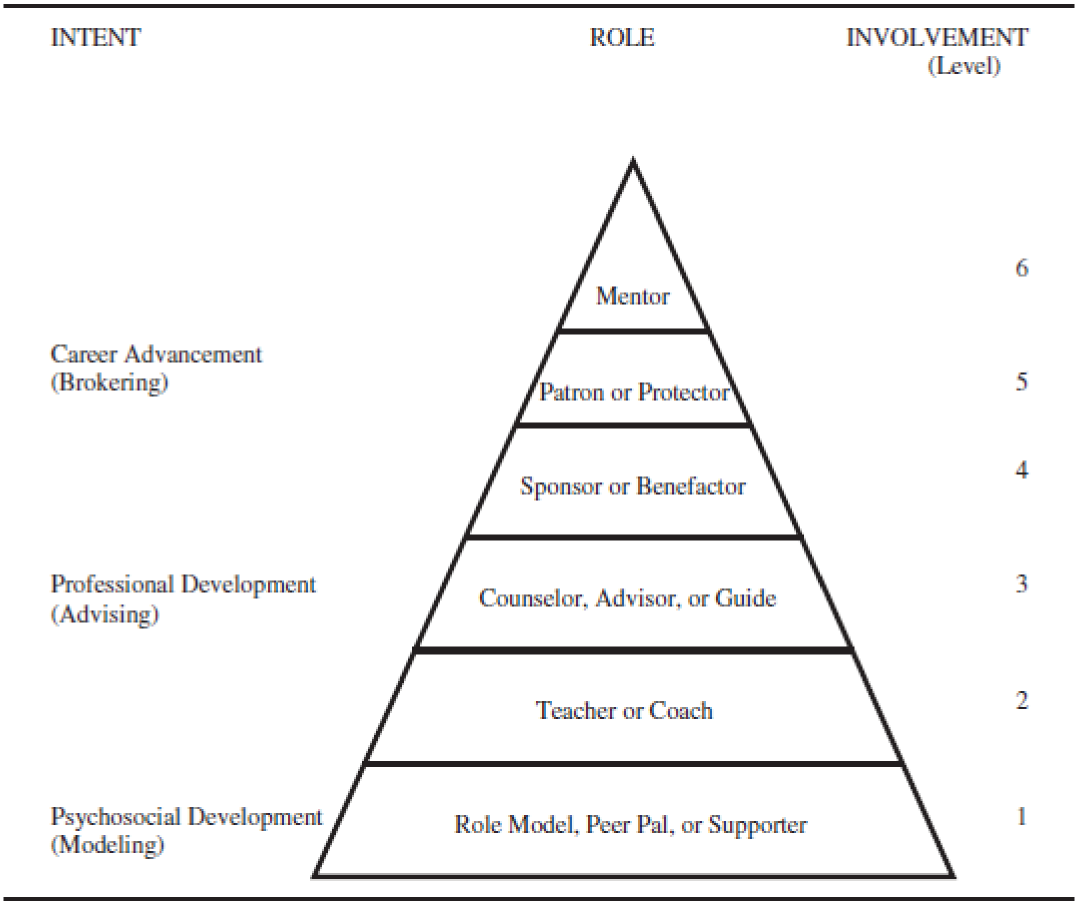

Figure 4. Supportive work relationship arranged hierarchically in terms of primary intent and level of involvement. (p. 551).

Note: Reproduced with permission from “What's a mentor, anyway?” by N. T. Mertz, 2004, *Educational Administration Quarterly, 40*(4), p. 541-560.

One other variable might be relevant to this construct; the size of influence or *reach* has a connection to involvement and intent. For example, while a mentor might have larger influence on a particular person and a single mentor might have several mentees over a time period, the mentor's reach could be characterized as smaller compared to the reach a role model likely has connecting with larger numbers of people. I posited a third variable to measure the relationship's reach (as shown in Figure 5) in a strengthening direction opposite to involvement level.

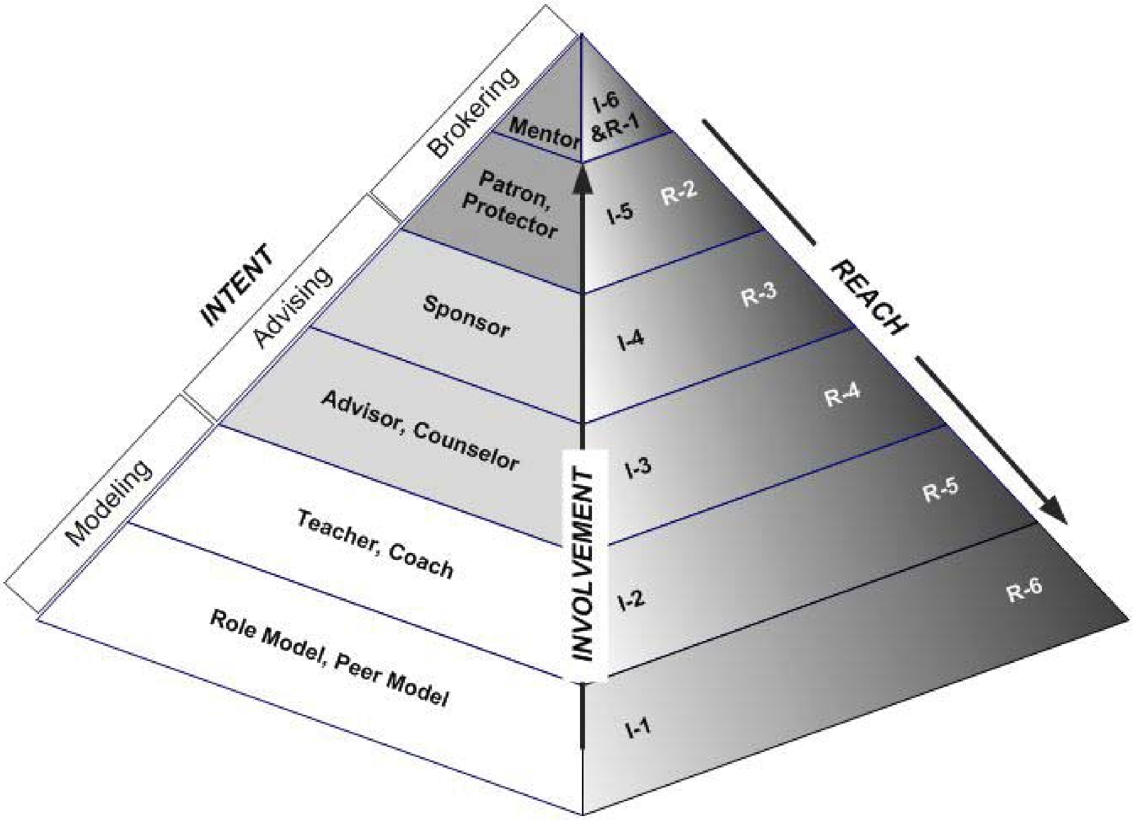

Figure 5. Supportive relationship three characterizing dimensions: Intent, Involvement, and Reach.

Note: Adapted from Mertz (2004, p. 551), with permission.

A role model's reach is exemplified by the influence Judith Weis, a biology faculty member at Rutgers, had on a young girl who went on to earn a pathology Ph. D. after seeing Weis and her young daughter in a television commercial for Tang (the breakfast drink) in the 1970s (Bonetta, 2010). "One of the factors that has inspired more women to pursue scientific careers has been having examples of successful women who have done the same" (p. 889). At the other end of the reach dimension, effective mentor programs have helped female engineers and scientists succeed in academia and women in those academic departments have reported how important mentors have been for retention in academia, gaining tenure, and navigating an institution's power structure. Thus, the modified model shown in Figure 5 includes three dimensions that were used to describe types of heroes throughout the literature review

Defining Experiential Influences for Career Decisions

The second factor of interest in my study was the influence from experiential or hands-on activities, specifically high school robotics programs. This factor, like heroes, seems obvious to many. However, the real influence of an experience on a career decision continues to be investigated and debated.

In a study of eminent scientists, Roe found "once any of [the eminent scientists] had actually carried through some research, even if of no great moment, there [was] never …any turning back" (1952, p. 81). If an FRC program can reveal the excitement of science or engineering to young people, those teens might have the same type of pivotal experience. A significant point is that "simply learning about science or mathematics as a subject was not enough; learning about the fun of solving a problem and enjoying the journey to reach that end is the catalyst" (Craig, 2009, p. 20). Experiential programs can help shape those beliefs.

Seminal Research on Conceptual Framework Elements

The essential ideas behind career intervention programs are that "development…can be guided" (Super et al., 1957, p. 14) by influencing interest development and that a specific time in a person's life might be better than another. Super described an "early exploratory stage, from age 14 to 18" (p. 38) as the time when career patterns develop, influenced by exposure to opportunities and ideas (Super et al., 1957). Ginzberg, Ginsburg, Axelrad, and Herma (1951/1966) outlined a similar period for career decision making during the preadolescent and adolescent years, "tentative choice" (p. 60). This *tentative choice* period included four stages: the interest stage from ages 11 to 12, the capacity stage for ages 13 to 14, the value stage for ages 15 to 16, and finally, the transition stage for age 17-plus. These periods and stages posited by Ginzberg have many similarities to Super's career life plan and some differences (Sharf, 1992).

Both life cycle theories developed periods and stages drawing on research with predominantly white males from higher SES levels. Considering what Super wrote in 1957 (1978/1957), "it is important to point out that woman's role as child bearer makes her the keystone of the home, and therefore gives homemaking a central place in her career" (p. 73), the applicability and details for the life plan construct would need further research to validate for women today. Both theories did suggest that adolescent years were a good time to offer intervention programs when teens were exploring and gathering ideas. Influences during the exploratory period from Super (or tentative choice period from Ginzberg) are found within the FRC intervention program. That idea forms the basis of my conceptual framework of heroes and experiences. Seminal research on both of these is offered next.

Heroes. Roe's theory of career choice (1956), with its eight groupings of occupations, influenced vocational psychology work that followed; for example, Holland's RIASEC model has six groups and was similar to Roe's construct (Tinsley, 1997). Roe suggested that early childhood would ultimately influence a person's orientation or need for people or for objects. This orientation connected to occupational choice. Vocational psychologists posited that engineers and scientists were oriented towards objects or things, whereas nurses and teachers were seen as people oriented. This people versus object orientation became a "dimension underlying Holland's hexagon" (Tinsley, 1997, p. 281) and is a belief commonly held by career counselors.

Nevertheless, Brown, Lum, and Voyle (1997) suggested that researchers misinterpreted Roe's work assuming the theory described a direct link between early childhood environment and occupational choice. Instead, they posited Roe's theory actually suggested a more indirect link. Specifically, the early childhood environment affected personality development which in turn influenced career choice. In other words, the complexities and problems experienced in early childhood influenced how a person's personality developed. These influences were from many different sources. Researchers have demonstrated consistently over the past several decades that personality traits correlate with career choices. Holland's RIASEC (1963) model depends heavily on that correlation. This subtlety was important when considering the influence of heroes and experiences on personality development (including interests).

Ginzberg et al. (1951/1966) suggested that adolescents sought ideas from "key persons" (p. 92) during the career decision making transition stage (ages 17-19) within the tentative choice period (ages 11-19). Details (pp. 205 – 207) about key persons found in their study included examples from the full range of the Mertz (2004) model. Ginzberg et al. (1951/1966) iterated that results across the career decision making periods might be different for girls than for boys, in particular during the tentative period. Coupling this with Roe's ideas about heroes (1952), a hero (i.e., key person) might have a stronger influence during the adolescent years and for young women the influence might be different than for young men.

Experiences. Super and Overstreet (1960) suggested schools should provide experiential activities via classes, clubs, or special projects; these "steppingstones" would expand the vocational horizon (pp. 153-156). Super and Hall (1978) suggested self-initiated activities, such as career information rooms (p. 341), as possible avenues for experiential programs, like robotics (or more common in those times, science and math clubs). Barker and Ansorge (2007) expanded on this idea using "Kolb's experiential learning model" (p. 232) as a framework with its five learning phases: experience, share, process, generalize, and apply (p. 232). They found that experiential learning via a robotics program helped students learn scientific concepts.

Considering the FRC robotics program, several studies looked at the experiential influence of FRC. In a discourse analysis study exploring student experiences in a single FRC team, Webb (2009) found students created a community similar to that of scientists and engineers, solving real world problem by designing and building an FRC robot. Webb concluded that the student learning and influence results would be difficult to mimic in a science classroom with its limitations on time (50-minute periods versus six intense weeks) and knowledge (science teachers versus engineer working in industry). Welch (2007) found that the experiential learning part of FRC improved student's attitudes about science and technology. In another study, Murphy and Whitelegg (2006) concluded a student did not see a field as relevant if the classes on those fields or subjects (e.g., physics, math, and engineering) did not provide connections to student experiences, in particular finding that girls needed to see connections. Overall, these sample studies validate the point made by Super and Overstreet (1960): After-school activities can have a strong influence on career decisions.

Key Prior Career Development Research

Three alternate major career development theories were considered and deemed unsuitable for the research questions of this study. I will explain how these well researched career theories—Tiedeman's career decision making model (Dudley & Tiedeman, 1977), Holland's RIASEC hexagon (1963), and Social Cognitive Career

Theory (SCCT) by Lent, Brown, and Hackett's (Lent & Brown, 1996)—did not provide an exploration framework for heroes and experiences. This section concludes with discussion on gender nuances studied by Almquist and Angrist (1970).

Tiedeman's decision making phases. In 1961, subsequent to Super's (Super & Bachrach, 1957) theories about adolescence and early adulthood, Tiedeman and O'Hara posited a career planning model with two stages of activities, anticipation and accommodation (Dudley & Tiedeman, 1977), which were similar to stages in Super's career lifecycle. They saw these stages as non-linear, in that, the order of decisions did not always need to occur in the same sequence. Super's approach was based on exploration versus Tiedeman's focus was on making decisions (Super & Hall, 1978). However, they had common aspects, focusing on vocational development, whereas Roe (1956) emphasized traits affecting choices. Dudley and Tiedeman asserted that their decision making model took into account the actions and beliefs of the individual and saw *choice* as different from a *decision* (p. 270), suggesting Super did not see the individual "as an agent in formation of a career pattern" (p. 6). Tiedeman saw the adolescent (in this case) actively involved in the decision making process (Duys, Ward, Maxwell, & Eaton-Comerford, 2008). Tiedeman's theory about career decisions did not use heroes or experiences as influencers and thus did not appear to be a good fit for my research questions.

Holland's RIASEC hexagon. Holland is a noteworthy, and often studied, career theorist in the career development research arena. His theory and the tests developed using it (e.g., Strong Interest Inventory) strive to match people with careers by identifying possible matches between interests and careers. (Holland, 1963). Holland's RIASEC (Realistic, Investigative [originally Intellectual], Artistic, Social, Enterprising, and Conventional) occupational personality type model was a subject of numerous studies over decades of vocational research. Holland (1963) outlined these types beginning in a seminal, four part article for *Vocational Guidance Quarterly*. The study of college bound students on which he reported used six occupations as types: "engineer, physicist, teacher, accountant, business executive, and artist" (pp. 236-237) Only six were picked because that "ma[de] it possible to organize all results around a common criterion for each type" (p. 234). No healthcare profession was selected and all descriptions were written in masculine form. Asserting that one type represents all engineers or all physicists would likely be refuted today by professional engineering and science organizations and can perpetuate stereotypes that oft develop into barriers. Moreover, doing studies with people currently in an occupation can show what traits those people had, but do not necessarily show what traits are needed to be successful in those careers.

Holland's RIASEC theory (1963) has been frequently studied from various perspectives. For example, Lee and Roberts (2010) compared the Holland personality-trait based system against another that was interest based (by Armstrong) finding similar vocational results from both instruments for ninth and tenth grade study participants. In another study, Toker and Ackerman (2010) made a strong case that the Holland scale was too amorphous in its directional answers. In other words, the same RIASEC segment contains mechanics, draftspersons, engineers, and architects, all Realistic but with varying levels of positional complexity. Their instrument-based study added a complexity level to the RIASEC segments, providing a better signpost to career decision aspirants. Their significant findings showed a high validity with the original RIASEC segments. Bottom line, Holland's approach matches people to careers, not how to influence the development of those interests or how career decision making occurs. As Duane Brown stated in a review of Holland's theory in 1987, "one weakness of most trait-factor theorists is their rather vague formulations about how traits develop" (p. 17). He further asserted that RIASEC was biased against women and minorities because their personalities have different development paths and influences (p. 19). Thus, the RIASEC theory was not readily applicable to a study of an intervention program for young women.

Social Cognitive Career Theory (SCCT). Another significant and much researched career theory was developed by Lent, Brown, and Hackett in the early 1980s (Lent & Brown, 2006). They posited that career decisions were made based on a person's self-efficacy for specific careers or in certain skill areas. These social cognitive factors connected with interests, career development, and achievement became known as SCCT as defined by Lent, Brown, and Hackett in 1994 (Lent & Brown, 1996). SCCT provides insights into results, not causes per se. Academic achievements (i.e., results) and interests are influenced by higher outcome expectations and academic self-efficacy.

Hackett, Betz, Casas, and Rocha-Singh (1992) studied engineering college students using an SCCT framework. They found that career self-efficacy, interests, and progress in classes were related positively to academic achievement. The only gender unique result found was that "women… report[ed] significantly lower positive outcome expectations" (p.536). The SCCT construct has had research focused on women and this was noted as a positive factor for its theoretical usefulness when compared to Holland's RIASEC hexagon (Holland, 1963). Nonetheless, I needed a framework further back along the influence path, to explore what intervention steps could influence and help build self-efficacy and interest in engineering (as well as physics and computer science). This led me to the theories of Roe and Super.

Gender pathways. Relatively soon after Roe (1956) and Super (e.g., 1963) did their seminal works in career development, in 1970, Almquist and Angrist wrote that women's occupational choices had not been researched in any depth at that time and no theories for their choices had emerged. They suggested that any theory needed to consider a woman's whole life, including family, to be accurate. Also, they found the influences on women might differ for men.

In 1970, Almquist and Angrist distinguished between a career-oriented woman and simply one who worked. In their longitudinal study of 110 women at one college over 4 years, they studied two dependent variables, career salience and a typicality of career choice. An atypical career was one where women were less than one-third of the workers in it (consistent with data provided earlier on engineering, physics, and computer science). Proposing two alternative and possibly complementary hypotheses, they suggested that a woman's atypical career choice was from either a renegade or a deviance point of view, or were a result of certain enrichment experiences or influences. Women who had made an atypical (for that period) career choice, so called career salient women, were less interested in social oriented life elements, such as family, dating, or social activities. Women less interested in a career had more "feminine values including working with people rather than things" (p. 243). Professional and academic people influenced career salient women, whereas family members and peers influenced non-career oriented women. Work experiences influenced both.

Work values showed a different picture for Almquist and Angrist in that 1970 study. Career salient women with atypical careers valued a career that used special abilities, allowed independence, and had a higher income possibility. Non-career oriented women were less interested in those values, instead valuing more people- versus object-oriented roles, careers more acceptable to their parents and that helped others. Overall, the deviant hypothesis was not strongly supported, that is, career oriented women in atypical occupations were not much different than non-career-oriented women considering social or family factors. Except career salient women often had a mother in a profession or the world of work; this influenced career selections by career salient women.

This study (Almquist & Angrist, 1970) did support its enrichment hypothesis for mothers and daughters. If a mother worked, her daughter was likely to value a career (i.e., career salient) and potentially select an atypical career as well. “Atypical choosers [were] nearly twice as likely as the typical choosers to have an employed mother” (p. 246); in addition, the women studied had a much higher incidence of working during college (p. 246). These career salient women often learned from their mother that having both a career and family was possible. In addition, a role model from their ultimate occupation influenced 68% of career salient women (p. 246); less than a third of non-career-oriented women identified this influence. These factors also correlated with atypical career choice. Overall, daughters with mothers who were educated or employed, women’s summer job experiences, and their occupational role models strongly correlated to career salience and to a lesser extent to atypical career choice. (p. 247).

As Almquist and Angrist (1970) stated, the study’s conclusions cannot likely be extended to other college women of this time period since the study was conducted at a high-end private college, with a potentially, though not stated, higher than average socioeconomic level. Moreover, how the study selected atypical careers was somewhat arbitrary, as the authors themselves stated. Nonetheless, this study broke ground in 1970 by viewing career theory through a female lens, showing gender differences might exist and needed consideration by career theorists. Almquist and Angrist concluded that career salience and atypical career selection might follow different pathways for women than for men, an instructive point for my dissertation study.

Career development theories, summing up. Three notable career development theories— Tiedeman’s career decision making model (Dudley & Tiedeman, 1977), Holland’s RIASEC hexagon (1963), and Social Cognitive Career Theory (SCCT) by Lent, Brown, and Hackett’s (Lent & Brown, 1996)—do not seem to fit well with my research questions involving heroes and experiences as career influencers for young women. The work by Almquist and Angrist (1970) did reinforce the likelihood of different career decision paths for women. The next section has relevant studies of the conceptual framework for my study that informed the research and study data gathering questions I developed.

Relevant Applications of Conceptual Framework

Relevant applications: Heroes. Agosto, Gasson, and Atwood (2008) distinctly separated role model and mentor definitions, similar to Mertz (2004). While mentors provided advice, counsel, and shared a more intimate view of a profession, role models were a catalyst for entering a career demonstrating that men do not solely populate it, that is, computer science was not “an exclusionary club for white males” (Agosto et al., 2008, p. 215). If young women have not seen women in computer science roles, they are less likely to pursue those careers themselves (Agosto et al., 2008; Margolis & Fisher, 2002).

A yearlong career intervention program (Fouad, 1995) including a career shadowing element had a demonstrated impact on career interests and provided knowledge to students about STEM careers. The quasi-experimental study investigated the effectiveness of a year long career awareness intervention program with eighth grade students. The program's hope was to raise minority and female awareness of non-traditional career options and prepare them for selecting a specific high school or high school courses that better prepared them for those careers. The intervention focused on sharing information about careers, as well as providing role models in those careers via speakers and job shadow opportunities. It inspired the young women in the study to take higher-level math and science courses, helping them prepare for college entrance into those careers. Sevian, Hao, and Stains (2010) found similarly that participating in STEM intervention programs had a significant correlation with STEM career aspirations. Ultimately, young people select careers where they see success as possible and that interest them (Eccles, 2005).

Relevant applications: Experiences. Project based learning has the ability to reach young people more deeply than traditional lectures (Barak & Zadok, 2009). By presenting STEM concepts in short, focused doses as a secondary part of the learning process, integrated with the prime learning path—solving a problem—young people were more highly motivated and learned more effectively. Barak and Zadok evaluated this idea in a 3-year qualitative study of seventh and eighth grade robotics classes. They found when a concept was presented within the context of solving a particular problem (e.g., building a vehicle to climb an inclined plane) versus as a concept to be learned (e.g., physics of center of mass), the approach was more appealing to young people. This process fit within a constructivist framework where students built their own learning from prior work, sharing it with others, and using physical objects in the learning process.

Bers and Portsmore (2005) described a pair of classes for introductory engineering students and pre-service teaching students using experiential robotics activities. These two dissimilar sets of students worked together to develop a curriculum unit for use in elementary grades using robotics as a key delivery element. For example, one curriculum project was to teach K-1 grade students the concepts of addition and subtraction; it used a robot that moved back and forth a specified number of units driven by the elementary grade students. This concept, built on a constructionism framework, benefited both the group developing the curriculum (teaching and engineering students) and the elementary age students for whom the curriculum was intended. Two key constructionist principles, in particular, were met: "the notion that powerful ideas empower the individual… [and] the premium of self-reflection" (p. 62). Engineering type projects were particularly well suited to the constructionist framework because it helped students at all levels (i.e., education students, engineering students, and elementary age children) learn by doing something hands-on, applying what they learned, and making concepts “personally meaningful” (p. 61). My study uses a more general vision for experience-based activities within a career development framework versus constructionism, though the experience based robotics activities have similarities.

Resulting Definitions and Summary of Conceptual Framework

Heroes range from mentors (high involvement and low reach) to role models (low involvement and larger reach). The hero types are shown in the modified Mertz (2004) model (see Figure 5 in prior section) that were used in the literature review details and for the balance of the study. Mentors spend numerous hours with a student, helping them in many ways: learn a new scientific or engineering concept and its potential applications;

learn what a career in engineering, physics, and computer science is like; find how to deal with failure or discrimination; or show a young woman that she can find satisfaction in a career where her gender is under-represented. Role models inspire in other ways. With minimal face-to-face contact, a role model affects a number of young women's career aspirations all at one time: delivering a keynote address or speech at an event that has a cathartic effect, sharing a passion for an engineering problem in a video, describing how a computer program solved a large meaningful problem when talking to a large group. Other heroes could be teachers and parents with a mixed level of reach and involvement. Heroes have a range of types as described above: mentors, role models, teachers, and parents.

Experiential activities include many types of hands-on activities, solving a problem and creating a solution, or simply having fun within a particular engineering, physics, or computer science experience. In the context of this paper, experiential activities include (but are not limited to): brainstorming problem solutions, developing designs and software, building a prototype or a final design, driving a robot, and competing with a team.

This study's conceptual framework explored both of these career influencing elements: heroes and experiential activities. These two elements were suggested from career theories of Super (Super et al., 1957; Super, 1969; Super & Bachrach, 1957; Super & Hall; 1978) and Roe (1952) as described more fully in prior sections.

Literature Review Details

To add framing, walls, and windows to the scaffolding of my conceptual framework, I found research that explored each of its elements (heroes and experiential activities), sometimes singly, sometimes together, through two other orthogonal slices: robotics and gender. This research is summarized in the next sections. This major section will be summarized with a strengths and weaknesses analysis and summation of key points, gaps, and relevance to the study that I executed.

Relevant Studies: Stereotype Influences

Gottfredson's (2004) "theory of circumscription and compromise" (p. 2) included four processes in self-development relevant to teens: (a) "cognitive growth" or growing thinking processes with age; (b) "self-creation" or making decision individually to grow as a person; (c) "circumscription" or reducing not so positive career options; and (d) "compromise" or identifying and accommodating outside influences (p. 4). She posited that most career development frameworks asserted that career choices were about matching interests to careers and how those components influenced career choices. The self-creation process element speaks to the experiences a child or teen has. Robotics programs and other hands-on experiences can influence the self that a young woman creates and potentially changes the limits or eliminate the barriers, avoiding a "constricted opportunity" (p. 26) that might otherwise occur without those non-traditional experiences.

Career interests develop from a “close partnership between nature and nurture” (Gottfredson, 2004, p. 7); however, those interests are dependent on culture, gender and experiences. “Vocational choice is a highly public way of asserting who we are” (p. 12). Thus, how a career or skill is perceived by one’s social peer group and how one will operate in a specific career will be strong influences on a person’s perceptions about that career or skill. For example, if young people perceive that computer scientists or engineers spend their days in a cube without much human contact and those young persons are gregarious by nature, valuing social contact each day, they might not see those careers as a good match. If a teen’s peer group or familial group viewed engineers and computer scientists as nerdy or geeky and not *normal*, then again a youth might avoid those careers if she or he was looking to fit into the norm. Gottfredson’s theory of compromise and circumscription described career eliminations made by teens. Experiences make a difference in career decisions by influencing those developmental processes.

Career eliminations begin early, “ages three to five” (Gottfredson, 2004, p. 12), by seeing stereotypes: *only women are nurses* or *only men are engineers*. These limiting processes continue well into adulthood. Up to age 14 (p. 17), eliminating a career or field might be occurring mostly at the sub-conscious level, based on familial and school factors. However, at age 14, career choice limitations become more conscious and specific, matching to their personal selves. Teens begin to frame their choices between “idealistic [and] realistic aspirations” (p. 18). Unfortunately, many young people have not had exposure to enough information from heroes providing career data and examples or from experiences to accurately make those compromises. For example, a young woman, skilled in math and science, who always loved solving problems and puzzles, might have an idealistic goal to be an engineer going to Mars and a realistic goal of being an engineer working in some industry, but choses a compromise of being a science teacher because she sees that role as more gender appropriate. None of the choices was wrong or right for her. The question is: did this young woman compromise without an opportunity to explore the other careers more fully? “When forced to select among the minimally acceptable, choice shades into compromise” (Gottfredson, 2004, p. 19).

Weber (2011) chose a study framework that paralleled my own study framework: role model influences and “the impact of …informal learning activities” (p .18). The project studied at the California University of Pennsylvania, part of an American Association for University Women grant, had a twofold scope: middle school girls and undergraduate women in STEM curriculum. The program included three events for 58 girls: (a) two “Girls’ Night Out” (p. 19) evenings where girls had the opportunity to experience four different hands-on activities; and (b) a culminating event involving their parents. This event contained hands-on activities for the girls. In parallel, parents learned information on the need for people to take on STEM careers, how to prepare their daughter to earn a STEM degree, and what options were available at that university. Pre- and post-study surveys showed an increased interest in STEM and specifically engineering careers. By building the girls’ confidence and giving them opportunities to experience engineering type problems through role models and experiences, their interest in those types of careers increased.

Providing another view of stereotype influences, Cassie and Chen (2012) investigated career maturity through a gender filter using a quasi-experimental design. The experimental group of tenth graders attended a multi-week career development course in Canada. The course development used an NCDA (National Career Development Association) framework, consistent with career maturity constructs. The first part of the course included several instruments to help tenth graders characterize their own interests and readiness. The “self-directed search (SDS)” (p. 6) instrument based on Holland’s RIASEC model helped students determine potential career interests. The career decision scale (CDS) instrument assessed the readiness for making a career decision and was used to assess effectiveness of the intervention (e.g., the course). Finally, students completed a “self-report inventory” (p. 7) considering their results from the SDS and CDS compared to their own first interests. Exploring those careers and identifying necessary steps for their personal results were the second and third phases of the career development intervention course.

Young women in the career course described did (Cassie & Chen, 2012) experience a higher level of congruence between interests, abilities, and plans as shown in a one-way ANCOVA for each gender. Females who did not experience the career exploration course were more likely to move towards overly represented female careers while in tenth grade. In other words, females without any intervention were more likely to narrow the career possibilities for themselves, that is, circumscription, eliminating many that were appropriate for them and instead aiming for more so-called traditional roles (e.g. teaching or nursing). On counterpoint, males did not show these results; instead their self-efficacy increased after the course, though otherwise, the intervention did not have an effect. Neither gender was more certain about any specific career choice after the intervention. Males' interest in career exploration activities decreased after the intervention. Cassie and Chen speculated that a "satiation effect associated with exploratory activities conducted in the course intervention [might have added] clarity to male students' planned career direction and reduc[ed] the need for subsequent exploration of career options" (p. 10) accounting for this unexpected result. In their study, grade 10 was a critical time for teens, though the influences varied by gender.

Encouraging young women at this age to explore careers in which women have been under-represented could be an important intervention. Interventions that help facilitate this exploration could be effective to counteract stereotype threats.

Relevant Studies: Experiences and Heroes via Robotics

Keathly and Akl (2007) studied the influence of heroes and experiences on ninth through eleventh grade girls through two mechanisms: (a) summer robotics camps hosted by the University of North Texas Computer Science and Engineering (CSE) Department; and (b) outreach to junior college and high school students by female Ambassadors from higher grades in the CSE department. This study shows a repeated theme of experiences and heroes. Their aim was ultimately to spark a vocational interest in these young women to choose computer science and engineering programs. This program gained experience from another high school robotics competition similar to FIRST called BEST Robotics.

The BEST robotics model for students is similar to that of FTC (see Table 2), in robot size and complexity. BEST teams have six weeks to design and build (similar to FRC for schedule brevity versus FTC with its longer period of design and build), competitions, and judging (BRI, 2012). The financial BEST model is different from that of FIRST's programs; "Schools participate at no cost" ("What is BEST," n.d., para. 6), which was not relevant to my study, but a major differentiator. For 2014, FRC entry fees were $5,000 for the first regional competition ($6,000 for a rookie team), $4,000 for additional regionals, and $5,000 to attend championship (FIRST, n.d.c); FTC registration fee was $275 plus $650 for a kit of parts reusable year after year (FIRST, 2012b). "BEST is less about building robots and more about teaching students how to analyze and solve problems" (BRI, "Program Overview," n.d., p. 4). All BEST teams are provided with the same kit of parts to use making their robot, whose size must not exceed a 24-inch cube or 24 pounds, and many of the parts are returned to the organization. Overall, these differences likely help BEST maintain a lower cost delivery model. (BRI, "Game Rules," 2012; FIRST, "FTC Registration," 2012b).

The BEST build models were used by Keathly and Akl (2007) in their summer robotics camp. The robotics camp exit surveys showed high levels of interest in science and engineering fields. Data from six months and twelve months after camp completion was gathered and analyzed from student participants and parents. Positive results about the influence of the camp on the young women participants included doing better in high school math and science classes and being more interested in science and engineering careers. Last, the university experienced a notable increase in women entering CSE, though they could not solely attribute this rise to the summer camp and ambassador program. The authors noted that the publicity on the projects and the general positive interest generated raised the university's image with young women and minorities.

At Jackson State University (Skelton, Qing, Jianjun, Williams, & Wei, 2010), a three-pronged robotics summer program effectively used hands-on experiences and mentors to excite seventh to eleventh graders about engineering and computer science. The program showed incoming freshmen what possibilities existed in their upcoming curriculum and helped them gain confidence. It also gave K-12 teachers an opportunity to try out a hands-on program they could use in their classrooms. The incoming freshmen were also subsequently mentors in the 7th - 11th grade student phase of the program. By using mentors who were nearer in age to the participants, the authors believed communication was more open and comfortable for the younger students.

Many researchers asserted that experiences from FIRST programs as well as "having the opportunity to work with peers and mentors" (Brand, Collver, & Kasarda, 2008, p. 45) motivated students involved in it and that as a result, their career interests in STEM increased. Brand, Collver and Kasarda (2008) studied a 9-year old Virginia-based program—a collaborative effort across four schools and Virginia Tech University—where mentors were undergraduate engineering or computer science students working with students throughout a school year. The program's first semester consisted of four three-week courses followed by a six-week design and build course. The second semester began with the six-week build season of the FIRST competition, followed by the competition, analysis, writing, and competing. With this after-school course, offered in a central location for all four high schools within a district, many benefits occurred: university students found it easier to participate and mentor, no single school needed to fund and manage the program, and collaboration was both a role model and a skill developed in the program. Mentoring in this program showed benefits, per Brand et al., however, no specific statistics were provided to back up this claim (2008).

The prior studies contained both elements of my conceptual framework. Some robotics programs used only one. These studies are described in the next paragraphs.

Heroes. In Australia, a Science in Schools (SiS) project, started in mid-2007, had begun to bear fruit with 500 teacher-scientist partnerships established by the end of the 2007 school year (Howitt, Rennie, Heard, & Yuncken, 2009). While the project had many goals, the goal to "enable scientists to act as role models" (p. 35) was relevant to my research. Howitt, et al. detailed three case studies of SiS partnerships between a scientist and teacher or teacher team. In one case, it was a virtual relationship as the school was a combined grade school in the rural Australian Outback. All cases reported increased understanding and strong interest of students as a result of interactions and information from their scientist hero.

In another study, Buck, Clark, Leslie-Pelecky, Lu, and Cerda-Lizarraga (2008) examined a mentoring program involving graduate student scientists with eighth grade girls. They found the program resulted in the girls (i.e., mentees) making a personal connection with the female scientists (i.e., mentors/heroes) and finally seeing scientists as a whole in a new light and possibly female. Similarly, a yearlong career intervention program (Fouad, 1995), including a career shadowing element, demonstrated impacts on career interests and provided STEM careers knowledge to students. It inspired them to take higher-level math and science courses, helping them prepare for college entrance into those careers.

DuBois, Portillo, Rhodes, Silverthorn, and Valentine (2011) performed a meta-analysis of 73 mentoring programs from 1999 – 2010. They found modest gains on average, with effect sizes around 0.2. DuBois et al. concluded the programs were generally effective. Gains were more positive when the mentors and mentee had similar occupational interests. They found that mentoring programs melded well with most middle-class belief systems of do-it-yourself, essentially connecting a problem (insufficient role models for youth in their lives) and solution (volunteer mentors from elsewhere) together to help youth develop (p. 57). What was often a “by-product, not the focus” (p. 62) of any youth mentoring relationship was an emotional connection between mentor and the adolescent. The mentor elements used in the meta-analysis were consistent with the modified Mertz (2004) model (see Figure 5), though the authors used another model by Rhodes (2005).

Experiences. Piotrowski and Ressly (2009) focused on experienced based interventions. They developed a high school classroom curriculum centered on a socially relevant problem: removing IEDs or Improvised Explosive Devices. Students worked in pairs to design and build robot solutions (VEX-based) to collect IEDs. Moreover, the entire class considered the problem as a group and developed a plan for IED disposal. Results: "Robotics with a social conscience has not only energized our students with desire to improve our world, but it has also begun to bring teachers from mathematics, science, and even English to the technology education lab" (p. 18). This connection of STEM learning with a social problem energized the students and engaged other teachers.

Maud (2008), an Australian grammar school (i.e., elementary grades) teacher, used robotics to inspire students, generate learning, and "take the brakes off education" (p. 55). In either competition or collaboration, his students achieved beyond his expectations, when considering both problem solving and level of learning. He posited that the hands-on nature of the robotics activities engaged students in learning.

The Coast Guard developed the Coast Guard Academy Robotics on Water (CGAROW) project to foster an interest and aptitude in STEM among young people. (Hademenos, Russell, Birch, & Wosczyna-Birch, 2010). It used a Project Based Learning (PBL) curriculum with aspects of teamwork, technical reporting, and creative problem solving. Teachers gained exposure to CGAROW with a seven hour design, build, and test day; students explored the curriculum over four partial days. The kit itself was VEX based and sold through VEX Robotics (see Table 2). Though the article was more informational than a quantitative assessment, the authors recommended this kind of experiential learning project to other high school teachers to "encourage high school juniors to pursue STEM careers" (p. 49).

High school teachers do not usually have sufficient experience or knowledge in engineering to use its concepts in their classrooms. Thus, Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, and Kimmel (2010) developed a program in New Jersey aimed at remediating this situation. They saw robotics as an effective platform for the specific curriculum they developed. This project that links curriculum with in-service training helped teachers implement medical-robotics using LEGO MINDSTORMS®. The curriculum taught the *engineering problem solving process*, a parallel to the probably better-known *scientific method*. Students designed robots to perform simulated surgeries and teachers implemented the curriculum in various high school science classes.

Barak and Zadok (2009) used qualitative methods to explore reactions of young people involved in a 3-year study of robotics classes. More specifically, the study was about the teaching methods used in these classes (for more details: see Conceptual Framework section). The seventh and eighth graders involved kept journals; some classes were videotaped; interviews were conducted with parents and teachers; some class conversations were captured; and student presentations were analyzed. These various data gathering methods provided a rich textural view of participants' feelings and thoughts about the robotics classes as well as about their own learning process.

Keathly and Akl (2007) noted that high school girls who participated in their robotics camps (described earlier) liked the creative part of robotics. Nonetheless, "anecdotal evidence from women attending [the BEST Robotics competition] suggests that interaction among team members could be improved significantly if women-only teams were allowed to compete and work together" (p. 2). My own study's findings saw many positives from young women in single-gender teams, though this might have been more about personal self-efficacy or relationships as will be seen in Chapter 4.

Hands-on experiences as described above showed that robotics can grow student interests in learning STEM subjects. Next, from an orthogonal view, the influence of robotics programs specifically on career interests is described and synthesized.

Relevant Studies: Robotics Affects Career Interest

Connecting the real world to a subject is important, in particular for females. In a Taiwanese study of elementary age pre-teens (fourth - sixth grades), Liu (2010) found, in a quantitative survey study, that males more than females saw robotics as a "way to high technology…[and a] source of employment" (p. E46). This same kind of connection to the real world was found in another study. At Augustana College in South Dakota (Swets, 2010), the computer science (CS) department found that including robotics in their introductory course helped to grow an interest in the curriculum. They changed how the *Introduction to Computer Science* class was taught. By employing a relevant application, they hoped for an increased student interest in computer science that would result in students taking follow-on classes and ultimately graduate in CS. Swets concluded that interest in computers will be fueled from a different source today than in times past. When computers were new and different, students wanted to learn how to use them just because of that uniqueness. Today, computers of many types are ubiquitous and well-known to students. Students come into college knowing tablets and PDAs, social media applications and multi-media. Thus, growing interests in computer science concepts needed a different tack, Swets posited. Margolis, Estrella, Goode, Holme, and Nao (2008) identified this need for new tactics as well in their studies of computer science classes in the Los Angeles School District.

LEGO NXT robots and a multimedia component were added to the course curriculum in several classes for the same introductory computer science course (Swets, 2010). At the end of those courses, higher numbers of students signed up for the follow-on class than those students in the unchanged class. Moreover, students showed an increased understanding, “sometimes substantial” (p. 60), of core computer science concepts, an unexpected though positive outcome. Swets suggested that the robotics curriculum addition helped bring an answer to the “so what?” (p. 59) question not answered in standard course fare and could be one type of change that inspires more young people to enter computer science fields.

Welch, in her mixed method dissertation study (2007), studied teen science attitudes and assessed FRC participation influence using a Test of Science Related Attitudes (TOSRA) instrument. TOSRA was originally developed by Fraser (1978, as cited by Welch, 2010), tested and validated first with Australian students and subsequently with students in the United States. Using a theoretical framework of Piaget's constructivist learning and Vygotsky's ideas on involvement in shared activities, Welch posited that FRC provided experiential or project-based learning to participants in a communal or team-based environment (2010, p. 189). Welch found (2007; 2010) that students participating in FRC, when compared to students who had not, had improved science attitudes in four categories of TOSRA: "Social Implications of Science, Normality of Scientists, Attitude toward Scientific Inquiry, and Adoption of Scientific Attitudes" (2010, p. 187). Together these four categories measured attitudes towards science, science projects and research, as well as the people involved in them.

Welch's 2007 study within the Kansas City school system involved nine schools across different areas, both private and public schools, with students from ninth to twelfth grades. The control group was drawn from science classes in the participating schools. Welch administered the TOSRA to both groups before the FRC season began and then after the build portion of the season was done, just over six weeks later. Many FRC veterans would have a concern with doing a posttest after only the build season. Part of its influence derives from the competition portion of the season (e.g., responding to challenges, redesign, rebuilding, judging), not only the build portion. The competition phase of the season occurs over eight to ten weeks post-build completion. Both positive and negative influences could occur during the competition portion of the overall season. Welch did not test that phase of the experience in this study; regardless, her findings are enlightening.

Reviewing the results (Welch, 2010) of the study, students who participated in FRC (n=80 pre-survey, n=58 post-survey) had a more positive attitude towards science, scientists, and the scientific process; students who did not participate in FRC (n=52 pre-survey, 41 post-survey) all experienced drops in those four TOSRA areas (p .191). Moreover, FRC students had a much larger positive attitude change (2.49 more than 36.75, the initial mean) than non-FRC students (0.13 more than 34.50, the initial mean) concerning scientific inquiry concepts (Tables 1 - 4). However, neither group showed an increase in interest in science careers.

Considering the improvement overall in attitudes towards science observed in the FRC intervention group, Welch (2007, 2010) found positive results in the FRC group when compared to those in the science classes that had not participated in FRC. Welch concluded that FRC was a valuable tool to improve adolescent interests in science related processes, people, attitudes, and activities.

Females were about a third of the FRC group in Welch's study (2007) while in the non-FRC group they were a bit over 50%. A key finding relevant to my study, Welch found gender differences in only one place: females showed a positive change in "Normality of Scientists… [T]he significance of the post-survey results must be due to the intervention produced by the students' participation in [FRC]" (p. 113). Additionally, from the qualitative portion of the study, she noted roles taken by three of five girls on one team interviewed were not technical roles per se ("scrapbooking, photography, and record keeping" (p. 147). Both the non-technical roles taken and the change in attitude towards views of a typical scientist had a connection to my study outline and were reinforced by several of my findings.

Hurner (2009) explored career trajectories in her qualitative ethnography of an all-girls FRC team in northern California. She focused on social identity within a community of practice framework. The results were mostly about formation of social identity within a robotics team, but did not reveal much about career decision making influences from participating in FRC. However, her study participants were within the geographical area I studied.

FIRST has commissioned program studies over its 20 plus years (e.g., Brandeis, 2011; Melchior et al., 2005). Melchior et al. at Brandeis University's Center for Youth and Communities, performed a proprietary mixed methods study for FIRST, with participants principally from the northeast United States, "from schools largely in the Detroit/Pontiac and New York City metropolitan areas" (p. 10). This study was focused on long-term results, surveying FRC members who had "graduated…between 1999 and 2003" (p. 2). They compared FRC participant results with a nationwide database, Beginning Postsecondary Student Survey (BPS) from the U.S. Department of Education. Many more female FRC alumnae "majored in a science/engineering field…41.3% [versus]…21.7%" (p. 38) of females in the BPS Study. More highly significant ($p<.01$) was that 32.6% of female FRC alumnae pursued engineering when compared to the BPS participants (8.7%). This data seems to show that participating in FRC has a positive influence on young women's career decisions, though the starting point for the female

FRC alumnae is unknown. The higher FRC numbers could be because more girls participated in FRC that already had an interest in science or engineering.

More recently in 2011 (Brandeis, 2011), FIRST commissioned a cross-program evaluation of FRC and FTC, both FIRST high school programs as described in Table 2. Notably, no long term influences were explored in this recent survey study. The study found several significant gender differences, in particular for FRC (note: all percentages in this paragraph and the next are for FRC only). Young women were “more likely to be involved” (p. 6) in social skills activities, like marketing, outreach, or finances. Young men, on the other hand, were involved in robot design, build, and operation. (p. 6). This finding was similar to that found by Webb (2009) in his critical discourse study of an FRC team and Welch (2007) in her TOSRA study of Kansas City schools. Girls were outsiders, not insiders.

Girls more highly reported growth in social or soft skills whereas boys reported growth related to STEM career interest or knowledge (Brandeis, 2011, p. 42). Positively, more than 90% of girls and boys said (*agree* to *strongly agree*) that FRC helped them learn that math, science, and technology could solve real world problems. However, only 72.5% of girls versus 87.6% of boys expressed interest in being an engineer or scientist (p. 50). While young women overall expressed positive comments about the programs and its influence on them, “other young women…found it a struggle to break through the gender stereotypes and gain the opportunity to contribute as equals” (p. 61). One female (an FTC member) expressed concerns with her treatment by a teammate and a mentor (in the open-ended portion of the survey):

> Though I was willing to work extremely hard, my coach did not listen to my ideas. If I said it, he didn't listen. He and one other member on the team acted differently with me because I was a girl. I hated being identified by my gender, rather than my qualifications. This treatment greatly negatively affected me in all aspects of my life and made me at points extremely depressed. I knew if somebody just gave me a chance, I would be able to do [sic]. (p. 61).

One key study conclusion was "it will be important to look at how to make sure that [FIRST] programs engage girls in both the 'technical' and the 'social' aspects of the programs" (p. 7). I appreciate FIRST sharing this report with me for my dissertation. Some of my findings affirmed the Brandeis study findings mentioned above with partially similar points. The young women in my study expanded on these ideas in more detail as shown in Chapter 4.

FRC team roles differing by gender was also seen in Webb's study (2009). He described how the "skewed level of participation" (p. 245) by gender found in industry was mimicked in the FRC team he studied, speculating what practices would change females from "outsiders to…insiders" (p. 245). The girls on the team were "invited" to participate in design and build sessions, but Webb and his study participants saw that word, *invite*, as a subtle indicator that the girls were not insiders. (p. 152).

Relevant Studies: Gender Nuances

Gender of heroes. Heroes influence teen career selections, whether they are parents, teachers, public figures, an engineer or scientist met in an intervention program, or someone who worked side-by-side with a young person for many weeks (Roe, 1952; Jacobs, 2005; Messersmith, Garrett, Davis-Kean, Malanchuk, & Eccles, 2008). Heroes may influence females more so than males. Jacobs asserted that girls were more likely than boys to consider STEM careers if they received positive input about math from mothers and other adults (Jacobs, 2005, pp. 87-89). On the other hand, in another study by Messersmith, Garrett, Davis-Kean, Malanchuk, and Eccles (2008), both men and women described how parental influence influenced their career selections with few observed gender differences.

Quimby and DeSantis (2006) asserted that even though prior research showed role models influenced women, “whether role models have a direct influence on women's career choices or if they are related to career choice indirectly through their influence on self-efficacy” (pp. 297-298) was an unknown factor. Their study of female undergraduates found that role models did influence career decisions, supported by Social Cognitive Career Theory (SCCT: espoused by Lent, Brown, and Hackett in 1994, cited in Lent & Brown, 1996); the role models helped to provide a secondary or vicarious experience to the mentee (Quimby & DeSantis, 2006). They suggested that examining both male and female role models for young women would be enlightening. While, Buck et al. (2008) did examine male and female differences, their study participants were much younger than my study's planned participants.

Carrington, Tymms, and Merrell (2008) studied a large cohort (n=8978) of 11 year old children in the United Kingdom to determine if having a matched gender teacher had a positive, neutral, or negative impact on a child's learning as demonstrated in various tests. No statistical relationship was found. The authors also reviewed numerous studies with similar findings. The gender of the teacher did not matter. In this case, the authors assumed the teacher was a mentor. Again, since the young women in my qualitative study were college age, this might better assess long-term influence of heroes from high school on young women's career interests.

Many studies have been performed using the Draw-an-Engineer or Draw-a-Scientist approach (Hoh, 2009; Bodzin & Gehringer, 2001) demonstrating that if young people (or teachers) were exposed to a scientist or engineer (a role model) in the classroom or at some special event, perceptions of people in those careers typically changed. In the posttest drawings, children (and teachers) drew more female engineers and scientists (even if a male role model had been provided). The drawings also showed people that were actively involved in designs, experiments, less stereotypically nerdy, more average.

Hoh's (2009) study of biology teachers changed their perceptions of "who is an engineer" through a workshop activity. After first drawing a typical engineer, teacher teams then researched a noted female bioengineer or bioscientist. The teams then shared their findings with the larger group. Last, they drew again a typical engineer. The perceptions of female teachers changed dramatically, from 91% drawing male figures to 31% after the workshop activity; the perceptions of male teachers changed significantly as well, albeit not as dramatically, from 100% to 62%. In addition, when surveyed a year later, 91% of the female teachers and 78% of the male teachers had used the workshop activity in their own classes to help all students gain a less gender-biased perception of who can be an engineer.

Several other relevant findings resulted from the workshop participant discussion (Hoh, 2009). Sharing personal details about notable women that participants researched helped participants see a more balanced perspective of a woman engineer or scientist's life, "combining work and family" (p. 462). Participants found how teachers and parents influenced the women's career selections, reinforcing the importance of a teacher's role in student career decisions. Most of the women studied did mention some sexism or discrimination. Teachers "felt that although these difficulties truthfully reflected the experiences of the female bioengineers, such revelations could deter talented young women from pursuing careers in bioengineering" (p. 462). Hoh highlighted that sharing improvements in those kinds of life experiences with participants was an essential step for future workshops.

Having both male and female role models for young people was also studied by Bodzin and Gehringer (2001) with fourth and fifth grade students. A female engineer visited the fourth graders and a male physicist visited the fifth grade classes. After each visiting professional talked about their specialty, each led the class in an experimental, hands-on activity, and finally related it to his or her profession. In the posttest, drawings had fewer nerdy or stereotypical scientists and engineers, and in general, children saw these professions in a different light, with more females in their drawings.

Studies (Holub, Tisak, & Mullins, 2008) of pre-adolescent children showed that while boys rarely picked a female hero (15%), a girl selecting a male hero was not rare (29%). In addition, girls were much more likely (31%) to select a non-gender specific hero than boys did (13%). Girls were more likely (greater than 75% of the time) to choose a private figure, that is, someone they know personally, whereas boys selected someone they knew a little over half the time (55%) (p. 570).

Possibly the influence of heroes on female adolescents is stronger than it is for male adolescents. Girls almost evenly selected male, female or non-gender specific heroes (e.g., religious heroes, parents as a set versus mother or father) in the study by Holub et al. (2008). The reasons for hero selection were different by gender as well. Girls valued both stereotypical male and female traits, showing a more open acceptance of them. However, girls might have selected female and male heroes more equally because society considers certain traits to be stereotypically male and then high aspiring "girls may be more likely to choose male personal heroes" (p. 576). Boys, on the other hand, more strongly selected traits associated with males, reemphasizing a pattern of avoiding traits or values associated with women more than with men.

Gender nuances for different types of heroes. Fried and MacCleave (2009) raised a critical point regarding the definition of role model versus mentor. They described a model by Mertz, from 2004 (see earlier sections around Figure 4 and Figure 5), where mentors were at the top of the pyramid of relationships defined by Mertz with role models being at the bottom. For Fried and MacCleave's (2009) study of female graduate students in Canada, definitions for these two types were

> Role model was defined *as a person you know personally, or know of, who has influenced your career decisions by being admirable in one or more ways* whereas *mentor was a person who has influenced your career decisions by actively giving advice, encouraging (or discouraging), supporting, providing information, or helping you make decisions* [emphasis present]. (p. 485)

This quantitative study of engineering and physical sciences majors used a career decisions instrument to assess how mentors and role models influenced a respondent's career decisions and found some gender variances. Role models more frequently influenced men's career decisions than women's decisions. Fried and MacCleave suggested this was because so many male role models were available. No gender differences were found for mentors. Women did more commonly identify female role models or mentors as being an influence. Results also varied by discipline area. Engineering graduate students more frequently said mentors influenced their career decisions than the physical science students; though no differences were found for role models across those disciplines. Overall, their study confirmed a difference between the

Role Model and Mentor types, and that the gender of that person was less important than simply having a supportive relationship of either type.

Hearing women's voices. "Despite theoretical developments and advancements…few researchers since the Career Pattern Study (Super, 1957) have investigated the career concerns that *adolescents perceive* to be *personally important* and essential to the development of their careers [emphasis added]" (Code, Bernes, Gunn, & Bardick, 2006, p. 163). The study by Code et al. explored this question without considering gender: "what discourages [a teen] when [thinking] about [a] career?" specifically to explore adolescent perspectives on negative (i.e., barriers) and positive (i.e., windows) influences for their career decisions. In the National Academies study on Engineering in K-12 Education (Katehi et al., 2009), the focus was on programs, their impact, and content; the study did not solicit feedback from the young women and men in the programs. Again, the voices of the teens involved were not sought. Hearing young women's stories and ideas about a program aimed at encouraging them to pursue engineering and computer science careers could illuminate the situation of continued low percentages of women in engineering, physics, and computer science. Giving voice to these young women to talk about intervention programs was a research gap my study could help fill.

Summing up. From the research, gender bias with respect to heroes needs further exploration. The gender of the hero or the genders of the type of hero (e.g., role model or mentor) are areas for further research. Also, in most studies, the ideas, concerns, thoughts of the young women that were the target of all this research have not been sought. Overall, these findings informed the conceptual framework of my current study and were used for interview questions as well.

Strengths and Weaknesses of Prior Research

Hackett, speaking at the 2012 National Career Development Association annual conference said: “The influences of role models and experiential, problem-solving activities on young women have not been studied as deeply as self-efficacy and expectations about outcomes, the two significant elements in SCCT.” Hackett is known for Social Cognitive Career Theory (SCCT), developed by Lent, Brown, and Hackett in the mid-1990s (Lent & Brown, 1996), which has been a fertile research ground for career selection causes. Heroes and experiential activities influence self-beliefs and interests (Lent, Brown, Sheu, Schmidt, Brenner, Gloster, et al. & Treistman, 2005). My dissertation delved further back on the pathway of career selection influences to *causes* of those interests, self-efficacy beliefs, and what was expected in a person’s future based on career choice. In this section, the strengths and weaknesses of studies on heroes, experiences, robotics, and career choice causes are synthesized.

FRC STEM and career interests study. Griffith’s (2005) dissertation research viewed FRC influence against a backdrop of “problem-based experiential learning” (p. 42). He investigated STEM attitude and interest changes in a quasi-experimental study of high school students in South Carolina public schools. The experimental group contained students from FRC teams; the control group was selected from students taking STEM classes and not participating in FRC. The pre- and post-study tests were taken about six weeks apart, predicated by the beginning and end of the design, build, and test portions of the overall season (similar test points to that practiced by Welch, 2007, with similar concerns about not included the competition phase). He also examined the data through race and gender filters. The analysis methods included one-way ANOVA analysis for pre- and post-study comparisons and a two way ANOVA for between-group comparisons (FIRST, n=131 and Control, n=373). His study filled a research gap by studying a control group using the same test instrument, in the same timeframe and locale, and by using the experiential learning framework.

In Griffith's literature review (2005), he described seven evaluation studies of the FRC program between 1996 and 2002, all proprietary in that each was either run by FIRST or initiated by FIRST. He noted no data had been collected from students not in FIRST for those studies (Note: in the 2005 Melchior et al. study, the researchers did use a national dataset for comparisons). His theoretical framework was constructivism via problem based learning, similar to Welch (2007). He investigated both interests and attitudes towards STEM with a control group, but only over the build season.

Interest in career fields was evaluated pre- and post-study (Griffith, 2005), that is, before the FRC season began and then after the *ship date* (a specific date each year for everyone in the competition, six weeks and three days after kickoff), but not after its subsequent competition phase. This was a limitation Griffith highlighted (i.e., not including the entire FRC experience). Based on my own experiences as an FRC mentor for about eight years, student's attitudes after the ship date [now called *stop build* date] often go through a low period until the actual competition in subsequent weeks occurred. Student long-term reactions differed mightily depending on how the team fared in the competition matches and judging processes. A better post-test time for the experimental group might have been some weeks after their final competition for that year, near the end of April. As Griffith described himself, experiential learning typically needs a result to have an influence. Many teams ship a robot that has been built, but not tested or run until at the first regional competition. Thus, I suggest that attitudes at the ship-date were nascent at best for those in the experimental group. Testing so quickly after the first test (a six week interval) was intended to show the influence of FRC on attitudes and interests without other confounding factors coming into play (e.g., later months of school, other experiences like science fairs) and was a worthwhile set of data to gather.

Using those testing times, Griffith (2005) found that while the FRC group had higher scores overall for interest and attitude about STEM, both groups did not show any significant changes pre- and post-study in their STEM attitudes or interests. The FRC group did show an increased understanding about the world of work after the design and build phase experience. He recommended that a larger, similar study include the competition phase of the program and include private schools as well as public schools (it should be noted that including private schools might include some all-girls teams, since few all-girls FRC teams exist in public school systems). Moreover, Griffith recommended future studies investigate the longer term impacts of FRC on interests and college degree choices years after the competition, which was what my study explored.

Gender differences were observed and discussed by Griffith (2005) and he recognized FRC might have a unique influence on girls (p. 41). Certain gender nuances in Griffith's dissertation are thought–provoking and were not specifically discussed. For example, within the experimental group, girls' interest in engineering pre- and post-study went down from 10.75 to 7.94 versus in other areas where it increased: architecture 1.90 to 4.76; business and finance 2.53 to 5.56, and math 4.43 to 9.52 (Griffith, 2005, Table 21). These numbers were significant: $p < 0.005$. Whereas boys' interest in architecture (6.47 to 8.46), business and finance (1.67 to 3.08), and engineering (18.37 to 22.31) all went up, though their interest in math (12.32 to 10.38) went down. (p. 78). Summing up the results, girls' interest in engineering went down after participating in a FRC program, though girls' interest went up in other STEM fields besides engineering. On counterpoint, the boys' interest in engineering and other STEM fields (all but math) increased after participating in FRC. This finding is thought provoking and worthy of future study.

Other robotics programs studies. Studying the influence of robotics on a younger group of students, Barker, a Principal Investigator for several NSF and 4-H grants using robotics, investigated the use of robotics in 4-H based curriculum in Nebraska. His conceptual framework was an experiential learning model using constructivist theory, partnering effectively with the 4-H model. In 2005, Barker and Ansorge (2007), working with the Robotics Academy at Carnegie Mellon University, piloted a robotics curriculum using LEGO MINDSTORMS with elementary age students. In that quasi-experimental study (n=32, about two-thirds male, n=14 for experimental group, and n=18 for control group), pre- and posttest evaluations were done with the experimental and control groups. The experimental group showed significant increases with large effect sizes (overall 0.943, p. 237) in Science, Engineering, and Technology concept understandings after experiencing the robotics program.

Three years later in 2008, in another NSF sponsored study in Nebraska, Nugent, Barker, Grandgenett, and Adamchuk (2010) investigated the influence of a week-long robotics and GIS summer camp on young people's STEM knowledge, self-efficacy and attitudes. The experimental groups (n= 147 students, 24% female, about 12 years old) were drawn from six Nebraska week-long summer camps. The experimental and control groups took pre- and posttests assessing content knowledge and attitudes. Subsequently, the control group students took part in a half-day robotics event using similar activities, designed for short-term and high interaction; the control group took the tests again after the robotics and GIS short-term activities.

Results on content knowledge from above study (Nugent et al., 2010) showed that both males and females scores increased after a robotics and geospatial camp, though the overall scores for males were higher to start. Posttest programming content knowledge for the experimental group was significantly higher (p<.0001) than for the control group (5.85 versus 4.1 with an effect size of 0.30). (Table 2, p. 399). “Both the cognitive and self-efficacy results suggest that an intensive, 40-hour robotics instructional program can directly support the learning of challenging STEM concepts and processes" (p. 402). Moreover, short term activities, while not affecting STEM learning, did improve student attitudes about robotics and STEM. As the authors shared, this attitude improvement could be due to the short term activities being fun and experimental versus focusing on learning new skills. In general, the researchers did not highlight any gender nuances.

Do females relate to STEM differently than males? Fouad, Fitzpatrick, and Liu (2011) asserted "there is not a significant body of research on female engineers" (p. 71). Participation by women in computer science is worse at some universities than the national aggregate data, and better at others. For example at Drexel University's College of Information Science & Technology, their IT programs had only 9.7% women enrolled in them, lower than prior years (Agosto, Gasson, & Atwood, 2008, p. 205). To combat this shrinkage for women's participation as well as for under-represented minorities and for the IT program as a whole, Drexel's researchers proposed a four part "Changing Mental Models Framework…[including programs to provide] mentoring, social cohesion and peer support, role modeling, and curriculum re-design" (p. 205). This program aimed at changing what women and under-represented minorities think about careers in IT and computer science. Instead of lonely roles, occupied by nerdish, white men, the many pieces of the Drexel program showed how IT careers had problem solving, collaborative interactions, and solved problems the world needed solving, much like the messages suggested by the National Academy of Engineering's (NAE) *Change the Conversation* program (NAE, 2008).

From another perspective, Larose, Ratelle, Guay, Senecal, and Harvey (2006) analyzed science self-efficacy and career decidedness data in a Canadian longitudinal study (n=411, 216 female) of high school to year two college students, through a gender filter. Females showed a lower science self-efficacy than males at the end of high school. On counterpoint, females showed improved levels (over males) at year two in college, eventually to the point of higher than males, *if* those students were in physical science or engineering programs (versus biological sciences): "four times more likely than boys to experience an increase of [science self-efficacy] beliefs after high school" (p. 387). This finding did not correlate to SES or grades. Moreover, if females experienced a decline in self-efficacy in these subjects, their career decidedness declined as well. The females seemed to question more than males if they had made the correct career choice. If science self-efficacy was maintained or grown, a more stable career interest resulted. The study's conclusions have limits: notably, no comparisons to other self-efficacy measures (e.g., reading comprehension, language) were available. One might ask if these changes are because of gender alone or because of the confluence of gender and a non-traditional female curriculum.

In the past, girls had been found to be more susceptible than boys to barriers—experienced or perceived. Researchers (e.g., Margolis & Fisher, 2002; Marra, Shen, Bogue, & Tsai, 2010) have identified a chilly climate for women in engineering and computer science that further influenced young women away from those fields. Nonetheless, a 2005 quantitative study by Lent et al. showed gender differences to be more negative for boys than girls when considering both social support and social barrier factors. This might suggest that times have changed with a “growing receptivity to women in engineering” (p. 90). However, Lent et al. cautioned: “women with weaker support systems may have opted out of engineering altogether” (p. 90), suggesting further research was needed to explore possible improvements as well as more exploration on barriers and support levels and subsequent influences (p. 91). Few qualitative studies were found on these differences.

It is possible that barriers and social support structures are becoming similar in their influence levels on males and females. In other words, boys and girls may both be receiving similar levels of support and have similar perceptions of barriers, unlike in times past. This is somewhat supported by society's responses to nerd and geek stereotypes overall today versus that of the space race decades with a peak in engineering graduates in the mid-1980s.

In a qualitative study of working engineers, Fouad, Fitzpatrick, and Liu (2011) interviewed 25 female engineers, where 14 were still working in engineering and 11 were not. Against a backdrop of three influences—SCCT, National Academy of Engineering research and a SWE study on persistence in the field, and engineering culture studies—the interview questions for those female engineers explored barriers, supports, self-efficacy, and reasons for persisting or leaving engineering. All study participants noted barriers at work and described work/life balance issues and solutions. A number of engineers who had left the field blamed themselves for leaving (versus blaming climate or work issues). Most participants, working in engineering or not, denied that any gender inequities existed, though many described what others would call unequal or biased treatment. Since the female participants had an average age of 43 and ranged 37 to 51 years of age, they do not match my planned younger participant pool. Nonetheless, I was aware of this potential that female engineers might have for blaming themselves versus the environment during the focus group dialogues, participant interviews and data analysis in my study.

Experiential short-term programs miss the mark. As Nugent, Barker, Grandgenett and Adamchuk (2010) found, short term activities (e.g., day long workshop) were not as influential as longer term efforts. Three female Australian IT professors (Craig [no relation], Lang, & Fisher, 2008) might agree. They gathered data from twenty years of programs whose aims were to increase the numbers of young women entering the IT profession in Australia. The programs varied from local to national, from small to large in participant size; most programs were organized by women for young women and were two or less days in length. Aimed at a grade range from sixth to twelfth grades (Australian grades appear similar to those in the United States), most of the programs were held at universities, and typically were repeated in subsequent years. None captured any consistent longitudinal data. While pre and post surveys were completed for many programs, those evaluations were completed around the event timeframe, not years later. For only a few were Craig, Lang, and Fisher able to find some semblance of longitudinal data assessing career interest or career achievement years after the events.

Craig et al. (2008) stated that relatively short events (one to two days in length) did influence career selections to some extent. Events needed to be earlier in a young women's schooling; it was too late in secondary school's final years for short term events to have an influence. Nevertheless, they posed significant questions for program organizers. First, the data did not conclude whether larger, statewide events were better or worse than smaller, local programs. Next, considering how many volunteer hours or extra hours beyond the normal work load were required to coordinate and hold a successful event, they asked "is it time to consider that neither strategy is successful enough on its own and that, therefore, other options need to be considered?" (p. 349). Last, but definitely not least, they raised a final point: "the second paradox is that the minority gender in the discipline (women) [has been] the predominant owner of the problem" (p. 350).

Literature Review Details Summary

Stereotype influences can be counteracted with heroes and experiences that show a different vision of female engineers, physicists, and computer scientists. Robotics programs often provide these two elements. Gender nuances exist at various levels in career influence research with respect to STEM. Prior research has left several areas for further study as will be summarized next.

Literature Review Summary

Super (Super et al., 1957; Super, 1969, Super & Bachrach, 1957; Super & Overstreet, 1960; Super & Hall, 1978) and Roe (1952) outlined how heroes and experiences influenced young people’s career decisions. Roe and others have identified gender nuances in these factors as well (Roe & Siegelman, 1964; Quimby & DeSantis, 2006). Experiential programs influence career decisions as confirmed in recent studies (Barker & Ansorge, 2007; Hurner, 2009; Murphy & Whitelegg, 2006). Other recent research supports both elements of my conceptual framework (e.g., Holub, Tisak, & Mullins, 2008; Messersmith, Garrett, Davis-Kean, Malanchuk, & Eccles, 2008; Sevian, Hao, & Stains, 2010). Moreover, Gottfredson’s concepts of circumscription and compromise (2004) suggested experiences have the potential to influence career decisions by influencing developmental processes (Cassie & Chen, 2012). The FRC program could be one avenue that helps young people avoid narrowing their options too quickly, in particular young women. Exploring two key elements of career decisions—experiences and heroes—through a gender filter could inform the research community interested in improving female participation rates in engineering, physics, and computer science.

A second finding from the literature review was that prior studies have not provided young women a place to share their voices and opinions about career decision intervention programs. Moreover, several studies have examined experiences or heroes or both together often with a gender filter, but again, these studies have not actively sought the voices of the young women involved. The program at Jackson State University (Skelton et al., 2010) included both experiences and heroes observing how both elements excited seventh to eleventh graders (male and female) about engineering and computer science, though no quantitative study data was shared backing up those claims. The California University of Pennsylvania quantitative study (Weber, 2011) built a program using both role models and experiences, studying middle-school girls. Though their surveys found the girls' STEM career interest increased after the intervention, no qualitative data was captured, no voices were heard. Keathly and Akl (2007) survey data showing the influence of robotics high school summer camps and college age heroes, finding the young women's STEM interest levels increased but had only a few recorded anecdotal comments from the young women. In summary, many programs have considered the combination of heroes and experiences and their influence on career decisions. None have sought the young women's voices and ideas on heroes and experiences as influence factors using an in-depth qualitative approach, a research gap my study helps address.

Considering studies specific to FRC, the Melchior et al. (2005) study found that more young women were pursuing engineering and science degrees when compared to a nationwide database. However, the more recent FIRST study (Brandeis, 2011) recommended further data gathering and process steps were needed to improve the program experience for young women. The dissertations (Griffith, 2005; Hurner, 2009; Webb, 2009; Welch, 2007) that investigated or explored FRC influences did not study career influences, nor did they specifically study the influence of heroes or experiences on career decisions. Only one dissertation focused on young women (Hurner, 2009), though all the dissertations had some level of gender filtering in their data. My study qualitatively explored the impact of FRC on young college women several years after experiencing the program. Thus, my study's results provide a longer term look at FRC influences on career selections.

Conclusions

Career theory provides a scaffolding to explore influences from a high school robotics program on young women's career decisions. Prior research has not sufficiently explored this type of intervention program or more fully considered the long-term nature of its influence (Brandeis, 2011; Griffith, 2005; Hurner, 2009; Webb, 2009; Welch, 2007). Giving voice to young women, now in college, who experienced this type of high school intervention program was a research gap (e.g., Skelton, et al., 2010; Webb, 2009). Additionally, young women's accounts about the heroes and experiential components of these intervention programs had not been sought (e.g., Keathly & Akl, 2007; Weber, 2011). Overall, I had not found a qualitative study that linked together the two factors in my conceptual framework—role models and experiential programs—in particular for young women and STEM careers. Most significantly, the problem is not fully understood, because women continue to enter other careers, not engineering, physics, and computer science, though they have the capacity and skills to be successful in them. Giving voice to young women who participated in one intervention program—FRC—helps fill a research gap, improving the understanding of how heroes and experiences found in high school intervention programs influence young women's career decisions.

The next chapter describes the rationale for selecting grounded theory as the research method and what advantages it brings to the research questions. That chapter will describe the methods, participants, data collection, and analysis plans for this study.

Chapter 3: Research Method

This qualitative study explored how a high school robotics program (FRC) influenced young women's college major (career) choices using grounded theory methods. Online asynchronous focus groups were the first process step, followed by initial coding, then interviews, either face-to-face or using an online meeting application. The initial study plan remained consistent except for slightly smaller numbers of participants than had been planned. The first sections here summarize my study's research design and the rationale for it. The researcher role is depicted next. Last, the method and plan are described in detail.

Research Design and Rationale

Research Questions

From Chapter 1, the main research question and sub-questions are repeated below. Other questions were asked in the focus groups and interviews; these are shared and discussed in a future chapter section on Instrument Development and in the Interview Processes section of chapter 4. Information about additional questions and messaging can also be found in Appendix A. The linkages between research questions and the questions used in the data collection processes are shown visually in Figure 6 and in Table 3 with the specific research questions repeated below:

1. How did the FRC program influence young women's career choices?
    a. How and when did young women make their career decisions and college program selections?

b. How did the experiential part of the FRC program influence career choice?

c. What FRC heroes affected the young women and how?

d. How does a team's gender composition, that is, a single-sex versus mixed gender team, make a difference, if any?

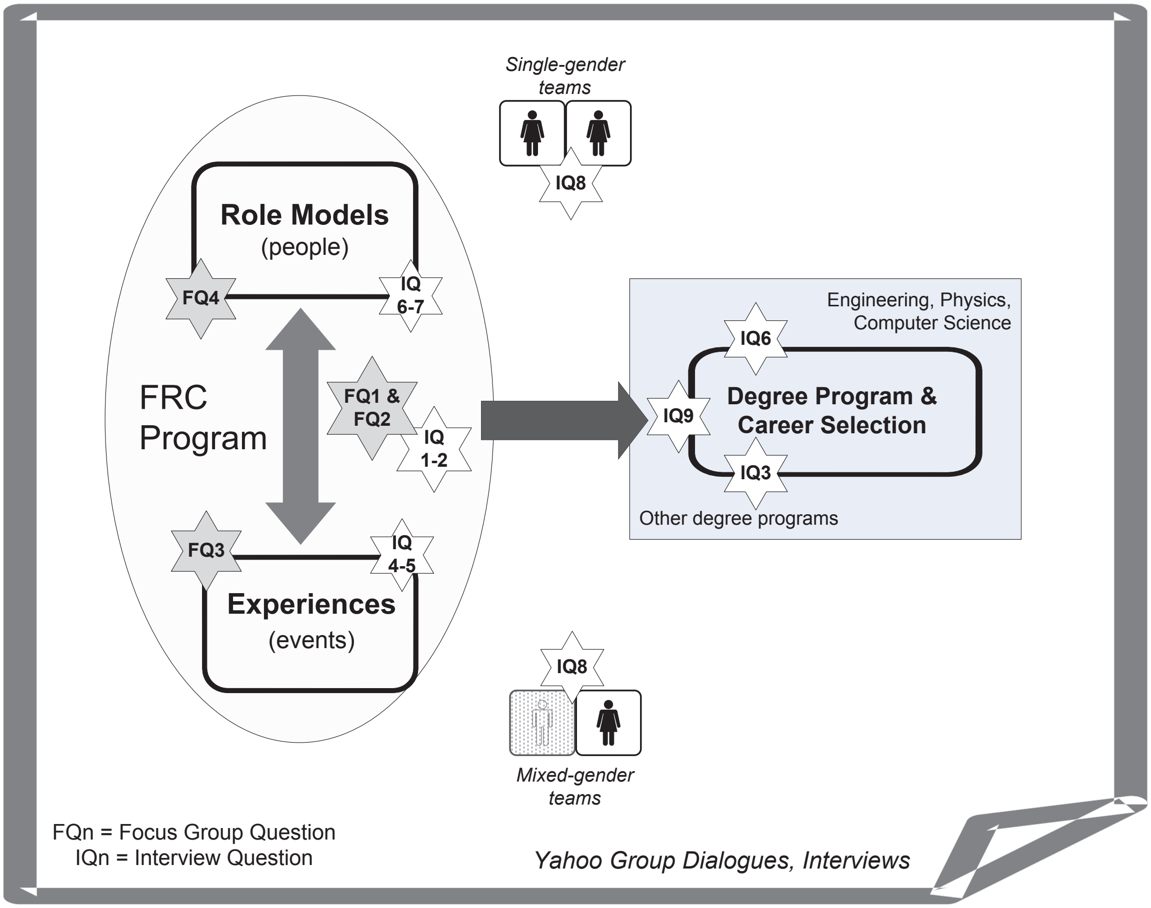

Figure 6. Study framework for research questions regarding FRC program experiences and heroes informing career decisions of college women, alumnae of single- and mixed-gender FRC team.

Table 3

Focus Groups Questions Mapping to Interview Questions

1. How did the FRC program influence young women's career choices? a. How and when did young women make their career decisions and college program selections?	**Focus Group** *Introductory threads, participants asked to post answers to these questions as an introduction to the group. Heroes are defined in the opening posts by me.* FQ1: Please share your degree program, when you decided on it, and why you chose it. FQ2: Thinking back to your time in FRC, what part of the program do you remember most?
	Interview Questions IQ1: What do you remember about FRC in high school? IQ2: Tell me about your favorite part of FRC: Designing, building, raising money, competing, software programming, or? IQ9: How do you think FRC affected your career choice? Describe if it made a difference, one way or the other.
b. How did the experiential part of the FRC robotics program influence career choice?	**Focus Group** *Main Discussion Threads*: FQ3: Describe how the experiential part of FRC influenced you, positively or negatively.
	Interview Questions IQ3: How did the experiential part of FRC affect your career choice? Any negative experiences? IQ4: How were you involved in the design or build process? IQ5: Describe your position in the team and how you got there. Were you on the drive team? If not, any thoughts on that?
c. What FRC heroes affected the young women and how?	**Focus Group** *Main Discussion Threads*: FQ4: What *heroes* do you remember from FRC program? Why?
	Interview Questions IQ6: Describe your heroes in FRC? Any negative experiences with heroes? Describe how heroes affected your career choice. IQ7: If you were an FRC mentor, what actions or behaviors do you think would be important?
d. How does a team's gender composition, that is, a single-sex versus mixed gender team, make a difference, if any?	**Interview Questions** IQ8: Describe your team's composition (single- or mixed-gender team). How did that affect the FRC program for you, in light of what you've shared already?

Conceptual Framework Revisited

This study applied a career development framework across two dimensions: heroes and experiences (Roe, 1952; Super et al., 1957). Using a grounded theory method, I explored influences from a high school robotics program called FRC. Participants began in online focus groups, and then with selected participants in interviews, the young women shared more deeply their stories and ideas. By listening to young women's voices about those influences with respect to their career decisions, my study explored answers to the research questions.

Research Tradition and Rationale

A conceptual framework was outlined in prior pages. To explore the research questions other methods approaches were considered but rejected (e.g., phenomenology, narrative, case study). After first considering case study methods at length (Stake, 1995; Stake, 2005), a grounded theory approach was selected (Charmaz, 2006). This iterative and comparative process offers several advantages, outlined in the next paragraph, and was a better fit for this study that explored how the FRC program influenced young women's career decisions. While much was known about the two factors in career theory detailed in my conceptual framework, the overarching problem of low numbers of women in engineering, physics, and computer science has continued to exist. Many intervention programs have been developed and tried (see Chapter 2) considering the two career theory elements (heroes and experiences) alone or in combination. Since the percentages of women graduating in those fields has stagnated for more than a decade (see Chapter 1), more information was needed on the positive and negative influences of these kinds of programs. Thus, exploring the FRC program's influence on young women and learning from it could improve understanding about solutions to the larger problem.

The grounded theory process for this study used a conceptual foundation on which to build (layer 1), with stories and ideas gathered in focus groups and interviews to illuminate that foundation (layer 2 using open and line-by-line coding), followed by theoretical sampling testing emergent concepts, explored further in more interviews (layer 3: developing categories and beginning theoretical coding), finally developing a model of the FRC program's influences on young women's career decisions via a General Systems Theory scaffolding (Charmaz & Bryant, 2010; Harry, Sturges, & Klingner, 2005; Zohar, 1997). Heroes and experiences were found to be foundational elements or generators, as is described in Chapter 4. The layering concept shown in Harry et al. (2005) was a visual way to build a theory from the *ground up*. This layering approach was consistent with constructivist grounded theory methods (Charmaz & Bryant, 2010; p. 409).

Abductive logic was used as well as inductive logic for this study. Abduction is often a part of grounded theory end processes (Haig, 2010). "Abduction arguments reason from factual premises to explanatory conclusions, as when we reason from presumed effects to underlying causes" (p. 81). Themes from the focus groups initial data gathering were inductively analyzed and those results were used for the interviews. Final conclusions, concepts, and recommendations made use of abductive logic at times.

As a last point in favor of grounded theory as a process for this study, Charmaz (2005) recommended the researcher become familiar with a grounded study environment and what happens in it (p. 521). Thus, my experience in FRC and as a female engineer was an asset for this method.

In summary, with an unresolved problem and a somewhat broad theory base, using grounded theory techniques to explore and compare learning about the baseline framework was a good match. My study's results have suggested a new construct with similarities and differences when considered against the conceptual framework. The young women's stories also provided insights into the influence of the FRC program on their career decisions and what might improve the program's influence in the future.

Researcher Role and Reactivity

As the main researcher in this study, I performed all the interviews, moderated the online discussion groups and performed the analyses and interpretations. As a female engineer, albeit from an earlier generation, my relationship with these young women could have drifted into a role model or mentor role; I did strive to keep any of these hero roles out of the relationship, though for two women, I did provide inputs based on discussions that arose in interviews, only after the interviews were completely transcribed and confirmed by them. My primary goal was to hear their stories, not share my own. Nevertheless, simply by listening to them, knowing who I am, the young women might have tailored their answers or been shaped by the experience, of meeting a long-term engineer (who is female too).

My decision to not share my own narrative during the interviews was designed to limit potential researcher bias. My own entry into engineering was the result of an experiential program much like that used in the study and strongly influenced by personal heroes; because this combination was so powerful in my personal life, I was conscious of the need to establish a professional distance to keep my own background from coloring my analyses.

Between my junior and senior year in high school, I participated in a National Science Foundation program studying engineering at the Ohio State University. This program had a profound impact on my development, as I had grown up and lived my whole life to that point in Minnesota. There were many factors in my personal STEM pipeline program experience. I got away from three younger brothers for six weeks; lived in a dormitory for the first time (with six other girls and some 40 boys) at the age of 16, in the summer of 1969; watched men land on the moon in the basement of the dorm with my fellow students; learned about calculus, statics, electronics, programming; and more. It was a tremendously cathartic and moving experience. I went to that program because a male chemistry teacher had suggested it to me. After the NSF program, I aimed myself at a career in engineering.

Heroes and an experiential program were my career decision influences. Those two factors certainly spoke to me during my early work at Walden University when I researched career theories and how they might connect with the FRC program’s influence today. Though, I had not made specific connections until the literature review was well underway. I believe this background provided me with insights and an ability to understand more deeply the women's stories and was not an influence on the analysis itself. Nonetheless, I was cognizant of the potential to introduce bias and I remained vigilant in the comparative and iterative analyses, sometimes memoing about one piece or the other to validate what I was finding and avoid bias.

Stakeholder support letters from Western Region Robotics Forum (WRRF) and Chief Delphi were obtained at the start of the study design. FIRST provided the data used in Chapter 2 along with a letter supporting its use. Consent forms, supplemental participant support material, and focus group and interview questions were approved by the Walden University Institutional Review Board (IRB) on March 14, 2013. The approval number provided by the Walden IRB was 03-14-13-0094048. With this consent, the study began shortly thereafter.

I was also cognizant of potential problems with *reactivity*, my influence on the setting and the research subjects (Maxwell, 2005, pp. 124-125). The FRC teams that I worked with in northern California knew me in a leadership capacity as the WRRF Board of Directors Treasurer and as one of WRRF's main faces to the community. Each autumn, WRRF hosts *CalGames* (an off-season robotics competition), an offering of the FRC events for teams in northern California; in 2012, I led the planning for that event. I also have organized over six years of robotics workshops for WRRF, and students knew me from these events held multiple times a year.

My involvement with FIRST and WRRF has not been tangential. It did help me bring deeper sharing and understanding of the young women's stories. Charmaz (2005) suggested that a grounded theory researcher "establish intimate familiarity" (p. 521) with the environment and this was consistent with my years of experience with the FRC program. As a female engineer, I had experienced some of what the young women participants described and that did enhance my analyses. My letter to potential participants clearly stated that this study was an academic one (sharing its purpose), and that WRRF or Chief Delphi was not responsible for the study or its results. Moreover, participants had a clear understanding that participation did not benefit them inside the WRRF, Chief Delphi, or FIRST organizations in any way.

Planned Study Methods

This grounded theory study explored the influence of FRC program participation on young women's career decisions.

Participants and Site

Female FRC alumnae from Northern California and their career decisions helped me answer the research questions. After IRB approval, participants were obtained through four paths: (a) outreach to FRC alumnae through my contacts in northern California; (b) a request sent to FRC alumnae using the Western Region Robotics Forum (WRRF) community; (c) outreach to teams directly through faculty and mentors known to me; and (d) outreach at *ChiefDelphi*, an online, long-established website for FIRST robotics teams.

A purposeful sample identified alumnae from northern California FRC teams in college or recently graduated from when the study began. The purposeful selection of young women considered two vectors: current degree program (engineering, physics, and computer science degree programs, as well as other STEM and non-STEM programs) and the gender composition of their FRC team (single or mixed).

The first level of data collection was conducted using a Yahoo online group website set up specifically for the participants. Interviews were conducted through a variety of means. Some were held face-to-face and others were conducted using the GoToMeeting online teleconference application; and conversations were recorded with the participants' consent.

Sampling Plan and Justification

Qualitative methodology theorists argue that a qualitative sample plan should seek to be information-rich, criterion based with purposeful sampling (Creswell, 2007; Merriam, 2009; Patton, 2002). Selections for qualitative design sampling should be purposeful in nature, not random (Patton, 2002, p. 240). The intent of this purposeful sampling is to help a researcher "discover, understand, and gain insight" (Merriam, 2009, p. 77). After using purposeful sampling to begin, grounded theory then uses theoretical sampling (Charmaz & Bryant, 2010) after a more broad data gathering was completed (i.e., focus group) and initial coding of ideas and categories from that layer was accomplished (Charmaz, 2006). These different types of sampling were all used in this study.

Purposefully selected samples served two purposes. First, encompassing extreme cases helped to gather patterns of similarity and identify any unique elements (Patton, 2002, p. 235). Including certain extreme cases, or possibly more correctly, including confirming and disconfirming cases, supported triangulation (p. 234) by including female alumnae who did not select engineering, physics, or computer science as a career path as well as those who did. Second, the focus group participants were not random; they were purposefully chosen considering three items: team composition (single- or mixed-gender), teams (not all from one team), and degree program (engineering, physics, and computer science vs. other). After the focus group coding was completed and theoretical sampling was used to analyze the focus group answers, a subgroup of participants was purposefully chosen and invited to participate in the next layer of the study, an in-depth open interview, as recommended by Harry et al. (2005). The three stratification levels for both focus group and interviews were used as suggested by Creswell (2007) and Patton (2002): (a) team gender composition, (b) class level in college (e.g., sophomore, junior), and (c) degree program.

Study questions drove one stratification level, specifically the influence of single- versus mixed-gender teams (see Table 4). Another stratification that I considered represented progress within the degree program, that is, if the participant was a freshman, sophomore, and so on. Margolis and Fisher (2002) in their study of college women in computer science heard different views from the same women depending on what college year the young women were in. Thus, to more deeply explore longer-term career decisions, the minimum sample for junior and senior (year 3 & 4) was planned to be larger. A qualitative sampling plan goal is not representation; instead, its goal is building credibility (Patton, 2002, p. 241). The final stratification level involved degree program. Adding participants who are studying liberal arts, finance, and other fields to the sample brings in a disconfirming element (p. 239). Finding out why those young women did not select engineering, physics, or computer science was informative. However, these disconfirming elements were not the prime focus of the study and the lower minimum sample sizes for this criterion reflected this. Expanding the sampling plan to include this criterion provided more information-rich results. (Merriam, 2009).

No attrition occurred during the interview process. If I had been unable to obtain participants in the early college years, I would have eliminated that level in the plan and focused on juniors and seniors; that did not occur. As noted above, Margolis and Fisher (2002) heard different views from women in their study depending on what year of the program they were in; later years could address more specifically a longer term career decision. From volunteers gathered via the outreach approach described in Participants and Site section above, with emails to my contacts FRC community, to the WRRF community, and posted on the ChiefDelphi site, focus group participants (FRC female alumnae in college) included participants from seven teams, and of those, three were all-girls teams. Not as many young women responded to my study request as I had hoped. . See Table 4 for the study’s original plan.

Finally, I had only eight young women participate in two focus groups (layer 2). Two others came into the study after the focus groups had completed: one from a mixed gender team and one from a single-gender team. These two contributed to triangulation efforts. The interview participants were selected using theoretical sampling (Charmaz & Bryant, 2010) from categories and code groups that arose from initial coding of the focus group dialogues. Ultimately, the planned numbers did not occur as noted in Table 5. The focus groups had less than originally planned for the mixed-gender participants in years 3-4 of college. Otherwise, the quantities were close to plan. I did make one more outreach effort specifically to mentors of mixed-gender teams and one of the last two interviews came from that email set. I also did one more interview from the Focus Group set after the model had been developed. These final interviews helped test the emergent theory from the analysis of focus groups and interviews (Schwandt, 2007, p.131) and no new codes of merit emerged. Thus, the categories appear to have saturated.

Table 4

Sampling Growth Plan for Study with Female FRC Alumnae in Northern California

	All-girls teams		Mixed-gender team	
	Focus Group Composition Plan			
Years 1 – 2	Engr/Physics/CS (2)	Other degrees (2)	Engr/Physics/CS (2)	Other degrees (2)
Years 3 - 4	Engr/Physics/CS (2-3)		Engr/Physics/CS (4-6)	
	Interviews Planned			
Years 1 – 2	Engr/Physics/CS (1)	Other degrees (1)	Engr/Physics/CS (1)	Other degrees (1)
Years 3 - 4	Engr/Physics/CS (1)		Engr/Physics/CS (2)	

NOTE. Quantities are in parentheses. Interview numbers and types were to depend on learning from focus group discussions.

Table 5

Final Study Sampling with Female FRC Alumnae in Northern California

	All-girls teams		Mixed-gender team	
	Focus Group Composition Result			
Years 1 – 2	Engr/Physics/CS (1)	Other degrees (1)	Engr/Physics/CS (2)	Other degrees (1.5)
Years 3 - 4	Engr/Physics/CS (2)		Engr/Physics/CS (0.5)	
	Interview Composition Result			
Years 1 – 2	Engr/Physics/CS (1)	Other degrees (1)	Engr/Physics/CS (2)	Other degrees (1.5)
Years 3 - 4	Engr/Physics/CS (2)		Engr/Physics/CS (1.5)	

NOTE*:* Quantities are in parentheses. Interview numbers and types depended on learning from focus group discussions and added interviews to assess saturation.

Instrumentation

Focus group research was conducted using an online Yahoo discussion group using specific, threaded discussion questions (see Table 3). Intensive interviews (Charmaz, 2006, p. 25) were conducted, beginning with open-ended questions (see Table 3) built from the research questions. No interview protocols or focus group questions were used from other sources; all were created by me with advice and counsel from my dissertation committee.

Instrument Development and Content Validity

The interview and focus group questions developed from the literature and research questions were reviewed with my committee prior to IRB submittal. This process step added some validity to the planned questions and approach.

Data Collection

The study included a mixture of data sources supporting triangulation: (a) interviews, face-to-face or by phone; (b) threaded conversations around discussion questions (similar to face-to-face focus groups) within private online Yahoo Group(s); (c) photographs and other text files provided by participants and from my own sources; and (d) observation data from a local FRC regional held in 2013. In addition, to providing texture and information for the study report, participant demographic data included university name and location, initial and current degree program, how many years spent in FRC, what type of team, and other items. Interviews of FRC team mentors and male FRC alumnae could have provided further triangulation opportunities (if the analysis of focus group dialogues and interviews suggested it would be helpful); however, these were not needed.

Focus group. As the first step, a focus group was formed from volunteer participants to first explore questions developed from the foundational conceptual framework. One reason for using a focus group to begin was that it might better allow young women to feel comfortable with sharing any negative parts of the FRC experience. If these arise, further exploration could occur in the 1:1 interviews (Kamberelis & Dimitriadis, 2005). “Focus groups afford women much safer and more supportive context [to] explore their lived experiences and the consequences of these experiences with other women who will understand what they are saying intellectually, emotionally, and viscerally” (p. 897). Two online focus groups were organized about a month apart. Analysis of the first focus group was used to tune the second one. Theoretical sampling of the focus group participants based on themes that arose in those dialogues guided the selection of interview participants (Charmaz & Bryant, 2010).

Threaded conversations. This generation of young women is accustomed to online group conversations and this approach spoke to their digital generation accustomed to texting, sharing in Facebook, and creating web sites. A strong level of privacy was achievable in Yahoo and Google groups, by limiting access to participants approved by a moderator; in addition, I could have, but did not have to, implement further privacy restrictions. Privacy and confidentiality are not readily available or guaranteed in Facebook and other online social networks and thus those virtual approaches were rejected. Participant release forms noted the unlikely, though possible, legal requests for data or to which Yahoo would have to respond. Also, while I did set up housekeeping guidelines for the online focus group about access and sharing, the very nature of online communications brings forward a risk of sharing content beyond the forum. (James & Busher, 2009).

Yahoo groups have a solid file management system allowing folder hierarchies; Google groups did not. A benefit to this online group approach was the automatic availability of digital text transcriptions of the conversations, given these groups are online to begin with. Additionally, people will share online ideas dissimilar to those they might share face-to-face; it was simply a different interpersonal dynamic. Last, with the participants spread across many cities and with varying schedules, this approach allows them to discuss virtually and asynchronously (James & Busher, 2009). If the files were too large or if vetting them first in some way was necessary, I planned to use the DropBox application (an FTP sharing site) to which I have access, but it was not necessary. It also has high security levels limiting access to only those allowed access by the owner, me in this case. I have been working online and with email, using virtual methods of communication since 1982, have taught online college classes since 2002, and am skilled at managing nuance and issues that arise in virtual conversations. That said my study participants were potentially not mature in that regard and need support or coaching at times. Maintaining my researcher "hat" at all times guided this coaching.

Interviews. Interviews, using an IRB approved list of questions and structure occurred either face-to-face or by Internet meeting (see Table 3 for basic questions). Face-to-face was the desired environment; an online meeting was the backup offered. Given that several of the young women were going to school outside of the geographical area, the online meeting approach was used more than I expected. Hearing stories, ideas, and thoughts from these young women was critical to this study. Exploring "what meaning they make out of the experience" (Seidman, 2006, p. 11) helped answer the research questions, what it was like to be in FRC and how did it influence them. All but two participants were in the initial focus group discussions. Using theoretical sampling, I selected participants from those dialogues to enrich and build the understanding of the young women's stories for emerging themes and coding groups. Initially only one interview per participant was planned. However, a second interview could have been undertaken if comparative analysis suggested that step was needed for a participant. (See Chapter 4, Demographics for more details on the final study participants).

Photographs. Photographs added texture and broadened the information base beyond the interviews and online discussions. Participant supplied photos and other artifacts enriched the participant's stories. "Telling stories is essentially a meaning making process" (Seidman, 2006, p. 7) and with these additional threads, a richer and more nuanced meaning resulted.

Observations of FRC event. As another source of triangulation, I did perform an observation of a local regional event for two days. That is reported in the Chapter 4 results section. This observation was not from the same time period that the young women in my study participated in FRC, of course.

Study limitations. While I had planned several data gathering processes and have explained these above, none was a direct observation of the young women by me. Thus, what the participants told me could change in their memory, affected by other experiences or dialogues since that time; and thus, their responses may not be what they would have been if asked in high school. That said, the research questions and intent was to focus on longer-term effects of the FRC program. Thus, exploring this program with them several years later was consistent with the study's intent.

Data analysis and interpretation

An inductive data analysis of conversations, observations, and electronic communication depended first on a mind-mapping tool from Mindjet: MindManager™. Coding made use of *in vivo* and manual coding techniques, first open coding, then grouping into developing categories, comparing along the way during the process of interviews. I coded the first focus group dialogues line by line, using Word tables only. Then after mapping those into a mind map, I moved forward coding the second focus group and all interviews with Provalis Research's QDA Miner application. Mind maps of the coding efforts provided additional visual displays to share with stakeholders and participants (Thomas, 2003) in follow-up presentations and articles.

Content clouds (also known as word clouds or tag clouds) of the data provided an orthogonal view of dominant themes from a frequency point of view (Cidell, 2010;

McNaught & Lam, 2010). These content cloud figures provided a visual guide to all the main categories for the reader. Content clouds essentially count the occurrence of words in a file and depending on the frequency show the word in larger or bolded font. What words are counted can be managed to eliminate non-useful words. An example of a content cloud developed from the Walden University social change webpage (Walden University, 2012) using TagCrowd (Steinbock, n.d.) shows its potential. To fine-tune this content cloud, I eliminated four words: Walden, around, social, and change. The results of the content cloud analysis are shown in Figure 7. This visual represents key messages from Walden's social change vision. While I primarily used the QDA Miner content cloud feature, I also used one of the Web 2.0 content cloud applications available (e.g., Wordle, TagCrowd) to analyze codes and categories.

Figure 7. Content map of Walden's University social change website developed with TagCrowd.

For the photographic artifacts, I engage interview participants in a photo-talk activity. This photo-talk activity, developed by Serriere in a 2007 dissertation, “us[es] the photographs to access [participant] interpretations and visualizations of change [to] bring new social possibilities and awareness” (p. 54). With the participants discussing the photos, Serriere asserted “configurational *validity* [is established, as] Goldman-Segall…describe[d] a similar process in which ‘layers of interpretation are added because data are analyzed by multiple users’ (1998, p. 16)” (p. 56). In some cases, asking the participants to describe a representative photograph from their memory proved just as useful if they did not have one available.

As the data was analyzed, staying alert to new framework elements was important. For example, if self-efficacy ideas arose consistently in the interviews, adding that element might have been necessary and this addition would have been consistent with ground theory concepts (Charmaz, 2006; Harry et al., 2005). Maxwell (2005) recommended checking themes in the study framework and developing alternate theories if the need arose.

Study limitations. The participants highlighted some career influence decision factors beyond role models and the experiential nature of the program. These additional theories and concepts are discussed in Chapter 5.

Trustworthiness Plans and Ethical Considerations

Credibility. Planned measures to improve the quality and trustworthiness of the study data include triangulation from multiple data source types, feedback from participants on both their interview transcripts and the study's findings, and a review of the initial findings with key stakeholders (e.g., FIRST, WRRF, team mentors) (Thomas, 2003, p. 4). These process steps—member checks, peer review, triangulation—helped develop credibility of the analyses.

Transferability. Generalizing the findings from this study has some merit for females in other robotics programs that have similar elements, such as heroes and experiential activities. It is possible that some findings could be transferred or generalized to males. However, since the findings were not reviewed with young men nor were they part of the study, it is difficult to comment on this quality measure. (Maxwell, 2005; Merriam, 2009). Nonetheless, some of the model is likely transferable to males given the findings discussed in the recent study by Brandeis University (2011) for FIRST.

Dependability. Different participants studied by another researcher may bring different results. While the interviews have the possibility of self-report bias, since they are historical in nature, the impact was partially limited by the use of photographs they discussed. These historical snapshots of the young women's FRC participation should provide a view contemporaneous to their high school involvement. If the themes developed suggested this, interviewing male alumnae or mentors from that time period, could have been a testing step (Harry et al., 2005), albeit also self-reported. Maxell

(2005) suggested these approaches as another form of triangulation to improve dependability.

Confirmability. As Maxwell (2005) stated, “what the informant says is *always* influenced by the interviewer and the interview situation” (p. 109). Thus, analyzing why I might be influencing a participant was important for me to remember (as described in prior section on researcher role and reactivity). Avoiding leading questions, using open-ended questions, and working with pre-established questions helped avoid issues in this area.

Ethical Procedures. Stakeholder support letters from Chief Delphi and WRRF were provided to the Walden University IRB. As noted in a prior section (Researcher Role), I could be known to participants in my role as a WRRF BOD member, CalGames organizer, or FRC volunteer. Since I could not always know if they remembered this, the consent letter iterated that this study was not associated with FIRST or WRRF.

Since all participants were in college, all were adults, 18 or above in age. This was a requirement to participate. Recruiting was accomplished through the WRRF community, team contacts in California, the ChiefDelphi website message board, and finally personal contacts I have within the FRC community. Potential participants received an email with a digital letter describing the study, how they can withdraw at any time, and that no remuneration would be provided. Participants who were interviewed had the opportunity to review their interview transcripts; they saw their focus group dialogues in the online Yahoo groups. Participants selected their own pseudonyms. FRC team names and numbers easily trace to the team's origin and location. Thus no team numbers were used at any time. Pseudonyms for participant team names were not needed after all.

All participant interviews (after transcription) and threaded conversation files (using only pseudonyms) have been kept in password protected Microsoft Word files. The files used in the QDA Miner application could not be password protected during the analysis. When the analysis was completed, the password feature was turned back on. These pseudonym (i.e., private) files are only available to the dissertation committee members. Portions of them were used in the analysis chapter. The participants had the opportunity to know this was planned and ask me not to use certain quotations; none did. Interview audio files were archived in password protected compressed files. One single file contained the cross-reference between actual names and pseudonyms, password protected. These data files will be maintained securely for the number of years required by Walden University and will then be destroyed.

Methods Recap

This qualitative, grounded theory study of the FRC program explored the influence of FRC heroes and experiences on young college women's (FRC alumnae) career decisions. The study included participants from northern California beginning with two online focus groups and then using theoretical sampling selected participants were invited for an intensive interview (Charmaz, 2006). To add credibility, both the focus group and interview participants included young female FRC alumnae who did not select engineering, physics, or computer science as a college curriculum. Several interactive methods of data gathering were used with analysis using software applications available to me as described. In the next chapter, the stories and ideas from these young women help build a structure around the conceptual framework scaffolding, resulting in a proposed model for understanding young women's career decisions, for those young women who are FRC alumnae.

Chapter 4: Results

Introduction

The purpose of this grounded theory study was to explore how a high school robotics program (i.e., FRC) influenced young women's college major and career choices. Career theory supplied the scaffolding for a conceptual framework, notably the influence of heroes and experiences, on which to build a theory. The primary question and first sub-question related to the young women's career decisions and the influences of FRC on those. The next two questions considered each of the two factors, experiences and heroes. The final question captured stories about the perspective of single- or mixed-gender team influences. One main research question with four sub-questions was the result:

1. How did the FRC program influence young women's career choices?
    a. How and when did young women make their career decisions and college program selections?
    b. How did the experiential part of the FRC program influence career choice?
    c. What FRC heroes affected the young women and how?
    d. How does a team's gender composition, that is, a single-gender versus mixed-gender team, make a difference, if any?

This results chapter begins with an overview of the participant demographics and study setting, followed by a synopsis of the data collection steps. The main section for this chapter is the data analysis. A proposed model opens the analysis section. Explanations, using content clouds, demonstrate connections between codes and categories, leading to the model grounded in young women's memories and stories. An environmental analysis is next with a word picture of a regional competition and participant's ideas about team size and type (i.e., single- or mixed-gender). The chapter ends with a discussion of trustworthiness and a summation.

Setting and Demographics

Setting of Study

The participants joined the focus group discussions during their spring quarter or semester in college. For the first focus group in April, the timing appeared to present few issues. The second focus group was in mid-May. This timing may have limited their participation with the end of quarter/semester activities at their college or university. Most interviews took place in the summer and participants were readily available.

The focus groups were accomplished online using Yahoo groups as a virtual, asynchronous meeting room. One young woman had indicated an interest in participating, submitting a demographic form, and eventually a consent form. I set her up in the second focus group with a Yahoo ID; however, she never joined the group and my follow-up efforts were not able to determine specifically why she did not join. Later, I invited her for an interview though she did not respond. The online format may have been a problem for her or more likely end-of-quarter challenges arose for her.

Demographics of Participants

Twelve college women volunteered initially to be part of the study. Two college women, both from single-gender teams, after initially submitting a demographic participation form, did not participate. One did not return consent forms after more than one outreach attempt by phone and email, inviting her to participate in a focus group, or subsequent attempts inviting her for a 1:1 interview. The other did return a consent form, but did not join the focus group and did not respond to subsequent attempts inviting her for a 1:1 interview. Since these two participants were from single-gender teams, and half of the young women participating were from single-gender teams, I did not pursue this further.

Thus, ten participants were part of the study either by participating in an online focus group and/or an interview, and of those ten, seven were part of both processes (e.g., focus group and interview) from April to October 2013 (see Appendix A, for further details). Two more participants had volunteered at different times after the focus groups were complete and participated in an interview. After the model was developed in September, I interviewed one more from the focus groups. In addition, in October, I appealed directly to mixed-gender team mentors and one more volunteered and was interviewed. These later two interviews took place in October 2013 and while these did not result in any new categories or any codes of significance, they did validate the model and provide a richer set of stories to use in this chapter’s analysis review.

Demographics in Table 6 are for the ten college-age women who ultimately participated in an online focus group, an interview, or both. Two of the ten participants shared a university with all others being unique; some were pursuing similar degree programs (e.g., Mechanical Engineering); all were in 4 year institutions. All were alumnae from northern California FRC teams. Their age ranged from 18 – 22 years old.

Table 6

FRC Alumnae Study Participant Demographics (N=10)

	Mixed-gender	Single-gender	Total
Total	5	5	10
Data Gathering Process			
Focus Group Participants	4	4	8
Interview Participants	5	4	9
Grade Level			
Freshman	1	2	3
Sophomore	1	0	1
Junior	2	1	3
Senior	1	2	3
Degree Program			
Liberal Arts	1.5*	1	3
Engineering or Computer Science	3.5*	4	6

* One degree program was across both the engineering and liberal arts spectrums, and is counted half in each degree program.

Note: Grade levels were for participant's most recent prior college year. Most were interviewed in the summer after that year.

Data Collection

Two primary methods for data collection were used: focus groups and interviews. As a triangulation process step, an observation was conducted at a regional event. Photographs shared by some of the participants were also analyzed.

Focus Group Processes

The online asynchronous focus groups occurred in the spring of 2013, each running for two weeks. The first focus group was in April with five participants, the second in May with three participants (four had been invited, only three joined: see above). All messages posted by me and the participants were visible only to us. Each Yahoo group was kept private with access limited to only those in a focus group. Posts arrived by email as they occurred and I transferred those words and writer's names to Word documents as the discussion continued over the two weeks. Later, I imported these files to a qualitative data analysis (QDA) package for analysis. When the focus groups ended, each conversation was printed to an Acrobat .PDF file and password protected. At the close of each focus group time, I limited the access to only myself, sending emails to the participants beforehand that participant access to the focus group was closing.

The planned focus group questions were starter questions for threaded discussions, using the questions found in Chapter 3, Table 3. After the participants had responded, I sometimes used exploration questions based on inputs. For example, "thanks for sharing! Could you expand on creativity and what it means for you? Maybe some examples from FRC and the degree programs you mentioned?" or "interesting pathways for sure. Thanks for specifics! Could you expand on this thought: 'It really opened up my eyes to all the possibilities that I could do with engineering, and ultimately helped me pick my major?'" These exploration questions helped move the dialogue into deeper responses at times. Also, these exploratory or summative comments helped other participants visualize this online, asynchronous room as a place for interactive dialogue among us all versus being simply a survey.

In addition to the planned focus group questions, I made housekeeping posts to open the group, provide process help on thread management, and closing information (see Appendix A). Moreover, I shared with focus group participants the definition of heroes for this study; this definition was also mentioned at the beginning of several interviews.

Interview Processes

The first few interviews used all of the questions from Chapter 3, Table 3. After a few interviews, it was apparent that the participants were repeating themselves from the focus group. For the later interviews, I only used some of the planned interview questions depending on the depth of a participant's responses in the focus group on related focus group questions. For the two interviews where participants had not been in a focus group, I used all the planned interview questions plus one of the focus group questions.

For all of the interviews where participants had been in a focus group, I added prepared questions built from what they had said in the focus group and from the initial coding completed on the focus group dialogues. These additional questions were meant to tease out more depth and details about codes and categories formed in the focus group analysis. For example, in one interview I asked:

> You had several phrases that you used in the focus group to describe your memories that rang a bell for me. One of them was *equal parts work and laughter*. A sense of fulfillment following each night and morning. Learning and teaching. Can you share some examples?

The *in vivo* code, equal parts work and laughter, an initial code from the focus groups, remained throughout different versions of coding, becoming a strong code in the category of FRC experiences.

Throughout the interviews, I asked clarifying or exploration questions to elicit deeper reflection from the participant.

> C2: So, your team was a mixed gender team?
>
> SM: Yes.
>
> C2: Can you give me a picture of that? Roughly the proportions?

That led to a longer dialogue on the number of women in her team, and thoughts on being in a mixed-gender team versus a single-gender team. These kinds of questions in both focus groups and interviews were intended to be intensive interviewing techniques as described by Charmaz (2006).

One of the last questions I asked in interviews was if the participants had any photo memories they wished to share. For several participants, I asked this question earlier as part of emails setting up the interview time and location. The young women provided a range of photographs and other documents (blogs, websites) that I examined. In some cases, I asked this question instead: If you were going to share a photograph or two, that was a memory for you, what kind of photograph would come to mind? This question proved similarly productive compared to asking them to bring photographs or share photographs by email before the interview. I made it clear that this photo sharing was optional though all showed interest in participating.

The interview lengths ranged from about 29 minutes to an hour and 27 minutes. All but two were less than 45 minutes: three about 30 minutes, three about 45 minutes, and one an hour and a half. Four interviews were conducted face-to-face (F2F) in various outside locations. Five interviews were conducted using GoToMeeting (GTM) software from Citrix (www.gotomeeting.com). For the GTM interviews, I typed brief notes to capture the participant's ideas as she spoke, and she could view these on her computer screen as the interview progressed. The GTM approach allowed the participant to see what text I was capturing from her words, be able to see upcoming questions, and allowed her to easily share visuals (like photographs) without being face-to-face. The GTM meetings were recorded by the application with permission of the participants, and then stored on my computer. The F2F interviews were digitally recorded with permission and moved to my computer.

All interviews were then transcribed using f4 (audiotranskription.de), with time stamp connections to the audio (F2F) or video (GTM) file. I used Dragon Naturally Speaking to transcribe most interviews into text, repeating into it what I heard via f4.

Then, Dragon automatically generated text from my voice requiring some manual corrections. The transcriptions were mostly verbatim except where I did not capture some repeated idiomatic words. For example, I did not transcribe all the extra words when these seemed to get in the way of other content and did not add anything. For example, “thus,” “like,” “you know,” “so,” and similar words were not always transcribed. Transcriptions, password protected, were provided by email to the interviewees for review and comment. No editing was suggested by anyone. The transcriptions took longer than I had committed to the participants, from a shortest time of 1 day to a worst case of 32 days. Most were provided to interviewees for review about 3 weeks after the interview. The longest one was because of difficulty transcribing the file; it had been conducted outside in a park and I had neglected to have the young woman use a lapel microphone. That interview required a number of reviews before being transcribed completely.

The other two data collection processes used were observations and photo discussions as described in Chapter 3. The two-day observation at a local FRC regional competition in April did not include the young women in the study; it was the environment they described, albeit several years newer.

The data collection process took longer than planned, primarily because fewer young women volunteered to participate than I planned and the interest occurred over a longer period of time after receiving IRB study approval. The transcriptions took longer primarily because I was somewhat new to this process and had to develop the necessary skills to do it. The analysis of the focus group information began immediately after the first one concluded. Analysis, as will be described next, continued in parallel to the second focus group and the interviews. The women invited for interviews were theoretically sampled from what I had available using the initial coding I completed from the focus group dialogues. The last two interviews did not add new codes per se; instead they added depth to the categories that had matured from the coding analysis.

Data Analysis

This section includes a proposed model for understanding the influences of FRC on young women's career decisions through a General Systems Theory (GST) lens (Zohar, 1997). The model is first outlined inside GST principles, then in following sections, the women's voices and stories demonstrate how the elements within it were built.

Building the Model

Possibly because many participants were engineers or because I am an engineer, the model that emerged from the memories and reflections of these young women grew from GST. In GST (and engineering systems), systems have inputs, connected by processes to outputs, nurtured or bombarded inside an environment. As described in an earlier research paper (Craig, 2010),

> The beauty of GST is two-fold: first, it makes complex situations simple, and second, it supports a building and analysis of layers of sub-systems integrating

> into a much larger system. By analyzing a knotty set of inputs, outputs, within an environment as a *system*, a complex system can appear simple. (pp. 11-12)

Using GST as scaffolding for a young woman's career decision making model seemed apt as conceptually GST models are useful to improve the environment and processes they model (Zohar, 1997). That is, to foster and nurture change, to develop more prevailing STEM interests in more young women, "we have to change the thinking behind our thinking" (Zohar, 1997, p. 25). Zohar's quantum decision making concepts as applied to organizations apply here. The FRC experience and its heroes are inputs to processes used by young women as they generate career interests. The output was the person they become from these processes.

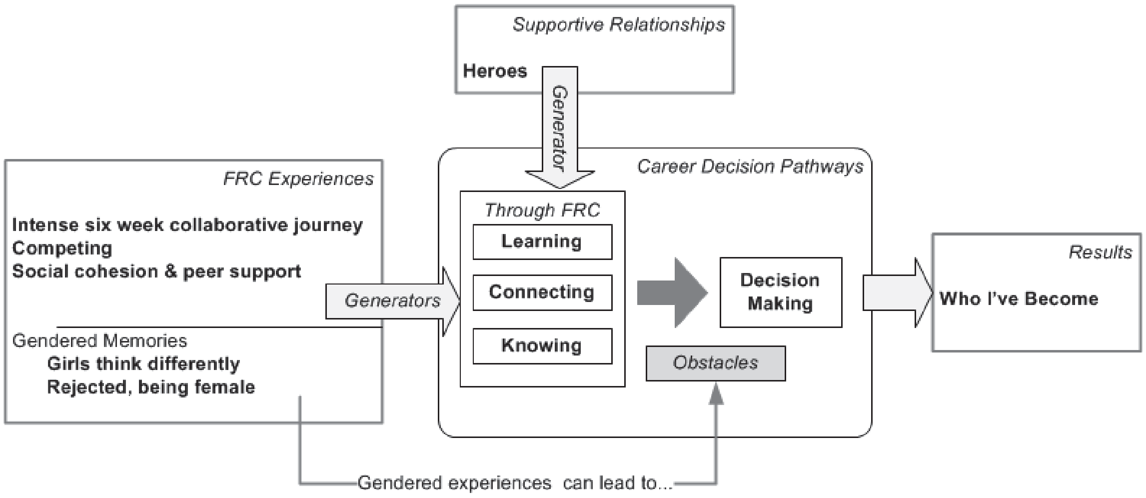

Figure 8. Model for FRC influences on young women's career decisions

The model (Figure 8) had two generators or inputs: (a) *FRC experiences* categories: intense six week collaborative journey; competing; and social cohesion and peer support; and (b) the *heroes* category: role models, teachers, parents, and mentors in FRC. Two gendered influences arose. Like noise on a circuit, these might move a system off its norm or alternatively keep a system from being effective in delivering power. The system modifiers (analogous to circuit noise) were *girls think differently* and *rejected, being female*. From this study's participants, stories emerged in three process categories of learning, connecting, and knowing, coalescing into decisions. At times, gendered memories became obstacles in the process. The output for this system was *who I've become*, the results of input generators and processes. This model is pictorially shown in Figure 8 and will be developed over the next pages.

Generators: FRC Experiences

The college women who spent high school years participating in the FRC program, with a few continuing to participate now as mentors themselves, had four categories of memories of their FRC experience: *intense six week collaborative journey*, *competing*, *social cohesion and peer support*, and *gendered memories*. These categories are presented first with a content cloud based on code frequency (see Chapter 3 for a more detailed description of content clouds). The larger and darker the font, the more frequent was the occurrence of the code. Following the content cloud for each category are explanations and quotations from the participants.

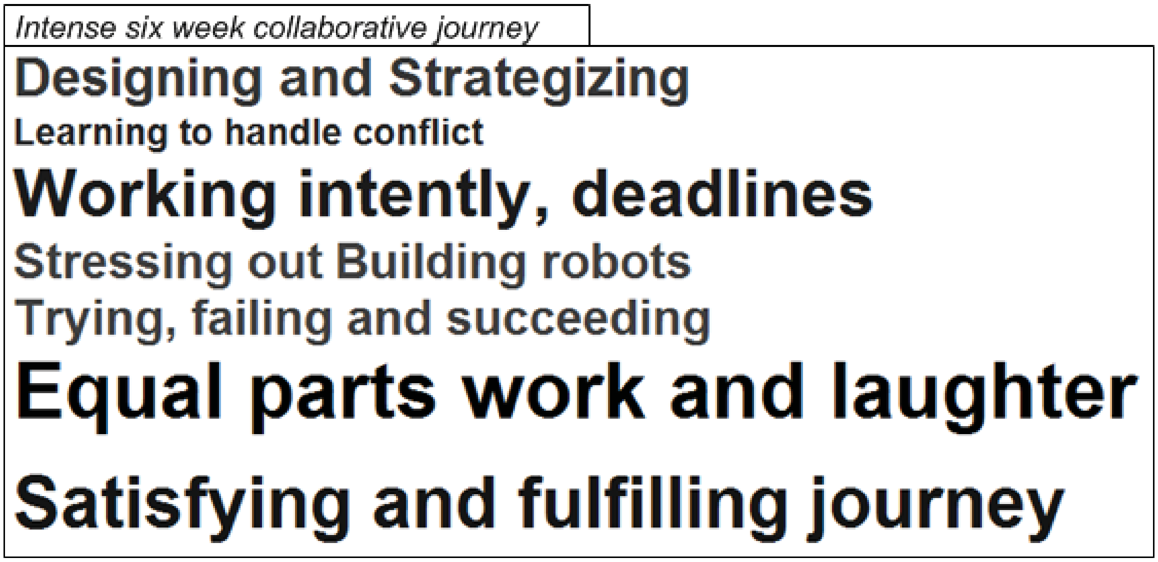

Figure 9. FRC memory codes for generator category: Intense six week collaborative journey

Intense six week collaborative journey. As noted in prior chapters, the FRC design and build phase runs six weeks (and two days) from kickoff to the stop-build day. When talking about the intense period after the season kickoff day, a common phrase in FRC is "six weeks is not a long time to design and build a robot." In my own rookie year as a mentor, I felt this short, indescribably intense period keenly. Thus, for this set of memories from before the competing time, I defined the participant generator category to include the phrase, six weeks, along with key words from the codes to provide a word picture of the intensity, the growth, and the satisfying journey (see Figure 9). Lexi described how the design and build season begins, for the first code, designing and strategizing:

> At the beginning of the build season, once the competition details were revealed, we immediately began brainstorming ideas on the best way to design a mechanism to accomplish that year's task. We broke up into a couple [of] groups and collaborated with each other to come up with a plan. From there we threw out our thoughts and once we shared and received feedback on how we could improve the design, we went straight to building the prototypes. After testing which was most efficient and finding what the pros and cons were of each design, we finalized and went on to building the actual parts.

Anne and Aria shared similar stories, Aria mentioning “everyone would have their own ideas and it went on the whiteboard and then we would discuss the pros and cons of each design.” Alexis asserted “with our club we were very adamant that everyone participate in the design process.” Most of these young women were active in the design process time, liking the brainstorming and creativity that occurred in it.

Conflict occurred periodically during this first phase of the season. Picking the final robot design, a color to be used for the team spirit collateral for that year, or selecting the robot’s drive team: all generated conflict. One team used a specific physical area in the robot lab for team members (and mentors) to move aside and develop how to best represent their idea if people were frustrated or angry, helping both students and mentors resolve conflicting views. Another example from Sarah was how her team selected a drive team, “we would have tryouts. Feelings got hurt because there were so many people that wanted to drive the robot.” Another young woman (pseudonym withheld) described how selecting that year's color (e.g., for tee shirts, robot colors) took "six or seven hours to find the perfect shade…we wanted," though the team finally did decide. Learning to handle these differences of opinion and conflicts was a skill that several women mentioned had helped them in their college days.

Lexi described the concept of working intently, often more at the end of those six weeks, sometimes everybody stressing out: "I remember it got really stressful because we got closer and closer to the deadlines when we needed to get our side of our project done. It just turned out to not be so much fun and games anymore." Nancy said "I primarily remember build seasons, late nights working on the robot with my teammates and mentors" and Anne described in her photo memories "various people on the team with their heads stuck inside the robot, carefully adjusting things with the wrenches. Working very intently on the robot." Alexis recalled "being continually stressed, [and] getting into arguments with friends, coaches and even my parents quite often." Aria remembered "deadlines…coming so fast that you would wonder if you would be able to finish. Somehow it always did. Somehow it always pulled through." Nancy wrapped it up with: "it's a stressful time, build season."

Build season, not surprisingly, was about building robots. Many of the young women in this study remembered being very involved in robot building. "I think the things from build season that stand out for me are problem solving and endless testing and equations to work out" (Julia). Or as Sarah put it, "I just loved putting my hands on something and working with it. So anything *build*, as long as I was in a machine shop, I was fine.” Even if the young women were not directly involved on the robot build team, they might help at stressful times when a build team needed a break. Alexis described how if “we needed to what we called *cheese* a metal plate, where we just put a bunch of holes in it to make it lighter,” team mates would plunge in to help each other in times of need.

Designing and building robots also included a lot of back and forth, trial and error, a normal part of engineering design, as Anne shared:

> A lot of times in programming, it's just kind of all or nothing. Sometimes with mechanical it's more straightforward. It's kind of working, but we need to make that piece smaller or something. In programming, if there is an error you missed…or you needed to declare something and your code is crashing and [it is] just not going to do anything.

Aria truly enjoyed the trial and error process:

> And I love when it doesn't work. Because then you have to start over again. And I feel you learn more when it fails a lot. If you do something and it works the first time that kind of takes some of the fun out of it. If it fails a couple of times, I think it is a little more fun because you have to get creative. Each iteration is [sic] better and better.

These iterative building activities usually led to a working robot, though these young women all expressed something like Sarah’s comment: it was “*equal parts work and laughter* and a sense of fulfillment followed each night and morning.” Golden Maiden remembered “everyone was enthusiastic; you see that in most of the pictures, everyone's happy and bouncing around and dancing, and trying to make the best of it.” Another echo of this code: “Equal parts work and laughter: that is so true. There is nothing like a late-night working at something to bring people together… to pizza after. You have to laugh about it at a certain point, because otherwise…,” Lily recollected with a laugh.

Though at times, the amount of work required in this intense period could have a negative side as Lexi shared:

> I suppose the only thing bad that happened was that I spent a good majority of my time working with the team and I started to ignore other responsibilities in my life, such as my classes. It caused my grades to slip and resulted in me needing to take a break from the team to get back on track.

For the most part, negatives were few from this study group of young women.

More commonly, the hard work led to feeling fulfilled and sometimes joy, a satisfying and fulfilling journey. Sarah shared “I also remember the stress of competition days, but then the immense joy of seeing your hard work come to fruition.” Julia said “it was such a thrill to compete and see the result of our hard work.” Alexis agreed with their memories:

> I guess there are a lot of wonderful things I remember. If I have to narrow it down I would say, competition. It didn't matter how we got there, what we had to do, or what spats we got in about design or hours working, we all knew that it only meant something if we got something working to competition.

This led to the next category from their FRC memories: competing.

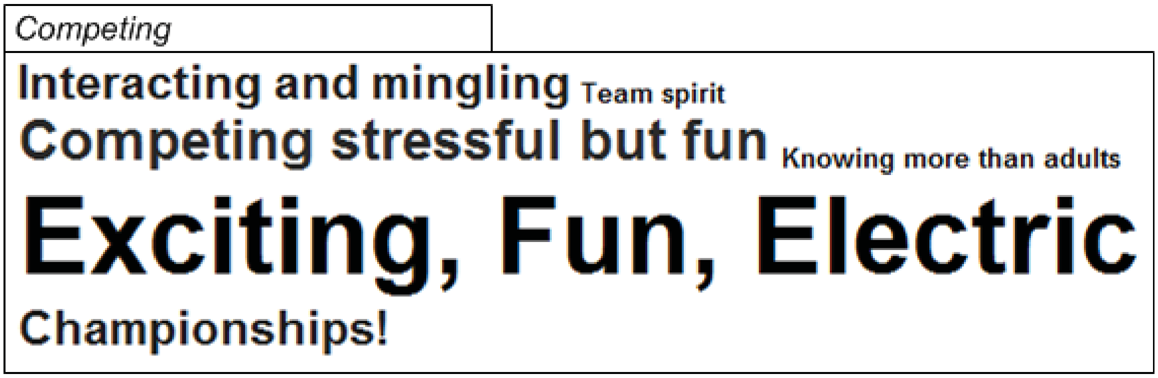

Figure 10. FRC memory codes for generator category: Competing

Competing. Most memories of competition had a level of emotive content and were people-oriented. (See Figure 10). Alexis remembered: “I loved interacting with so many people, and mingling with hundreds of creative minds.” Stress continued from the design and build phase into the competition phase of FRC. Sarah remembered that not every robot worked before it was shipped and the team had to finish it at the competition. Anne recalled:

> Competitions [were] always a lot of fun. You get the team together, you would be in the stadium all day, with the loud music going and trying to fix things…And, it was…it was kind of *stressful*, especially as I got to the point where I was actually part of the team that was trying to fix things in-between the competitions. *But* it was always a lot of *fun*.”

Lily also reflected on the stress present at competitions: “something would break on the robot and you would have to adapt as quickly as possible.…the high pressure…*gotta* get it done situation…being around [others] who were just as excited about this as you are” was fun and exciting.

Anne described team spirit: “[We would be] all dressed up, paint and stuff on our faces, and cheering.” Julia said “the atmosphere at competitions [was] almost *electric* - it was so *exciting*!” Nancy, Alexis, and most others had similar wonderful memories of competitions, as Smurf stated:

> Just having all those teams together in one arena and all the *camaraderie*, as well as the rivalries. It was just a grand time. I…was able to meet all kinds of different people who support robotics across the country and throughout the world. That was a fascinating experience.

Alexis explained how tough it was to help new people understand about competitions: “it's not something you can…explain fully without experiencing it once in your life…all the buildup and all the hype that goes with it:”

Competing for these young women was frequently more than regional competitions. Many teams also went to the FIRST Championships, in Atlanta, GA or in later years at St. Louis, MO, along with tens of thousands of other FRC team members. “My greatest memory of the competitions was when our team was in Atlanta, Georgia for Championships. That alone was one of the greatest experiences” (Alexis) and “I remember the National Championships in Atlanta, Georgia. Absolutely the best weekend of my life" (Smurf). The six weeks of designing and building following by competition events set the stage for a new category about the oil that lubricated the experience into a cohesive social environment detailed next.

Social cohesion & peer support

Becoming Friends and Family

FRC is my Community

Together--working, collaborating

Peer support

Figure 11. FRC memory codes for generator category: Social cohesion and peer support

Social cohesion and peer support. Surrounding the process categories (e.g., designing, building, and competing) was the social environment young women found within their teams. (See Figure 11). This category was originally named *relationships*. However, feedback from stakeholders and participants prompted me to reconsider what that phrase represented, how it might be confused with the other generator, supportive relationships. A more effective phrase for this category was needed. I reviewed participant's stories within the four codes in this group: becoming friends and family; FRC is my community; together—working, collaborating; and social cohesion and peer support. The first three codes connected well together and after brainstorming different words and phrases, two phrases resonated with a rich literature behind them: social capital and social cohesion. After researching those phrases, an article surfaced from my literature review (see Chapter 2) where an element of the Drexel program was named: "social cohesion and peer support" (Agosto, Gasson, & Atwood, 2008, p. 205). Thus, I changed this category of *relationships* to *social cohesion and peer support* providing a more illustrative category name, grounded in research literature.

The young women in my study spoke of experiencing a welcoming environment, being accepted, remaining in touch with past teammates still today. Lexi defined the major code, *becoming my friends and family*, "how much of a family that the team became. Everyone was so welcoming and the whole team treated each other like family." Others echoed this same impression.

Aria: It just means that you aren't in it alone. I think that's a beautiful thought. That at the end of the day, you have people who care about you and genuinely want to help you succeed.

Sarah: I remember immediately being accepted into a group of like-minded people,

GoldenM: Everyone wanted to see our team succeed which was awesome.

Lily: How friendly everyone was.

Nancy: We [were] very much a family…All the veteran members adopted the new members when they came in. We were also a small team and so that meant we were all extremely good friends outside of the team too…. All the times I had with the friends I made on the team - they really were a family to me. We laughed together until we couldn't breathe, and we also cried together during

> hard times. And we still continue to do that to this day, since we are still close friends
>
> Sarah: The emotional parts, the friendship parts, the relational parts are the ones that's really stick with people, just human beings, in general. [At] a team dinner …that's where it becomes a family, more than just a group of people doing one thing together.

Alexis wistfully said "we always tried to do a lot of group pictures to capture the moment" as she looked at a photograph of her team, taken her senior year. All the girls were in identical colorful shirts with shining smiles, surrounding their robot. The graduating seniors on the team were together with the team on their last scrimmage before beginning their last competition together.

Women from single-gender teams may have developed this family bond more deeply. As Nancy shared,

> Being on an all-girls team definitely created a different dynamic in terms of friendships, on top of being a small team. The returning members were always really good at taking the rookies in under their wings and teaching them, and becoming really good friends. Joining the team was more than just joining the team, it was joining a family.

This feeling of family extended into the larger FRC community. Nancy stated "the other thing about FRC is that besides just my team, it's also this incredible extended network of people." Or "these are everlasting connections and bonds which will keep us in contact" from GoldenM. Smurf remembered “talking to people who had…a passion for helping the students and want to see them succeed.” Aria summed these ideas up:

> That is the most valuable thing FIRST has to offer. The strength of the FIRST community comes in the fact that we are a family. We all share something in common: a love of knowledge. This love of knowledge is what drives us. We are not afraid to “let our inner nerd out.” These are people that you don't have to worry about what you look like around them. They're like family, and accept you for who you are. I think that's the most beautiful thing about this program. Everyone is accepted.

Teammates becoming like family, collaborative groups working together, and the FRC community all helped cultivate a social cohesion level that gave these young women a safe and nurturing environment in which to flourish.

Lexi helped me understand how peer support interwove with social cohesion: “Regardless of how inexperienced you were there was always someone there to lend you a helping hand. You could look up to people who were older, more experienced.” Julia described peer support in other ways: “[I] learned tons from the upperclassmen.” She also remembered “working though things with my teammates…made what would have otherwise been frustrating to no end really enjoyable.”

Several shared Julia’s ideas for working together and collaborating. Alexis reflected on this value that shone from an oft-mentioned role model, Dean Kamen, the founder of FIRST:

> Interesting to see someone pushing for collaboration, rather than competitiveness. Throughout every single year, [Dean] still continues to do that. That is impressive to me. I see so many people who give into the competition of it, rather than the…the way it's intended, which is a collaborative effort towards learning."

Lily reiterated this key FIRST value: "Even though you are competing against some of these other teams, if you ask for a wrench, somebody is going to go find you a wrench and bring it for you…Coopertition." (Note: *Coopertition*® is a trademarked word defined by FIRST combining the ideas of competition and cooperation; see definitions).

Beyond the main body of FRC experiences and the environment of social cohesion and peer support, some of the young women revealed memories and stories gendered in nature, unlikely to be experienced by males. These gendered memories were both positive and negative.

Gendered Memories. From mixed gender alumni grew a code: girls think differently. This feedback showed another dimension to their experiences. One woman described how it was difficult to get girls to join the team—if the professed goal was only *building* robots. The team changed communication tactics to bring girls in to be part of the soft skills of the project: "public relations…scrapbooking…communication between people and companies" (Sarah). Lexi shared "guys think differently than girls sometimes" describing how males and females communicate and attack problems differently. Sarah's comment below described how *girls think differently*:

> I think that girls are more relational beings more than boys. They bond over talking and through sharing emotions and just doing life together. And boys, I feel, could just sit next to each other and not talk and feel like they bonded just as well. I think that's why a lot of girls shy away from any STEM careers because they think that they won't get that bonding time with people. They go into more or different majors that have more communication in them.

Lily was positive about the idea of thinking differently, "thinking about things differently led me to have a niche on my team." Research has shown that males and females do approach problems, communication, and career choices differently (e.g., Cullen & Crowson, 2010). Several of the young women in my study resonated with that concept.

The second gendered memory brought back a few of my own engineering career memories and found in other research (see Chapter 2). One alumni (pseudonym withheld) from a single gender team shared a particularly profound experience coded as *rejected, being female*. She described several situations where boys on teams would treat them poorly, essentially thinking "Oh, you're all girls…you don't know what you're doing." This came across to the team while competing in matches within an alliance, both at regionals and later at championships.

Alexis expressed a concern that if she had been on a mixed-gender team, "I would have been so willing to be pushed aside because I didn't know what I was doing and I would've assumed that was… the habits, that was, the social norm." She made this observation about what she had seen on mixed gender teams: Sometimes "girls [are] pushed aside and not recognized for their efforts." This code, rejected being female, sometimes led to career decision obstacles as will be seen in future pages.

Summing up FRC experiences. The three subcategories within the FRC experiences generator—intense six week collaborative journey, competing, social cohesion and peer support— together with two gender unique codes provided a richly textured understanding of memories and reconstruction of the FRC experience for the young women FRC alumnae that participated in this study. Consider the range of codes within these three categories shown in Figure 12.

Figure 12. Codes for FRC experience categories, a generator for decision making model

The social cohesion and peer support category had four codes occurring frequently in the young women's stories and memories: becoming friends and family; FRC is my community; together—working, collaborating; and peer support. Every participant had codes within this category and the category resonated highly with all the young women in this study and the mentor stakeholders when I reviewed the model, codes, and categories with them.

The FRC experience was one of two influence generators on the career decision pathways for these young women. The next influence generator was the category of supportive relationships, considered next.

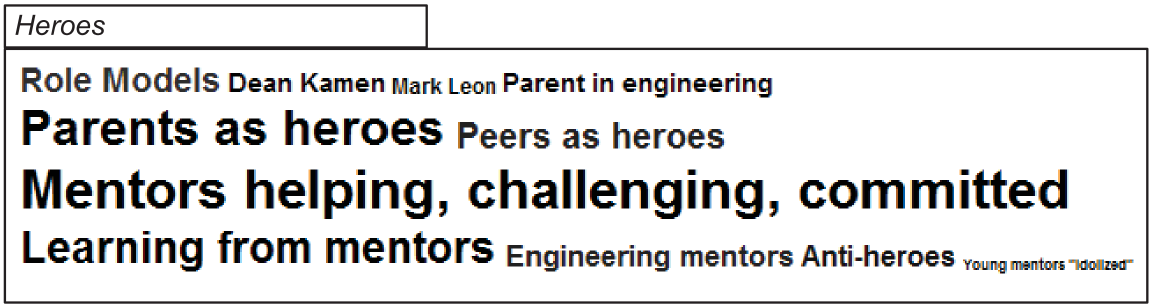

Figure 13. Supportive relationships codes for category: Heroes

Generator: Heroes or Supportive Relationships

The supportive relationship model developed by Mertz (2004) and modified for this study (see Figure 5, adapted from Mertz) proved a solid framework for young women's memories of their heroes from (mostly) FRC. Examples were provided from most of the levels in the model. The next paragraphs illustrate these levels and their influence from the codes in Figure 13.

Role models. Beginning at the bottom of the pyramid (see Figure 5) with role models, the young women's memories embraced well-known, public people long part of the FIRST community: Grant Imahara, an engineer on the television show, Mythbusters; Dean Kamen, founder of FIRST (more below); Dr. Woodie Flowers, professor at MIT and a part of FIRST from its first years; Mark Leon, a former Director of NASA education programs and consistent emcee for FIRST competitions (more below); as well as other FRC notables from the geographical area. Other role models included female scientists from an outreach event, specific FRC event volunteers. One participant shared: "[It] was a huge role model to see that they were so passionate about [FRC] and passionate about teaching the younger generation." Two men were mentioned by most of the participants: Dean Kamen and Mark Leon.

Dean Kamen stood out in many ways, touching those who were in STEM majors and those who were not. "He was an entrepreneur, who took simple ideas from previous great minds, and made them work with technology now" (Alexis). Sarah remembered his passion for innovation: "I would look him up and see his patents and all this stuff and I thought [pause] I want to do that, I want to be like that." Some remembered photographs taken with him. Dean Kamen was the leading role model mentioned.

Mark Leon has been an active FIRST supporter for over a decade, from his position at NASA, supporting two different FRC teams and many other robotics K-12 ventures, though most of my study participants knew him as an emcee for regional competitions and the championship event. Alexis avowed that "everybody loves him because he's the crazy guy with blue hair [dyed for the occasion]" doing somersaults across the field in his blue NASA jacket as he introduced teams for every match and led the awards ceremony. Nancy and Alexis remembered: Leon always emphasized math with his consistent passionate mantra: “Do the math” (Alexis). My observations of 2012 Silicon Valley Regional reinforced this influential image: an incredibly energetic man, at the end of a day, sweat pouring off him, smiling, telling thousands of students on the field and in the stands, that NASA needed them, reinforcing: “it’s all about the math” (Mark Leon). Leon helped young people see “subjects that people consider[ed] boring or mundane can still have exciting things surrounding them” (Alexis).

These role models had a large reach (thousands), a low level of involvement (hours), and intended to inspire young people to enter STEM careers and share their own life passions. Kamen, a successful inventor, quiet of speech, determined and passionate about FIRST as its founder; Leon with his blue-haired fueled energy, caring manner, and pinpoint focus on math; Dr. Flowers, a tall thin man, with long grey hair pulled into a ponytail, dressed in a tux, wearing red tennis shoes, passionate about engineering and the need to model that career for young people; and many others, FRC volunteers, key industry sponsors, and people outside FIRST, scientists and engineers sharing a love of their fields with young people. The examples described came from the young women who remembered these kinds of heroes.

Parents as heroes and engineers. Parents are in the middle of the pyramid (Figure 5, the pyramid with three dimensions: intent, involvement, and reach): involved, with reach, and intending to advise their children as well as other students. Four women described the influence of their own parents as well as noting how other students’ parents made a difference on teams. Some recognized the level of support after they graduated: “now that I am not around, and she continues to help out, I find myself looking up to her much more” (Alexis). Some recognized the support of other students’ parents, “the behind-the-scenes parents…are [the] unsung heroes in FRC” (Smurf). The “parents that…worked with us to make us the best we could be were my heroes on the team” (GoldenM) or “parents who drive to…school at 1 AM to pick [their students] up because they just finished the last part of the robot two days before it has to be shipped… Or who took three days off of work to go to [a regional]” (Smurf). Several young women discussed their own parents: “my parents were my heroes” (GoldenM); “[My mother] was always an inspiration… always very patient with me and would listen to whatever things I had to deal with” (Alexis); “my dad is by other big hero…he put his heart and soul into [the team]” (Nancy); “my dad always encouraged me to do what I enjoy doing” (Smurf).

Over half of the young women had a father (five alumnae) or mother (two alumnae), who was an engineer or computer scientist, and described a parent(s) as a hero, an influence in some way. However, for the most part, the influence seemed at a lower level, less intense than from other heroes, sometimes providing an opposing influence. “After seeing [my dad’s] hectic work schedule, I decided that engineering was not going to be in my future” (Julia), though Julia changed her mind later after being part of FRC and is studying engineering. This was also true for Lily: “The only thing I knew about computer science [before FRC] was that both of my parents did it and I didn't want to;”

she too went on to study engineering. She attributed that change to being in FRC. Two other young women described how their engineering fathers were a positive influence, encouraging them to join robotics. A parent's influence has been well studied in research; however, the dyad of an engineering parent and daughter has not been and in this study was only touched on. That dyad dynamic is an area for further research.

Mentors. The mentoring level of the supportive relationship pyramid found many gradations across it: general mentoring, engineers as mentors, and peers as mentors. Beginning with peers as mentors, well more than half identified a student peer as a hero or mentor. All but one of the peers mentioned specifically in this code were female. Moreover, all these peers were on the robotics team, often having encouraged them to join the robotics team initially, helping the young woman see a connection for herself related to her future career intentions. Some peers came back later to be adult mentors: "it's nice to see somebody a few years older doing something that you might want to do" (Anne). Peer mentors helped them believe in themselves: "She was one of the few people who actually showed that they believed in me, that I could accomplish my goals. Even when I doubted myself" (Lexi). Within the Mertz supportive relationship pyramid (2004, peers are positioned at the role model level, focused on personal development. The mentor level, with its future orientation, is a better fit for the peer-mentors that these women described. Peers as mentors had a deep level of involvement, smaller reach (i.e., interfacing with a small number of people), and were brokering or helping improve self-efficacy of the young women.

Mentors helped and challenged these young women and were committed to their success. Mentors taught these young women how to use machines (Aria) and they "shared their knowledge…wisdom and experience" (GoldenM). "One of my mentors, who pushed me to learn and grow and believed in me as an engineer, [gave] me the confidence to stick with mechanical engineering in college" (Nancy). Mentors "gave their time… So generous with everything… Always there. And ready. Whoever wanted to learn, they would teach" (Sarah). Mentors were "patient, knowledgeable, helpful, awesome [people]" (Nancy). When students were working so constantly that they missed lunch or dinner, mentors stepped in to correct that situation. "It's like having a second set of parents, or dads, I guess, it's kind of good" (Aria). Sometimes mentors challenged the young women to try activities they did not want to engage in, as Alexis remembered,

> Someone pushed me to do it, and sure enough, I'm really glad they did. But at the time I was just in…I don't want to do this, this teenage kid, what am I thinking. It was challenging because I was finding myself, finding out what I wanted.

While some mentors were parents, many mentors were not parents. "One of [the mentors] didn't even have any [family members] on the team, but she joined us every day in the robotics lab and worked with us and helped us each individually reach our potential" (GoldenM).

A similar but different code was learning from mentors. The young women shared how talking with mentors about programming, engineering design, or what they did at work each day were all positive influences on college major choices, "because [they] made it seem like if I did get a job in this area, it'll actually be fun and enjoyable and that made me think [it] was actually possible" (Anne). When mentors were enthusiastic about what they did for a living, that enthusiasm often excited and influenced the young women's career interests.

> I get more exposure to other types of engineering in real engineering careers through the mentors on the team. I saw exactly what it meant to be a mechanical engineer, electrical, and even chemical engineer, so I got a bit of a reality check in terms of what types of jobs were out there. (Julia)

One mentor, by encouraging the team to get involved with FLL, inspired a young woman to follow her nascent passion for teaching engineering to children. As Alexis summed up for herself and others, "I think a lot of what each of those people taught has affected where I have gone and how I approach things."

These young women learned from their mentors, sometimes specific skills, like welding, creating software, solving problems creatively, or how to use a computer numerical controlled (CNC) machine. While female technical mentors were rare for this group, Lily described how one woman "worked me through the basics of programming and helped me so much." Engineering mentors, in particular helped grow the young women's competence and self-efficacy for engineering. Mentors explained different engineering and scientific principles (e.g., physics, pneumatics, electronics, software, and manufacturing), helping these young women build the ability to apply them when designing or building a robot. Some engineering mentors have kept in touch with their mentees with encouragement to pursue their dreams in engineering college.

Female mentors were less common on most teams. Not many were involved with the design and build aspects either. “Many of the women who mentored us had studied engineering, but had gone into management, marketing or sales with their career” (GoldenM). One woman from a mixed gender team said when I asked if her team had female mentors:

> No [surprised voice], we actually don’t. We didn’t then and we still don’t today. I find that intriguing. I never thought about that. I’m glad that the girls at school are still interested in it, regardless. But I think that having that support would be good for them as well. We have team moms who go get food and stuff. But none of them try to help us work on the robot or anything. (Smurf)

Moreover, Alexis said “most of our mentors were male, so every once in a while we just needed to talk to a female mentor, to listen or to understand” and her team had one. For one team, Anne described “a good balance of male mentors and female mentors [on her team], and I like[d] that.”

For the last characteristic in mentoring, some young women remembered a few antiheroes. Women from both single and mixed gender teams provided examples. To protect confidentiality, even more so on this code, I am not providing any pseudonyms for the quotations. A couple of issues were shared that seemed to have a root in college-age male mentor/high school age female student dynamics. One situation, what might be characterized as stalking behavior, caused a serious credibility issue for the young woman involved and she could not gain mentor support to resolve the issue. She shared how she grew from this experience: “I wasn’t going to let one person’s opinion ruin my experience with [FRC], so I left….I really learned a lot.” Other antiheroes might be classified more as *adults behaving badly*. “[The mentor] didn’t lead by example, [the mentor] led by the opposite.” Another example: “we had a couple of mentors who it was really their way or the highway, if it wasn’t their design or their idea… They didn’t want to do it.” Another participant described some mentors as “in some ways, immature.” A more subtle negative image was this: “I see so many people just ready to have that competition, beat the other person and all that stuff, when the whole point of the exercise is to build a bond and build a community.” These anti-hero examples provide an inkling of the potential hostile environment a young woman may encounter: (a) when she is breaking new ground in a mixed-gender team, (b) when the team mentors are mostly male, or (c) when a member of an all-girls team competing against teams who are mostly male. Chapter 5 has recommendations from the group of young women about how these kinds of situations might be prevented or resolved.

Career Decision Pathways

The first sets of codes in this category, career decision pathways, are grouped within three sub-categories of codes shown on the model (see Figure 8) that outline three processes: learning, connecting, and knowing. These led to decisions with some obstacles along the way. First, in the next paragraphs, these women talk about these information gathering processes shown in Figure 14.

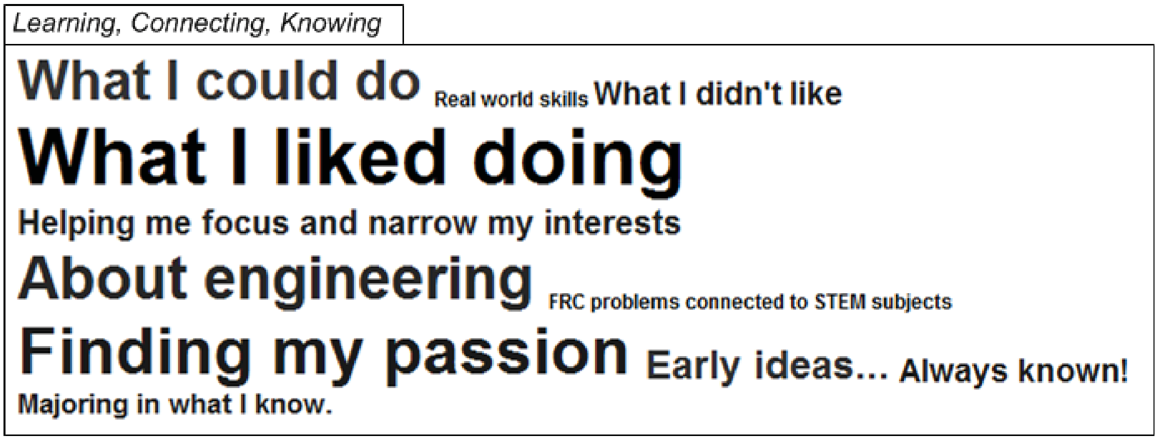

Figure 14. Codes for learning, connecting, and knowing codes sub-categories in career decision pathways

Learning, connecting, and knowing sub-categories. This group of codes has three sub-category groups. Each group centers on processes for investigating and experimenting with career pathways within FRC.

Learning sub-category. This sub-category contained many codes: *what I could do, real world skills, what I didn't like, what I liked doing, helping me focus and narrow my interests,* and *about engineering*. All were aspects of learning about a career.

Nancy declared "how much I learned over the years about building robots" and GoldenM remembered that FRC "taught me the skills of when to keep my head down and get my work done and when to ask for help." Many times it was learning things they did not know before: "I didn't know what I was doing, but I jumped in headfirst and learned tons" (Julia) and "It has taught me how to handle myself under the pressures of tight deadlines, budgets, and stressful working" (Aria). The skills were not only technical ones: FRC "taught me a lot about how to work with others" (GoldenM). Lily shared stories about being a liaison between the software and mechanical teams because she had good communication skills. Nancy remembered a broad range of learning as well: "my work on my FRC team was mostly mechanical, though in the end I did pretty much everything, except programming (design, build, electronics, leadership, PR, Chairman's [Award])." Smurf mentioned that the experience gave her "better ways to talk to people who don't see the world the way that you do." Many mentioned their early years on an FRC team as being "just learning years" (Sarah), learning what they could do.

Learning real world skills as Alexis noted "helped my career choice. It gave me the experience of real world knowledge, real-world experience." However, the most frequent code in this learning sub-category was *learning what I liked doing*:

GoldenM: If I [had] not…done FRC. Who knows where I would have ended up? …I really liked the electrical and computer, the programming part of being on the FRC team and so I ended up deciding to do that as my major in college. [Electrical and computer engineering major].

Smurf: All these people [were] building the robot but we've got nobody telling anybody about it….I said that I would do it. Just to see what it was like. And it stuck with me (voice smiling) and I really enjoyed it…. I did a lot of talking to potential team sponsors for the team…advertising our team to the community

[…ending] up in that niche. I didn't really choose it, but I ended up really enjoying it….Part of the reason I decided to become a communications major.

Aria: I like building stuff…I like having a challenge and having to design it and machine and figure out how it fits together….[FRC activities] helped me refine which [engineering] I wanted to do…I like being hands-on. [Mechanical engineering major].

Anne: It gave me the chance to see what it's like to work on a software project as a team…it was good experience. [Computer science major].

Lexi: After exploring several extracurricular activities, I found that robotics really fulfilled my need to do something hands-on that used my creativity. This was when I first chose engineering as an option for my future career. [Mechanical engineering major].

Sarah: I started designing things and that was my favorite thing to do. When I could actually tell people: ok, can you make this? I would draw the part and have them do it. [Industrial design major].

Alexis: FIRST played a major part into what I finally decided on. I worked on the team as what I consider a supporting role; sponsors, website maintenance, etc. These positions were something I was really good at and realized I could do successfully as a small business owner (when that day comes). [Business and communications major].

Julia: Working on and solving problems is exactly the kind of thing I want to be doing, so when I saw that I could do that as an engineer I was sold. [Mechanical engineering major].

Nancy: Build was my thing…Because I enjoyed it. [Mechanical engineering major].

Lily: I was somebody who enjoyed communicating with people, I ended up…being the liaison between mechanical and programming. [Design Engineering & Product Management].

Besides finding out what teens like during their high school years as just described, teens are often trying things out and sometimes finding out they did *not* like something (Super, 1963). *What I didn't like* rang true for several women. "I did not like it, I hate getting dirty…I did not like machining things; that was not my cup of tea." (GoldenM), or "I kind of eliminated electrical. I just didn't find electrical so much interesting" (Lexi).

These years were also a time of tuning and focusing. Lexi voiced: "I didn't even know what I wanted to do when I grew up, before I did it. It… just really…helped me delve into interests that I haven't really explored at first." This narrowing and focusing sometimes connected to engineering or a more specific career path:

Julia: After being on the mechanical committee…for all four years, I decided that it would be a fun field…. I don't think I would be as confident in this choice were it not for my time with FIRST and my team, especially since before high school I never thought to do engineering.

Lily: I'm looking at product management…you…take all…these different interests and what you want to do and coalesce them, negotiate between them to create a product.

Learning *about engineering* was a code shared only by the STEM majors. Aria stated that "[FRC] gives you a lot of life skills especially if you want to go into engineering. On how to machine, how to program, how to design stuff, how to do an engineering drawing properly." Lexi remembered that before FRC, "I really had no idea of what I wanted to be when I grew up." FRC expanded career ideas for these young women:

Anne: By the time I really started thinking a lot about careers I had already been through FIRST. [Without FRC,] it would have been sort of more mysterious to me, like "what do engineers do on a day-to-day basis?" And now I can kind of picture, they do stuff kind of like the same discussions and processes we went through as a robotics team. Obviously it is different. But it…gave me a better idea.

Lily: FRC was a completely different look at engineering. I had not been interested in engineering at all actually up the point when I joined FRC.

FRC activities make use of many kinds of engineering: electrical, mechanical, software, project management, and systems. Julia iterated that: "Through FIRST I was exposed to the many sides of engineering, and I had so much fun I knew that was what I wanted to major in." Anne also shared how it expanded her view of computer science:

> It was a lot of fun because when you are writing code, most of the time, you're just…you are writing code and then you make the computer screen do something. That can be exciting. But, what's more exciting, you write some code and makes the robot's arm move up or the robot drive forward. That was pretty fun, being able to write code that then moved things in the physical world.

Julia saw the excitement engineering can bring: "Working on and solving problems is exactly the kind of thing I want to be doing, so when I saw that I could do that as an engineer I was sold." That was echoed by Lily: "It wasn't just that it showed me what engineers did. It showed me that what engineers did was also really cool." Nancy described a challenging design problem and how it was a turning point for her and a catalyst for her study of mechanical engineering:

> I think that was really the first…pivotal point of having to think outside the box to figure out how to make that work. We made it work. That was kind of the first time where I was really feeling like maybe I really can be an engineer. So that robot has [a] really special place in my heart.

Since FIRST aims to inspire young people to enter the fields of engineering and computer science, these shared reflections on learning about engineering are evidence of achievement of that goal for many young women in this study.

Connecting sub-category. Two kinds of connections were raised by the study participants fusing into this category: *FRC problems connected to STEM subjects* and *finding my passion*. Julia shared how "I was able to connect my math and science classes to problems we encountered while building the robot, which, for me, is the most rewarding thing ever." Most of the connections were to personal passions, whether FRC inspired a new passion or fed an existing one, many of these young women found a connection through FRC.

Lexi's passion was cars and connecting with that passion in FRC led to majoring in mechanical engineering. Her face lit up as she described to me how she modified her car to improve its performance. Sarah found and fueled her passion in the design process:

> Drawing out mechanisms and comparing them to each other under the pressure of a week-long period was very stretching and straining. I would draw ideas during the day and dream them at night, and start the process over again the next day. It was an innovative process, ultimately combining many good ideas into one mechanism that served multiple purposes. Those were the things that brought me joy, and still do.

Nancy found her passion to be teaching children about the engineering process: "The work I did mentoring FLL teams…led me to realize how much I loved teaching engineering [to] kids." Julia had another passion. She loved connecting math and science to robotics:

> I was able to connect my math and science classes to problems we encountered while building the robot, which, for me, is the most rewarding thing ever. I think I genuinely weirded [sic] out my teammates when we were trying to figure out

> dimensions for a component and I realized the way to solve the problem was by using trigonometry and just started smiling—I was really excited!

GoldenM connected her passion for communication with engineering: "my favorite part was sharing my love of technology with everybody else…it got me hooked on public speaking and sharing people's stories," both in college and the position she took after graduating. Lily agreed that FRC was a place for "connecting, matching…Trying to find that intersection between career and passion." Animated about a career in communication, Alexis declared "I was able to find what I was passionate about, because I had had the experience [in FRC]." These women lit up when they shared these dreams and passions, describing how FRC helped them identify or match up these connections.

Knowing sub-category. This sub-category on career decision-making had three codes, somewhat sequential in a young person's developmental path: *Early ideas*, career thoughts from their younger days; *always known*, a feeling that they cannot fully remember when their knowledge about a career decision began; and *majoring in what I know*, matching what they found in FRC to a major in college.

Several young women had early ideas about their career path, not always staying in that direction. For example, Julia shared "I did think I would do something math and science related, because those have always been my favorite subjects in school, I just tried to keep away from engineering" though she went on to study mechanical engineering after FRC. Lily did not want to do what her parents did: "I had not thought about engineering at all. The only thing I knew about computer science was that both of my parents did it and I didn't want to [do that].” Julia and Lily both ended up in engineering even though before FRC they were not planning that path.

However, many did know early that they wanted to do something in STEM. For example, Lexi articulated “I was unsure what I wanted to be growing up though, because I have a very broad range of interests. I loved the sciences in high school, so that was one deciding factor.” She also had been involved with cars at a young age and had “always been interested in the mechanics of cars.” GoldenM remembered doing chemical experiments with bathroom products at a young age of 3-years-old. Anne began her studies of software in elementary school: “I would play around with visual programming systems [in fourth and fifth grade]. And then in middle school…computer science [was] part of their curriculum.” Some gained those early ideas from parents who were engineers: “my knowledge of just knowing what engineering is definitely came from [my mom]” (Nancy). And she also began in FRC “knowing that [she] loved building things.” Thus, many who went on to study engineering, design, or computer science expressed an early interest before experiencing the robotics program.

Those who had *always known* were also all from engineering, design, or computer science. Thus, FRC may not have inspired them to enter those fields; however, it might have solidified their early known interests. Aria remembered a “natural affinity toward taking things apart to find out how they worked” and GoldenM confidently stated “I knew I was going into engineering from [my] freshman year of high school” believing she would have studied engineering, whether she had been part of FRC or not.

Others built upon FRC learning and majored in a related field, or as Alexis stated it, “majoring in what I know.” Smurf decided to pursue communications in her “senior year of high school after completing the interview for the Chairman's award for the second time.” These three codes relating to knowing were the last process step in the model before the decision category. However, to begin with, consider the obstacle category for roadblocks experienced by these young women on their way to a career decision.

Figure 15. Codes for *obstacles* category: Career decision pathways

Obstacles to a decision. This category, shown in Figure 15, was different than the prior knowledge gathering process categories: learning, connecting, and knowing. Obstacles were roadblocks in reaching a career decision. These barriers added noise, analogous to electrical noise, to the system obstructing a clear result.

The young women principally identified obstacles in their environments or from stereotypes, either personally or externally generated. First, considering environmental obstacles, while Silicon Valley has more female engineers than many areas, not all northern California teams reside in Silicon Valley and not many teams have female technical mentors. In Silicon Valley, if a young woman in an internship asserted she was studying engineering, “people take it for what it is” (Aria). However, outside of that technical center, “You don’t really see a lot of women engineers out [there]” (Aria) so the treatment of young women aspiring to that field is different where they remain underrepresented. Lexi mentioned similarly “the only negative experience [was] being a girl in a mostly male… activity…I mean most of my friends growing up were guys, so it wasn't that big of a deal for me. But, at the same time, it was…” negative somehow. One other environmental obstacle for one young woman was parents, though from an unexpected direction: “When I first joined my team it was because my parents made me, not because I choose to…Each year I stayed, because I had grown to love it” (Alexis).

Stereotypes were the more frequent obstacles, though mostly the young women in STEM degree programs described these experiences in FRC. Some young women did encounter the stereotype that “girls are not good at math and science and engineering” (Nancy). Nancy met this for the first time from another team at a FRC Regional competition in the finals: “That was the one time that I can remember being so happy to have lost because it meant that I didn't have to talk to [that other team] anymore.” Aria’s team “never really had a girl that wanted to do the engineering side of things” until she joined them. It took a while before she could overcome that stereotype. “It wasn't always easy for me. I remember walking in on the first day and none of the boys would take me seriously” (Aria). Alexis voiced:

> I have seen so many other teams where the girls are cast aside or they aren't regarded as being involved. Part of it is social norm, it's what's expected, but it shouldn't have to be the case. Because maybe they're interested in it, and they should have just as much of a right and just as much of a chance to experience the FRC program.

GoldenM, a single-gender team alumna, did not experience this reaction until college: “Once I got to college and noticed the lack of females in my courses, I started to hear a lot more of the stereotype. It was in college I heard ‘oh! You’re a girl in engineering. You must be brave and smart.’” External stereotypes were evident at times and at some level were a barrier to entering engineering or computer science careers. Those women who shared these stores did decide on degree programs in those fields and overcame the stereotype obstacle. However, one wonders if other young women were turned away by these obstacles or stereotypes finding them insurmountable.

Stereotypes were not always from external sources. Two young women pursuing STEM degrees shared stereotypes they held about themselves, or personal stereotypes:

> I was interested in joining, but I had two roadblocks about considering the idea though. One was that I just didn't want be seen as a "nerd" in high school. (That silly high school popularity thing :P). That was what originally stopped me from joining robotics until my junior year…
>
> The other inhibition I had was that I was stuck in that whole idea that engineering is a guy thing…

> I realized that I never let the whole "guy thing" stop me before, so why am I letting it stop me now. I was really hesitant, but once I got in there, everyone was really welcoming and I fit right in. (Lexi)

Julia too had a personal roadblock: “I just didn’t want to do what my dad did,” because she did not want to sit in a cubicle in front of a computer screen all day. This type of perception roadblock was identified by the National Academy of Engineering (NAE). NAE suggests Changing the Conversation (NAE program) about engineering when talking with young people today, by emphasizing creativity, solving the next big problem, and other such messages (NAE, 2008). FRC helped Julia overcome that roadblock and pursue an engineering degree. Negative experiences can be turned to positive as Aria shared:

> I think [a negative experience in FRC] brought out an inner strength and made me realize that… the world is not a nice place…And it taught me how to handle very poor situations with difficult people, which is more important than anybody ever realizes. I think it also kind of gave me a voice.

The decision category is explained and connected next.

Figure 16. Codes for *decision making* category: Career decision pathways

Decision codes. Decisions were the outputs or synthesis from the knowledge process steps described in prior sections. These three codes—*still thinking, changing,* and *centering*—crossed both STEM and non-STEM degree earners (Figure 16). Anne, early in her college journey, made the distinction of career versus degree pursuit resulting in the still thinking code: “I don’t feel like I really have chosen a career yet.” Earning a degree in computer science could lead to many types of careers, as she realized. For a few young women, their ideas about careers changed during their college years. Sarah found that mechanical engineering did not provide the creative outlet she had found in FRC:

> I realized that maybe FRC wasn't the engineering that I thought it was. It is more of everything. I thought it was just straight engineering. I didn't realize how much fun I was having and how much creativity was in it until later when I was in Mechanical Engineering and it wasn't creative at all.

Alexis also began in one field, science related, and moved to business and communications, more similar to what she had done in FRC.

The code applicable to more of the young women was *centering*. Many of them centered into their degree programs, often times moving from other ideas or choices, in late high school or early college years. Specifically: “Dabbling a bit” (Nancy) in other engineering programs before centering on mechanical engineering; beginning college in a liberal arts school preparing to “continue [in] mechanical engineering” (Julia) elsewhere; expanding initial engineering career choice to a dual degree (GoldenM); and centering on mechanical engineering in senior year (Lexi). FRC contributed to those centering decisions for some: “FIRST played a major part into what I finally decided on” (Alexis); FRC was “part of the reason I decided to become a communications major” (Smurf).

Differences for STEM and non-STEM majors. Career decision pathways had a few differences for STEM and non-STEM degree pursuers, some mentioned in prior paragraphs. Non-STEM degree earners did not have an early interest in engineering or always knew they wanted to be engineers *(Knowing--Early Ideas* and *Knowing--Always Known*), whereas the STEM degree earners did. One woman started in engineering and moved to a somewhat ancillary STEM degree (see Table 6 for description of degree crossing engineering and liberal arts). This move helped her connect a need for creativity and design. Sarah had been interested in LEGO robotics as a child and also stated that “I knew I wanted to do engineering since I was really little.” She started in a prime STEM major, but did not find it creative enough, driving her decision to change to a different non-engineering program. This may speak more to how engineering was taught in college than Sarah's seminal engineering interest (e.g., *Changing the Conversation* research from NAE, 2008).

Both Smurf and Alexis had an interest in robotics, though primarily as something to talk about, not study. FRC gave them opportunities to develop communication skills in awards presentations and speaking to sponsors for the team. Those experiences also solidified their non-STEM career decisions.

Summarizing, female FRC alumnae pursuing STEM majors knew before high school that engineering or computer science was their interest. Through FRC, they were *fortifying technical competence* in those fields (see next category: Who I've become). And in a complementary way, non-STEM majors found FRC experiences formative in their own non-STEM major selections, "*majoring in what I know*" (Alexis), and learned from within the FRC experience.

Results Category in Model

Only one category formed as an output from the General System Theory model (see Figure 8). This category-- *who I've become*—included deep influences on personal characteristics and interests (Silvia, 2006), linking to their career choices. It gathered these young women's reflections about growing technical competence, figuring things out, becoming a communicator and a leader, ultimately to the code, *shaping me, defining me*. This section addresses the results from an FRC experience more than others discussed in prior sections. Ultimately, this category shows the person these young women have become and maybe are still becoming.

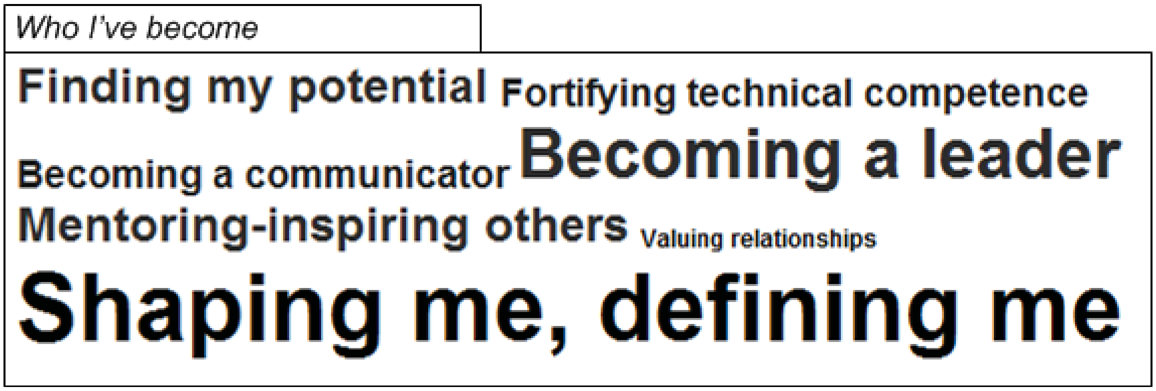

Figure 17. Category: *Who I've become* from Career Pathways and Decisions

Who I've become. This category (see Figure 17) fuses the results of the young women's career interests reported in their college-age reflections. Nancy described how the FRC experience pushed her "outside my comfort zone, and really shaped me into who I am today" helping her find her potential. Besides being part of the design and build activities, she was "giving presentations to sponsors, doing fundraising things to raise money, doing outreach activities." These many other activities provided these young women with many separate opportunities to grow, beyond what they thought they could have done. "I was at a time where I was trying to figure myself out and what I wanted," as Alexis remembered. She also commented: "Because I started early experiencing what people call the real world, it helped me notice what qualities I have that can contribute to the real world." The program "helped to mold who I am today" (Aria). FRC might even have kept them out of trouble: "high schoolers are all over the place and I could've been one of those" (Sarah). Overall, these distinct pathways helped the young women find their potential and shaped them.

Fortify, specifically *fortifying technical competence,* was a code only found with women pursuing STEM degrees. Aria defined fortify as "actually knowing it, and being able to teach it to others," beyond being book-smart. Lexi described how her FRC experiences helped her in a team-based college engineering project. Similarly, Nancy shared how her FRC experiences as well as those of another FRC alumnae on the team, helped effectively solve a college engineering team project. "Our perspective was if [we] can build a 5 foot tall, 120 pound robot in six weeks, I think we can do this too. Especially since both of us …had two different team experiences" to contribute to the class team. Anne cogently explained this: "FIRST definitely made me feel more technically competent." FRC gave these young women a level of fingertip knowledge beyond theory, fortifying their technical competence.

Several young women talked about *becoming a communicator* and described how when they started in FRC, they were shy or introverted. Lexi said "I learned how to work with different kinds of people of different ages," improving her communication skills. GoldenM learned "how to quickly determine…what kind of…strategies [would] work well in different groups and situations." Nancy learned to become comfortable being interviewed on TV as part of the FRC experience. Lily became a liaison between hardware and software teams and Alexis found her passion in communication.

Communication skills were an important part of who they became for many of the young women.

More than half of the young women talked about *becoming a leader*. Lexi realized as we talked, “I had to lead even without being an expert in everything I did… It taught me to use my resources.” Aria found another path to leadership by leading design sessions. GoldenM asserted “one thing that I learned was how to find something that needed to get done and take leadership over that part.” The growth experienced by these young women included many key leadership skills: Nancy learned “how to delegate [and] lead by example, how to be friends with the people I was managing, and how to manage time to get everything done.” Leading a team was when Sarah “got to put [those skills] really into practice.” Alexis too experienced this: “our coach…promoted…having the girls running the team. It’s been consistent, no matter whom the coach is, it’s the girls making the decisions.” The FRC experience provided many of these young women opportunities to learn to lead and to mentor others.

Another part of who they had become was their own outreach efforts, *mentoring-inspiring others*. A couple of the young women mentored FLL teams while they were in FRC, or had later become mentors of FLL, FTC, or FRC teams, or had volunteered at FIRST events, all efforts to inspire another generation of young people. Nancy recently reflected about this. Her words are exemplars of how this outreach became part of many young women and who they had become: “Writing out the whole story…was one of the first times I was really reflecting how big an impact [FLL efforts] had on my life…I helped found a small group that was dedicated to teaching middle school kids robotics."

My conversation with Nancy edified me about how these skills, these characteristics, these learning moments, these outreach commitments had shaped and defined the young women. As she said, FRC "taught me responsibility in a totally new way, and gave me so much more confidence in my abilities." Aria imparted how FRC "taught me how to handle poor situations… Gave me a voice… Contributed to who I am now." Sarah articulated "I think it did shape me towards the better." Alexis asserted that "I think a lot of what each of those people [heroes] taught has affected where I have gone and how I approach things even." Summing up *shaping me, defining me* for them all: "FRC was such a defining part of my life" (Nancy).

Environmental Analyses

To better understand the environment for this career exploration and decision making system, two more types of data were analyzed. Observations made at a recent FRC regional competition event held in northern California were analyzed. (See Appendix B for samples of personal photographs of the 2013 event and events from prior years). In addition, comments made by the participants about team type, that is, single- or mixed-gender, team size, gender of mentors, and a few other items were synthesized as well.

Competition Event Observation

Setting described. To supplement the focus group and interviews with the study participants, for two days I observed a local FRC competition, free and open to the public: the Silicon Valley Regional (SVR). The 2013 SVR had 59 teams, at least six of those from were single-gender schools or organizations (five female, one male); the balance were primarily from mixed-gender schools. Being from a mixed-gender school does not imply that the teams were mixed-gender in composition. Teams were primarily from northern California. I observed a practice day (Thursday) and a competition day (Friday); the event had one more day (Saturday) that included qualifying matches, finals, and awards, which I did not observe.

The event was held at a downtown college arena. The arena floor included 42 of the teams in pits on one half of the floor and the competition field on the other. Pits were 10 feet by 10 feet areas assigned to teams by team number, somewhat in numerical order. Team numbers have been assigned sequentially to new teams by FIRST as they form for about twenty years now. This year, the regional had been expanded to handle more teams than prior years. The teams with lower numbers, those with longer histories, were in the main pit area. The rest of the pits (17 teams) were in another area off a hallway leading from the field portion of the arena floor. I was seated at the line where the field met the arena pit area, about ten rows up in the stands, taking photos, making sketches, for both the field and main pit area.

My first impression was one of noise and lots of people. Hundreds of teenagers and dozens of adults, in team, volunteer, or other official (e.g., referee) shirts were roving around the arena floor in a purposeful manner. Some shirts were vividly colored: purple with yellow, orange, Kelly green, royal blue, purple with pink, teal, fluorescent yellow/green. Face paint was present, albeit not a lot; colored hair for some teams is traditional and I observed red hair for at least one team. Many people were seated in rising seats surrounding the arena. These spectator locations were focused on the field end of the arena. The main pit area was well lit; the field section was only lit in the competition field portion (about 54' by 27'). It was relatively dark around the field at floor level and into the stands. The field and main pit were split by a very tall (floor to ceiling) black curtain with field volunteers running the matches on one side facing the field, and pit administration with volunteers managing the pits and public information on the other side of the curtain facing that pit. About half the team pits in the arena pit area had banners mounted on PVC pipes, high above the floor at the back of pit spaces. That pit area seemed more open than usual (my memories from prior competitions), though the whole floor buzzed with sound.

Daily notes. Thursday was a quieter day than Friday, with fewer members of the public present. This practice day seemed calm and, to any newcomer, gave no inkling of the competitive storm that was to occur over the following two days. Another reason for the quiet was the split pit areas. Aisle-ways were relatively clear of a lot of public. Mostly I observed people who were in team, volunteer, or FIRST shirts on the floor and in the stands. All people, young and old, in the pits and on the field itself were wearing safety glasses. At the entrances, volunteers reminded people about that safety requirement. Music resonated from the field, though muted compared to Friday when ear plugs were desirable.

Other than the students and mentors of the all-girls teams, I did not observe many women or girls present in the pits. Where I was sitting, some traffic up and down the stand steps occurred. A female-Asian teen, of slender build with a ponytail, came up into the open stands below me. She began walking back and forth in the third row of empty seats: Lips moving, expressive, using hands purposefully. She was on a mixed gender drive team; I gleaned that from her shirt color, team number, and her special drive team button (drive team members cannot enter the field without those iconic entry badges). Finished, she stepped down, put her safety glasses back on and went back down to pit. I concluded she was practicing for an award interview of some type, most likely the Chairman's Award, since for most other judged awards, the judges visit the pits to interview student members.

Most interactions I observed appeared to be related to the competition, focused and purposeful. Most girls walking around were in all-girl groups or with only one boy. I am well known to the volunteer base and many teams, though during this observation I did not wear any team or organization affiliated shirt. Thus, I was mostly unnoticed and was only approached by a few people in my observation post. Not being part of the event was a unique role for me; typically, I am inspecting team's robots, volunteering in pit administration, or announcing in the pit (positioned in this regional at the curtain facing the pits). It was interesting for me to realize how I began to develop a feeling of not belonging, by only observing.

When I walked both sections of the pits, I observed that the two pit areas presented very different images and feelings. The arena pit had a very high arena ceiling, with wide aisles (12' plus). This gave people in that pit a wide visual field, with daylight shining in from the outside via a loading door. That large opening to the outside was next to the sponsor provided machine shop available to teams. The second pit area had a typical room-high ceiling, with narrower aisles (about 8'), resulting in a very warm area (they later brought in large fans), with no open windows, giving this pit an almost claustrophobic feeling with the teams, banners, robots, and volunteers so close together. The second pit area had most of the rookie teams and more recent team numbers. It seemed far removed from the competition field, though physically the distance to enter the queuing line was not much longer than from the arena pits. No observation post was possible in that room, so I was only able to complete two walk-through observations.

Some mentors made observations to me when I met them in my walkabouts. One mentor quietly imparted how he had helped rookie teams at another regional and the joy it brought him to see them do well. One team he helped had won a Rookie All-Star Award; the team thoughtfully sent him a thank you card. Another mentor asked me why I was observing and making notes. I told him of my study. He suggested "maybe it's genetics." Similar to the reason, in his mind, for the smaller numbers of boys in cheerleading. He posited that interests were gender based and asked why try to change it, saying maybe it can't be changed. I did not pursue this line of thought.

While recording data on the 59 drive teams, I noticed that the five all-girls teams had team numbers that were relatively close (as I mentioned, FRC team numbers have been issued sequentially after the first year or two, beginning twenty years ago). When a FIRST official stopped by to say hello, I mentioned that curiosity. The official described how after he became a FIRST official, he made it a focus to add all-girls teams, making a "concerted effort to get them" from 2005 to 2007. The official also mentioned that at least one female student from one of these teams had become an FRC mentor after college.

Friday, the qualifying competitions kicked off with speeches by a city councilman, a senior NASA executive, and last, an executive from a local technical museum. Since a team from Mexico was competing, the Mexican national anthem was played followed by the U.S. anthem. Then match #1 began immediately, robots and teams having been positioned at their stations before the kickoff had begun.

My overall impression was one of energy! Robots were fast, not smooth, instead usually moving with jerky motions. For the first 15 seconds of each match, robots were driven by a team-developed computer program; this is the autonomous period within the match. The two-minute teleoperated period in a match follows where drive teams behind walls of Lexan (i.e., thick polycarbonate, a transparent, strong material) and aluminum at opposite ends of the field drove and controlled robot movement and handling. The autonomous periods were either effective, quickly shooting Frisbees in a slot, or did not work, varying by robot.

The emcee, well known in the FRC community with blue hair for the occasion and blue jacket, was introducing teams on the field to the spectators exhibiting his typical incredible level of energy. The matches moved swiftly along: Six robots were lifted from six carts to the field by drive team members, drive teams positioned themselves behind the Lexan walls on either end of the field, a two minutes and 15 second qualifying match occurred with robots flying around and across the field, around the game elements that this year were hollow pyramid towers, referees decided on penalties and scoring, six teams picked up their robots off the field, putting them on carts and rapidly left the field going to their pits. Then the process began again for the next match. About every seven to eight minutes a match turned. By Saturday morning, all the teams had played nine matches.

Later, I saw a female emcee. She greeted each team with high energy, moving straight arms up and down for a team who has an alligator as their namesake, or bowing, lunging like a fencer for others, shouting out the team numbers while the announcer (who sits on the side lines and gives play-by-play commentary) said team names and schools. She seemed to be almost flying back and forth across the field.

As the day progressed, excitement built. Girls and boys both were excited. The postures of the drive teams became more intense: bent over the driver stations, eyes towards field. I watched a human player feed Frisbees into the field chutes moving these game objects to robots on the field—quick, deliberate—synchronized with a robot to be under the chute to receive it. When matches stopped Friday night about 5:30, the energy died quickly and teams exited to go caucus, eat dinner, and prepare for Saturday, the last day of the event. The mentors moved after the students, for the most part a lot more slowly. Volunteers wrapped up their work and moved out quickly too.

These prior paragraphs paint a visual picture scaffolding the physical environment. The next paragraphs will flesh out that painting with remarks on the all-important drive teams moving between team pits and competition field.

FRC Roles: Drive teams. One group that is highly visible for each team is the drive team. In 2013 and past years, FRC has required a drive team of four: two operators or drivers, a human player, and a coach. The drive team can be all students; alternatively, the coach, and only the coach, can be an adult and often is. The coach is restricted and cannot touch the driver station that controls the robot; only students can drive the robot.

The human player, also a student, is usually selected for specific skills. For example, in 2013, the game involved Frisbees. The robot and the human player could throw them into slots at the end of the field opposite their driver station. The slots were at different heights. Thus, the human players were most likely picked because they could effectively throw a Frisbee. At the 2013 Silicon Valley Regional, somewhat differently than in years past, the human players had a competition for who could place the most Frisbees in the slots out of 10 provided. Almost all the teams participated in the human player competition held at a break time on Friday.

At 2013 SVR, I captured data for each of 59 drive teams on Friday. Six teams were single-gender teams; the five female teams had all-female drive teams; the one all male team had an all-male drive team. For the 53 mixed-gender teams that competed on Friday, 57% were all boys, 9% had a female human player, 28% had a female as one of two drivers, 15% had a female coach (could be adult or student). These statistics are subject to some error since teams sometimes change drive team composition for matches to test out different drive teams and I was making gender determinations based on my observations and could have mistook some of the young people's gender from a distance.

Drive teams are stressful. I observed that at SVR. Observation of one all-girls team: Girls were focused intently, bent slightly, at the waist, shoulders tight, hands on controls (driver's hands only), absorbed in the match. The coach moved swiftly (back and forth) from human player to driver station, keenly watching the whole field.

Study participant drive team notes. Five participants, from both single- and mixed-gender teams, talked about the drive team; all were STEM majors. Only one had been a driver (Nancy), one had been a coach (GoldenM), and one had been a human player (Lily). In the coach role, GoldenM drove strategy with the other teams in the alliance. Nancy reminisced "how amazing it was to be on the drive team." Moreover, she made connections from what she observed being on the drive team to constraints and opportunities in the robot design:

> I was doing the design and the build of the robot, then being able to also be on the drive team and then operate in competition. It just was kind of a nice full circle

> kind of thing for me. I think also being the operator helped by the end. It was informing some of our design decisions. Because [after a complex robot the prior year], we were really trying to take into account how many functions can the operator really do and be effective at it. (Nancy)

Lily was a human player on her team’s drive foursome. It “arose somewhat accidentally… a lot of people wanted to do [this,] including me. But what made it actually happen that I was a representative from the software team.” She enjoyed the opportunities to meet other drive teams: “it was really cool.” Two other study participants wished they had been on the drive team, sounding wistful about an opportunity not available (Aria) or sought (Lexi). Aria described how she liked fixing things instead and being that person on the team, especially in competitions.

Other team roles for study participants. Other women remembered being a team member, learning each year, trying out different roles, with some taking on leadership roles in their final years. Five women were officers, safety captain, or team captains; three others took the lead over some aspect of the robot (e.g., software, mechanical). The gender mix for their team or their major did not show any significant differences across this leadership variable.

Team Sizes, Team Types, and Reflections

Team size. Aria posited that “size doesn't matter [as] much as team infrastructure.” Anne said her “team was fairly small” but they still did have several students on the programming team. GoldenM said team size “created a different dynamic," which was supported by Lexi who was in a large team (greater than 50). Nancy agreed suggesting that developing close relationships via activities like sleepovers, birthday parties, and such was less common as her team grew in size over following years. While size provided the team more options for organization and filling necessary roles, at times "some people were sitting around not really having anything to do" (Lexi).

Team type. Study participants came from both single- and mixed-gender teams. With only a few exceptions as noted previously, the FRC influences on these young women's career decisions was not dependent on what type of team they had been in. However, they did share observations about team composition that speak to the environment for young women in FRC teams, of whatever type.

Single-gender about Mixed-gender teams. Several of the young women shared ideas from their perspective of being in single-gender teams about being in mixed-gender teams.

> We would go to competition and I distinctly remember the first couple of years. Occasionally…a girl would come up from another team into our pits and be like "oh, you are all-girls team. That is the coolest thing ever. I wish I could be on one!" We were always like: oh, really? "Yeah the guys on my team never let me do anything. I'm the only girl. All they do is, they only let me do PR stuff or whatever it was and not actually touch the tools and build the robot." (Nancy)

This theme was seen by another single-gender team participant: "I can't say I have experience from mix[ed]-gender teams, but I noticed that the girls tended to gravitate to administrative or more leadership roles on the teams" (GoldenM). Another reflected about if she had joined a mixed-gender team: "most…other teams in my area are definitely male heavy…I think I might have felt a little bit more uncomfortable, like I didn't fit in as well, as [I did] on a single-gender team" (Anne). Alexis speculated:

> If I was in a mixed gender team, I would have been pushed aside. And I would have been so willing to be pushed aside because I didn't know what I was doing and I would've assumed that was… the habits, that was, the social norm….I think [being in a single-gender team] made it easier for me. As a freshman, I was pretty shy. New place, new people, wasn't very confident.

Mixed-gender about single-gender teams. Some young women on mixed-gender teams enjoyed seeing the single-gender teams from afar. "[I] enjoyed seeing other girls in the program because…there weren't a lot on our team…seeing this all-girls team was kind of amazing for me" (Smurf). But, Smurf believed being on a mixed-gender team was a plus: "it allowed for more diversity of opinions and ideas. Because I feel like with an all-girls team, that we're kind of like-minded so we only think in one direction. And with the guys there it really expands the ideas." Lexi reiterated that same thought: "it's good to have the different genders on the team…providing new ideas." However, members of mixed-gender teams did agree it could be difficult to get girls to join. Sarah described "my first year was about 50-50…[dropping steadily until in] my last year it was 20%. It just like dropped, dropped, dropped. I think *people saw it as a nerdy club. And that's where the guys belonged* [emphasis added]." Lily shared how relationships with the few females on her mixed-gender team helped them pull closer together. Possibly the posse factor was at work here (Posse Foundation, 2013)

Aria, Lily, and Lexi mentioned having close male friends or family growing up and being in mixed-gender teams was not a large problem for them, "[the boys on the team] were like brothers to me" (Aria). Friend and family relationships still developed as described in earlier sections (Lexi & Aria). Lily "couldn't really imagine it as a single-gender team. The team overall was mostly male. The friends I had had who were a part of it who I had known just through high school, they were all-male." All three mentioned prior positive interactions with males at an earlier age. "Like the [male] friends I already had known before the team, they knew and respected me, which might have helped things" (Lily). Those prior supportive contacts might have positively influenced their success pattern in mixed-gender teams. Other young women who did not have positive early encounters may have reacted differently.

Unique single-gender team. Within northern California, only one team has formed under the Girl Scouts banner. To protect confidentiality, in this case, the woman's statement is not attributed. The influence of Girls Scouts as an organization for that unique single-gender team was evident.

> The Girl Scout has a Girl Scout law, like being honest and fair, friendly and helpful, considerate and caring, etc. and that really really shaped the team. That was something we had on the wall, that we went over every couple months or so just to remind people…that helped shape the team because everybody knew…we

> were here to be Girl Scouts, we were NOT the super competitive cutthroat. We were here to be supportive of everybody [and] get through this together and not leave the slackers behind. We wanted everybody to succeed. I think that really helped.

Environment Summing Up

Competing, one of the FRC experience categories, is frequently an emotional time, with a constant flow of energy, and opportunities to gain satisfaction for the intense six weeks of design and build. The young women in this study remembered interactions with people at the competitions, the heroes who inspired them, but not one talked about the game itself or much about the matches or awards. Nonetheless, visualizing how a competition works helps gain an understanding of its impact.

For females, the pluses and minuses of single- versus mixed-gender FRC teams vary similarly to the advantages and disadvantages of single- versus mixed-gender colleges. More research is needed to determine which type is optimum, if either will ever be a clear winner. Likely the benefit varies as much as the young women themselves. However, a single-gender female team can provide critical mass that a mixed-gender team may not have. A few mixed-gender teams in the northern California area have more than a couple of females on their teams, though most do not. A critical mass of females in mixed-gender teams could help minimize barriers and obstacles.

Evidence of Trustworthiness

Charmaz (2006) listed four quality criteria: “credibility, originality, resonance, [and] usefulness” (p. 181) for grounded theory studies. In Chapter 3, plans were made for five criteria: credibility, transferability, dependability, confirmability, and ethical procedures. A summary of what was achieved on those five as well as Charmaz’ suggested criteria are noted below.

Credibility. Three types of data were gathered: focus group dialogues, interviews, and photograph dialogue. Focus group participants all were able to see what they shared via the online asynchronous Yahoo group. Each interview transcript was sent to participants by email; no changes were suggested from those who responded to the email. I did not hear back from each person. I also sent an early draft of selected sections from Chapter 4 to every participant; again, only a few responded and those were positive responses and no changes were suggested. The last two interview participants held in October viewed a version of the study model after answering interview questions. Based on their input, I did expand portions of Chapter 4 discussion on the connecting sub-category. Comments from the young women who did respond showed that the model and content clouds with codes and categories did resonate with them, contributing to Charmaz’ (2006) points on resonance (p. 182). To gain stakeholder feedback, I crafted a PowerPoint of the model and content clouds (no text or quotations) and reviewed it with two stakeholder groups via a GoToMeeting online call. Their feedback was incorporated in chapters four and five; in particular, they influenced the renaming of a category in FRC experiences as described above. Overall, the stakeholders said the model and details resonated with their experiences as mentors, teachers, and researchers. Having the model reviewed by participants and stakeholders helped build credibility (Thomas, 2003).

Speaking with these young women, all FRC alumnae, about its influences on them helped me become even more familiar with the program and how young women perceived it. The observations I made at one regional event matched much of what the young women described in their focus group dialogues and interviews. Energy, social cohesion within the teams, and post high school involvement with the FIRST community were all easy to observe at that event. Using the analysis tools in QDA Miner, I did search for phrases in all the texts that matched or gave birth to the categories that grew from the earliest initial coding. What might be missing are young women who did not see a benefit from their FRC experience. For the women who responded to my study, even those who were not studying STEM degrees, FRC fortified their passion and the career they have chosen. Beside those studying engineering or computer science, a couple of study participants are going into communication fields and connected their major with what they did representing their teams in FRC activities.

Transferability. Generalizing the findings from this study has some merit for females in other robotics programs that have similar elements, such as heroes and experiential activities. It is also possible that some findings could be transferred or generalized to males. However, since the findings were not reviewed with young men nor were they part of the study, it is difficult to comment on this quality measure. (Maxwell, 2005; Merriam, 2009). Nonetheless, certain categories within the model might be transferable for application to male FRC alumnae. The extent (or lack thereof) of this transferability is suggested by findings discussed in the recent study by Brandeis University (2011) for FIRST. For example, in that study, large numbers of FRC members (male and female) reported improved leadership, communication, and problem-solving skills and increased interest in STEM career fields after participating in FRC. Thus, the learning category from the model could be common to male alumnae. Other categories might have similar common threads. However, some categories may not: notably the gendered memories and the social cohesion and peer support categories.

Dependability. Different participants studied by another researcher may bring different results. While the interviews have the possibility of self-report bias, since they are historical in nature, the impact was partially limited by the use of photographs they discussed. These historical snapshots of the young women's FRC participation did provide a view contemporaneous to their high school involvement. The observation of a recent FRC regional provided other similar data about the experience, albeit at a muted and not time synchronous level.

Confirmability. As Maxwell (2005) stated, "what the informant says is *always* influenced by the interviewer and the interview situation" (p. 109). Thus, analyzing why I might have influenced a participant was important for me to remember (as described in prior section on researcher role and reactivity). Avoiding leading questions, using open-ended questions, and working with pre-established questions helped avoid issues in this area.

Originality and usefulness. While career decisions have been much studied (see Chapter 2), decisions by young women with respect to engineering, physics, and computer science careers still need further research. Many outreach or experience-based programs have been studied, though not as much with gender as a filter. Few of these studies used career decision theory as a framework or scaffolding. Thus, this study with its focus on career decision influences from a high school robotics program does fill a research gap. The proposed theoretical model can be explored further with continued study in other parts of the United States away from Silicon Valley. In addition, bearing in mind Super's life stages of career patterns (Super, 1957), more could be learned by delving into the influence of middle-school robotics teams by studying young women in college that are alumnae of them (i.e., of FLL). In Chapter five, I describe my plan for next steps to study other age groups. These ideas suggest a projected usefulness for programs and people that hope to inspire young people to enter engineering, physics, and computer science careers.

Ethical Procedures. Stakeholder support letters from Chief Delphi and WRRF were provided to the Walden University Institutional Review Board (IRB). As noted in a prior section (Researcher Role), I was known to some of participants in my role as a WRRF BOD member, CalGames organizer, or FRC volunteer. Since I did not always know if they remembered this, the consent letter iterated that this study was not associated with FIRST or WRRF. All of the files were protected during the study analysis actively on my laptop and are archived two forms of media.

Results of Grounded Theory Study

The research questions, repeated at the beginning of this chapter were answered by the women in this study, who described their experiences in FRC, the heroes present (or not), to what extent these influenced their career decisions, and finally the differences across single-gender or mixed-gender teams. These women's stories and memories, coupled with my observations of a recent regional competition, resulted in a model for the influence of FRC on young women's career decision, based on experiences and supportive relationships found in the FRC program (see Figure 8).

The FRC experiences included three categories: *intense six week collaborative journey*, *competing*, and *social cohesion and peer support*. The category intense six week collaborative journey refers to the intense and short time in which each year's robot must be designed and built. Competing referred to experiences at the regional or championship events. Social cohesion and peer support, a highly common category among the study participants, was defined by how the teams and competitors became their friends, family, and community. Those groups of experiences included two gendered memories: *girls think differently* and *rejected being female*. Some women posited that girls thinking differently was a positive and others saw this as a negative. A few of the women revealed experiences where they were rejected, simply because they were female. Supportive relationships, or heroes, were the other input into the career decision process. That process including information gathering steps, *learning, connecting, and knowing*, followed by *decisions*. Sometimes gendered FRC memories generated career decision making *obstacles*. Ultimately those inputs or generators were processed into a result by the young women into *who I've become*. The women in this study revealed their memories about the FRC experience and how it ultimately influenced where they are in college now. Reviewing this model with the study participants and stakeholders proved fruitful and earned their support of it.

Summary

Both supportive relationships and experiences within the FRC program influenced young women's career decisions in specific ways. This was true for women in STEM and non-STEM majors, from both mixed- and single-gender teams as well. They vividly remembered the six weeks phase when robots were designed and built. The regional competitions and for some the Championships were something to remember fondly with laughter and pride. They fondly illustrated the social cohesion that ripened in their teams and with the FRC community from being part of the experience. Some gendered memories of girls thinking differently or rejected, being female did occur for some. All remembered how heroes shaped them. For young women who knew they were interested in STEM careers before high school or before joining an FRC team, the experience fortified their early knowing. For young women who were exploring careers, finding what they liked doing, FRC proved to be a place to find their passion. Some experienced obstacles to making a career decision that grew from gendered memories. On the whole, the young women revealed how FRC shaped them, defined them, ultimately into who they became.

The transferability or usefulness of this model for male FRC alumnae will need further research. Brandeis University for FIRST (2011) underlined dissimilarities for male and female FRC participants: “One area that deserves continued attention is the difference in experience between girls and boys in the two [FRC and FTC] programs” (p. 85). Brandeis identified many aspects of the program’s influence on females similar to the model (e.g., career influence, skill building, and gender stereotypes). While males and females both enjoyed and valued the experiences of designing, building, and competing with robots, females responded to the program in distinct ways.

The final chapter includes an interpretation of these findings against a backdrop of other research not part of the original conceptual framework. Recommendations, limitations, ideas for further research, and implications conclude the chapter.

Chapter 5: Discussion and Recommendations

A more inclusive environment is needed in the engineering, physics, and computer science fields. In 2011, the National Research Council (NRC) identified two STEM education goals to increase representation and participation by women and underrepresented minorities (i.e., "blacks, Hispanics, and low-income students," NRC, 2011, p. 4). The NRC reiterated that enrollments today in STEM fields were insufficient to meet the U.S. needs.

The NRC (2011) asserted that closing the gender and minority gap in certain STEM areas is "needed for the nation's growth and development in an increasingly science- and technology-driven world" (p. 4). Unfortunately, young women are not seeing engineering, physics, and computer science as careers for them to thrive and help society, as noted by the National Academy of Engineering (2008), "no concerted efforts had been made to…to demonstrate to girls how science, math, and engineering are related to the things they are most likely to care about" (p. 59), helping society and people. Females tend to lose interest in science between middle school and high school and overall are more anxious about science than males in studies (Desy, Peterson, & Brockman, 2011), suggesting that the gender gap becomes larger after middle school. Females rated health related science degrees in six of the top seven career interests. Engineering and computers were numbers one and three respectively for males, but neither was in the top 10 college major interests for females. A conclusion from this and other studies is that most young women do not seeing engineering as a profession for themselves.

This lack of attraction to engineering runs counter to NSF policy, which promotes teaching engineering at the K-12 levels, both in school and outside of school, to help build a diverse STEM workforce. Khargonekar, the NSF Director of Engineering, recommended open-ended problems, teamwork, and project-based learning activities to promote engineering at those grade levels (2013).

My study explored the influence of role model availability, social cohesion, and peer support on young women and in particular on their career decisions. FIRST delivers all three of those elements in its programs and more. According to the young women that I spoke with, heroes abound inside FRC. They also described the FRC environment as one where they felt they could develop social cohesion and peer support as well. The model that I developed from their ideas and stories outlines how experiences and heroes generated inputs into decision making processes, including information gathering modes of learning, connecting, and knowing, resulting in a career decision and finally, who these women have become.

These findings are interpreted next and the original conceptual framework was enlarged to better scaffold the proposed model. Remaining research gaps and implications for social change close the chapter.

Interpretation of Findings

In the middle of Chapter 4, I showed a GST model formed from categories and codes gleaned from dialogue with the young women in my study who talked about their FRC experiences and its influences on them (see Figure 8). As part of grounded theory processes, revisiting the literature for connections to prior theories or research is an important validation step. The next sections reassess three models not used in the earlier literature review, consistent with that grounded theory step.

Expanded Conceptual Framework

From further research using phrases, codes, categories from my model, I found three other models or theories that had some type of connection or had some parallel to my proposed model. Bandura's theory of perceived self-efficacy (Betz, 2000) and Silvia's interest-and-interests model (2006; Dik & Hansen, 2008) had connections to my model, as will be outlined in the next paragraphs. Notter (2010) in her phenomenological dissertation exploring the influences of FIRST Lego League (FLL) and an another robotics platform on teenage adolescents found four themes, two in particular, with strong connections to my model's categories. Many of the female teens' stories in Notter's study resembled memories and stories from the young women in my study. These comparisons are all described next, followed by research on interventions similar to FRC and how those display ideas from an expanded framework.

Self-efficacy theory. My proposed model has certain roots inside a significant career development construct: self-efficacy theory (Betz, 2000; Betz, 2007; Lent et al., 2005). Betz (2000) depicted self-efficacy theory as four precursor elements feeding perceived self-efficacy resulting in three consequences. Betz (2000) listed four precursors that help a person build a perception of self-efficacy about some skill or field: “performance accomplishments, vicarious learning, emotional arousal, [and] social persuasion” (p. 207). As these apply to a career decision or a set of self-efficacy perceptions, such as the category “who I’ve become,” these four precursor elements have similarities to the FRC experience generator categories in my model.

All four of the elements that Betz (2000) outlined are present in the FRC influences model created for this study. The build time and competition times provided several aspects of performance accomplishments for the young women and for their teams. Participants experienced vicarious learning by observing and listening to their heroes as part of the FRC experience. The FRC experience was found to trigger emotional arousal through the relationships built, the competitions, and the ups and downs of the design and build 6-week period. Social persuasion came from peers, mentors, and the interactions at competitions and in the socially cohesive environment. If these were overwhelmingly positive generators or inputs then the young women developed a perceived self-efficacy in a diverse template of skills. Designing (mechanical, electrical, software), building (hardware), persuasion (presentations, talking with other teams in alliances, team interactions), and communication at several levels are only a few of the skills these young women chronicled.

Per self-efficacy theory, a person's perception of self-efficacy has three likely outcomes: either a positive (i.e., choose) or negative (i.e., avoid) reaction to the experience, an ability to perform it well, and a capacity to persist in doing it. The model proposed herein groups those three results into one outcome: *who I've become*. The women in my study are pursuing careers with skills and interests that they developed inside FRC, and are beginning to persist in those fields.

Silvia and Notter linkages. My proposed model has some parallels with Silvia's interest-and-interests model (Dik & Hansen, 2008). Silvia (2006) asserted that interest was an emotion and was transitive in nature, whereas interests are formed from an interest and become part of one's personality. A person's interests are prime influences in his or her vocational decisions. Recalling from the analysis chapter, participant statements and resulting codes from the learning category in the decision making process block in the model have similarities to Silvia's interests formation.

Notter (2010)'s dissertation spoke to me in many ways. Much like me, she was a technical person, with many years of technology experience, having personally experienced meetings and projects where she was the only female. In focus groups with teen girls participating in robotics programs, their stories raised two themes (discussed in more detail in later Recommendations section) with parallels to those in my study. One theme, "*It's like everyone is rootin' for you*" (p. 54), has connections to the category *social cohesion and peer support* and to supportive relationships or *heroes*. A second theme, "*I know who I am*" (p. 54), had echoes in stories from the *who I've become* category in my study. These connections and parallels are further discussed in the Recommendations section coming up.

Connections to conceptual framework. Circling back to the beginning framework outlined in Chapter 2, Roe (1952) and Super (Super et al., 1957) remain relevant to the model developed herein, synthesized with self-efficacy theory (Betz, 2000) and themes from Notter (2010). Roe's theory provided a "model for how vocationally relevant needs develop or influence vocational behavior" (Brown & Voyle, 1997, p. 311), in particular when young people's career aspirations are different from their social group or general population norms (p. 317). Women considering the fields of engineering, physics, and computer science are an example of these different career aspirations. Similar to my findings, Super's (Super et al., 1957) career theory constructs described the importance of experiences in interest development and career choice.

Ample recent research has shown that females frequently do not enter engineering, physics, and computer science careers even if they have good levels of self-efficacy and vocational interest in those fields. Females consider careers differently than males. In general, young women view some careers (e.g., engineering, physics, and computer science) as not helping others or society (Brown, Johnston, & Clark, 2010; Duffy & Sedlacek, 2007). If these women view these occupations as stereotypically more masculine (Gadassi & Gati, 2009) or perceive other obstacles arise seeming to bar females from those careers, young women may avoid them (Gottfredson, 2004). Inda, Rodríguez, and Peña (2013) found that persistence in engineering curriculums was linked to self-efficacy with those men having higher self-efficacy more likely to enter and persist in engineering, and if women had lower self-efficacy they were less likely to persist.

Heilbronner (2011) investigated STEM career persistence within two cohorts that one might posit were highly likely to enter STEM careers: Science Talent Search finalists from the late 1980s and a second cohort from the late 1990s. Those who “stepped off the STEM pathway… [were partially] associated with lower self-efficacy” (p. 893). Moreover, if the young person (male or female) believed that learning could happen with hard work, not only with talent, then persistence in a STEM major was more common. While her data did not include any gender specifics, the findings fit with other research on self-efficacy for women. BarNir, Watson, and Hutchins (2011) also confirmed the positive influence of role models on occupation self-efficacy and choice finding that female college students were influenced more than male students. In my study, I found that the FRC experiences and heroes helped young women move past obstacles, overcome stereotypes, and gain self-efficacy empowering them to be more successful in their career choice, whatever program they selected.

Females do not have the same levels, on average, of confidence about science, as males do when entering college. Cotner, Ballen, Brooks, and Moore (2011) studied this finding against a filter of teacher gender. When young women learned about science from a female teacher or teaching assistant, their confidence levels increased; whereas when the teacher and TA were male, no change was observed. On counterpoint, Ceci and

Williams (2010) suggested that teacher or mentor gender was not that influential, pointing to the growth in women's participation in veterinary medicine, medicine and law, which were historically male dominated professions and now are not. Some study participants did reflect on the paucity of technical women mentors in FRC and how if more female mentors participated, female teens could see more easily that females in STEM fields did exist. However, I did not hear a definitive recommendation from the young women about mentor gender.

Parents influence career decisions. Linkages between parents influence on young women's career decisions to enter professional careers have been found (e.g., Douglas & Guttman, 2000). An adolescent's confidence in career decision making was increased when parents are supportive of their teens overall and of their interests and career exploration activities (Keller & Whiston, 2008) as was seen in the supportive relationships (heroes) category in my study. Other studies have explored how heroes from family, friends, and teachers affected career decisions for those who were studying engineering in college. For example, Coward, Zaier, and Hamman (2010) sought "for understanding and insight rather than for prediction and control" (p. 6) in their qualitative study of early engineering students within an SCCT framework. Family, friends, and teachers influenced participant's career decisions to enter the engineering program, though the type of influence was not the same. Family and friends had more of a second-hand influence of the persuasive type. The college students shared phrases similar to "my uncle was an engineer and he was positive about it" or "my family has many engineers in it." Several of my female participants had engineer or computer scientist parents, as was noted in Chapter 4. This dynamic of parent-daughter needs further study for parents who are in engineering, physics, or computer science careers.

Auster and Auster (1981) found in their meta-analysis of factors influencing women to seek non-traditional careers, such as engineering, the influence of family was high. For those women in careers where women were few, "more likely than not," (Auster & Auster, 1981, p. 260) the father had modeled a high level achievement oriented occupation and the mother worked out of the home, often in a high level occupation. The women were making career decisions consistent with their home milieu. In my study, parents were positive influences for the young women, pushing them to move beyond their boundaries or supporting their decisions. Parents could become a limiting factor (Li & Kerpelman, 2007), though not seen in my study. If parents did not support their daughter's choice to participate in FRC or to explore engineering or computer science careers, their lack of support might have a strong negative influence.

Other heroes influence. Teachers and schools, while also providing a persuasive influence, offered opportunities for participants to explore and develop self-efficacy in engineering subjects, while in high school. (Coward, Zaier, & Hamman, 2010). Similar research with young women in science, mathematics, and technology programs also found a positive influence in achievement after participating in a mentoring program (Duyilemi, 2008). Programs offering these kinds of opportunities were mentioned as a potential intervention to help young people improve their self-efficacy.

Interventions within expanded framework. Interventions attempted have been many as discussed in early chapters. Darke, Clewell, and Sevo (2002) did a meta-analysis of NSF funded Programs for Women and Girls (PWG) held between 1992 and 1996. They found that programs involving “mentoring and role modeling, extracurricular [STEM] activities…were successful” (p. 295) helping females enter and persist in STEM programs (Darke, Clewell, & Sevo, 2002). One program (DiLisi, McMillin, & Virostek, 2011) melded the influence of peers on high school girls using a project-based goal to positively impact the community (i.e., K-5 students attending a museum). This program, Project WISE: Working in Informal Science Education, resulted in higher levels of interest in several STEM careers (e.g., engineering, geology). The young women involved were from various age groups. Each undergraduate (male and female) working with two high school students developed an activity, interactive museum exhibit, or media based performance aimed at K-5 grade students. The Project WISE program had many parallels to what several robotics teams do and that some of my study’s participants described.

Betz and Schifano (2000) investigated an intervention’s effectiveness at improving Realistic interests by increasing Realistic self-efficacy (engineering is one of the Realistic career interests). The study participants were psychology students with a mild Realistic interest. The seven hour intervention had design time, a time to see models of robots and meet role models, a build session repairing a lamp, with success at the end when the lamp lit up. FRC offers these elements on a longer term basis: design and build times (six weeks), observations of models (other robots, heroes), a competition section with success (though not all teams win, virtually all do field a robot). The result for both males and females in the Betz and Schifano study was increased Realistic self-efficacy and interests. One might project the same would occur if these women had been tested using the same instruments.

In several cases within the study, creativity was important to young women and it is worth noting that not all engineering curricula and faculty appear to emphasize that skill in their programs. For example, one woman, who expressed how FRC had fueled her creativity needs, moved to industrial design, finding her creativity needs met there, though not in mechanical engineering. Downey, McGaughey, and Roach (2009) recommended that universities, for CS majors, “focus…more on the creative aspect of computer science such as graphics, robotics, and virtual reality” (p. 365). I would posit this holds true for many engineering programs as well.

Summary of Expanded Conceptual Framework

The initial framework of experiences and heroes as career influences, described in Chapter 2, was supported by young women in my study. In addition, the self-efficacy theory elements (Betz, 2000) and Notter’s (2010) themes both had strong resonance with my model’s generators, process, and results. Research on interventions (Betz & Schifano, 2000; Darke, Clewell, & Sevo, 2002; DiLisi, McMillin, & Virostek, 2011) included similar key elements. The model itself remains an illustrative beginning for further exploration of the influence of robotics programs on young women's (and young men's) career decisions.

Limitations of Study

While the model did resonate with participants and stakeholders alike, my participants were overall positive about FRC and their experiences in the program. The participants were limited to alumnae from northern California, were female, and only 10 in number. The applicability of this model for females in other parts of the country or to male FRC alumnae is not known. This model, which was developed using grounded theory methods, does provide a launching point for further research and considering the feedback from stakeholders and the young women who shared their memories, the model appears credible. Finally, the phenomenological themes found by Notter (2010) do have parallels to my findings. However, given my engineering career background and nascent experience in education and career theory research, the coding and model development would likely not be replicated by other researchers.

Recommendations

Recommendations to improve FRC and other such experiential and hero-based programs include elements also found in a four-part Drexel University program (see Chapter 2 for more details). These types of changes could recast people's mental models about women in computer science (Agosto, Gasson, & Atwood, 2008) and other fields where women are below a critical mass. Drexel's "Changing Mental Models Framework" (p. 205) included a redesign of curriculum, with heroes—mentors and role models—and activities to build social cohesion and peer support. Recasting FRC rules, guidelines, and games (i.e., curriculum) into projects with relevance and connection to real-world challenges (as FLL does) has the potential to appeal more strongly to young women and underrepresented minorities (NAE, 2008). Developing and delivering a mentor training program could help form more consistently effective mentor-student team member relationships, avoiding issues described in the prior chapter, and helping mentors see how their behaviors influence young people, in particular young women. Creating activities and fostering a structure to be a catalyst for social cohesion is a mostly untapped area. These three ideas are described next. The recommendations conclude with thoughts on achieving critical mass and overcoming stereotype bias.

Ensure Experiences are Relevant and Connected to Real World

American Society for Engineering Education (ASEE) suggested “student engagement in engineering activities [using] PLTW [Project Lead The Way], FIRST Robotics and other enrichment activities” (Agarwal, 2013). Research has found that certain types of games or problems appeal to males and not to females on average (NAE, 2008). “Women tend to gravitate to social, community, and global issues, as reflected in the choice of engineering discipline that current women engineering students make” (Chubin, Donaldson, Olds, & Fleming, 2008, p. 254). Recalling data in Chapter 1, women have been graduating with bachelor degrees in the life sciences at a higher rate than men, almost two to one. Using robotics to solve a larger world or community problem could be one way to tap into this kind of connection for young women (and men) (Nauta & Epperson, 2003).

If robotics programs help young women see how to solve the next big problems for the world, they are more likely to consider engineering and computer science careers (Chubin et al., 2008; NAE, 2008). If game goals could connect with world problems, the "interestingness" (Morgan, Isaac, & Sansone, 2001, p. 317) of engineering and computer science careers for females might grow and choices in those careers could expand (Morgan et al., 2001). One Pennsylvania high school robotics team developed an innovative community project to inspire younger students about STEM (Kressly, Herbert, Ross, & Votsch, 2009) across their school district area for private and public schools. Technology and Engineering Club students "fueled by a passion to provide others with opportunities to learn about the excitement and benefits of STEM" (p. 26) created a portable robotics lab, which they took to elementary grade classes and other public events. Nancy told me how her team had organized tournaments for elementary age students and how that work helped identify her passion, not the FRC experience of building a robot per se, but what her FRC team did to help others. FRC has not typically made use of this *big problem* potential for its game problems, whereas in FLL games, large world problems that help communities have been yearly themes.

This is not to say that females do not value and learn from competition. Notter reinforced this nuance in her phenomenological dissertation study (2010) of girls in robotics competitions. "Female adolescents enjoyed the challenge of the [FLL] competition. The informal learning environments encouraged an atmosphere of *social engagement and cooperative learning* [emphasis added]" (Abstract). Notter's point harkens back to two places in my proposed model. First, one of the three FRC experience categories, *competing*, had stories similar to the younger women in Notter's study. Sarah defined the code equal parts work and laughter in the six weeks category, and many reminisced how competitions were exciting, fun, almost electric. Second, Notter's theme of social engagement and cooperative learning has many parallels to the *social cohesion and peer support* concept. As Aria asserted: "It just means that you aren't in it alone. I think that's a beautiful thought. That at the end of the day, you have people who care about you and genuinely want to help you succeed." This feeling of social cohesion was felt by all the women in my study.

While FLL games, what Notter (2010) studied, often have a community problem as their theme, FRC games in past years have included game elements and themes mostly from sports games with ball handling, like soccer balls and basketballs, or other game type elements: such as, Frisbees, and inner-tubes. This focus on competitive games with insufficient real-life meaning might be wielding a negative influence on female participation: "Women are more likely to engage in a task in which they help someone or create a product someone can use than participate in a competitive task in which the goal is to beat ones opponent or a clock" (Nair, Hanson, & Reidy, 2003. p. 3). That kind of competition or project has not been found in FLL games.

FLL typically selects a big problem for its theme. For example, in 2012, the FLL theme was “Senior Solutions^{SM}: Independent, Engaged, Connected” (FLL, 2012) The game board included a set of missions associated with senior living, such as, cardiovascular exercise, cognitive puzzles, walking, doing crafts, and taking medications. The team project in 2012, a judged team element each year, was to design a product or service to help seniors. Project research was captured in team notebooks. Teams were required to work with a senior partner they selected to gain ideas about his or her needs as a senior. As an FLL judge in 2012, I observed many thoughtful and unique ideas: for example, a vest that a senior could wear with remote sensors and places for personal information in case of accident. Seeing these young people passionate about helping seniors and learning the challenges of being a senior was in itself inspiring. The National Academy of Engineering suggested (2013) “recast[ing] engineering as inherently creative and concerned with human welfare, as well as an emotionally satisfying calling” (p. viii). Many robotics competitions, (e.g., FRC) have not had that consistent connection to solving the world’s big problems that could appeal better to young women and many young men (NAE, 2008).

As AERA special report writers Malcom and Malcom-Piqueux in *Critical mass revisited: Learning lessons from research on diversity in STEM fields* noted,

> Decades of scholarly research and programmatic evaluations aimed at understanding the factors that contribute to diversified STEM programs indicate that *sustainable diversity results from environmental changes* – that is, changes in

> culture…quality and quantity of supportive practices…that support the success of all students (see Chubin, Depass, & Blockus, 2009; DePass & Chubin, 2008; Fox, Sonnert, & Nikiforova, 2009; Margolis & Fisher, 2002; Maton & Hrabowski, 2004) [emphasis added]. (2013, p. 176)

Changes in FRC culture and environment could help build an even more welcoming climate to young women. Some of these changed could be initiated by FIRST, others would need to be driven at the regional or team level.

One suggestion from a study participant was for teams to avoid having non-technical roles that are typically occupied by females. Instead of a student responsible for public relations, communications, or presentations, have the group of leads (e.g., mechanical, electrical, software) or officers responsible for these soft skill tasks. Males could benefit by being more involved in communication activities and not be isolated in the stereotypical male islands of build and compete, helping male students grow outside of their classic comfort zone. Another similar suggestion was about how a team's drive team was selected. Several young women mentioned drive team competitions, where the selections of the drive team members were not left to power dynamics or favoritism. Instead, an open competition, potentially with focused encouragement to ensure that all team members participate, could increase drive team diversity. Drive teams are highly visible to the public and to young people on FRC, FTC, and FLL teams. Photographs of them are often used on web sites and in other marketing collateral. Increasing diversity in these highly visible positions could reduce stereotypes. Beyond these specific suggestions for teams and the connections to game purpose, most of the study participant's recommendations were about mentor behaviors.

Recommended Mentor Behaviors

The young women in this study had suggestions for mentors. Some of the women had been FRC, FTC, or FLL mentors since their time in FRC (or during their time in FRC). Most of these recommendations centered on letting students do more, making the dynamic less about a great robot and more about the students. Also, some suggested mandatory training for mentors about "how to support students" (GoldenM).

Make it a student decision, not a mentor decision. Sometimes mentors attempted to teach a concept that was beyond the students "trying to push…designs that were really too complex for the understanding that the students had" (Anne). This led to frustration and since "the students didn't really know enough to be able to make an informed decision…then the mentors ended up mostly sort of guiding them to the decision, and then it felt more like the mentor's decision" (Anne). Smurf suggested "listening to the students' opinions about things." Nancy reiterated this advice: "You have to let them do it." Anne expanded on this key concept: "[Let] students…make decisions… giv[e] them the information they need to make an informed decision." GoldenM agreed: "mak[e] sure the students are making all the decisions; that it is not, not parent driven or mentor driven." Alexis summed it up this way:

> If you are a mentor, you are supposed to be involved, you're supposed to help and you are supposed to support your team. But you're not going to do the work, and

> you are not going to do it for them. You can show them how to get to where they want, but it's still the student' job to make their team and to make their robot and to build what they want.

Push female (and male) students to stretch. Nancy suggested that mentors "try and push [students] to think outside the box, whatever box they are starting in, trying to get them to look at [the problem] from different ways. Be more creative about whatever it is they're doing." Lily suggested "making sure everyone is learning how to do as much as possible [and] keeping everyone busy is super important." But teach and coach, do not do. Mentors should not do anything on the robot, Aria asserted "unless there is a student there." This thought was iterated by several of the participants as was seen above. Supportive relationships—heroes—can help grow a young women's self-efficacy for problem solving and engineering practices (Nauta, Epperson, & Kahn, 1998) and help them move outside of their comfort zone and expand it.

Caring mentors, being good role models: Mentors showing supportive emotions helps: "Somebody that cares about you" (Aria). Along this theme, GoldenM suggested "being a good role model, never losing your cool [when others do]… Making sure you were always level headed…you are someone that the girls look up to or the teams look up to." Lexi looked for mentors who became friends: "I want to be their friend. I think that's really important." Sarah reminded mentors to "keep it fun too." Lily went further bringing in the concept of community: "building your own team as a community is a huge thing. The people who make up an FRC team…that's their main source of friends.

Being able to have that community is really important." This crosses over into another recommendation developed in upcoming paragraphs about nurturing a climate of social cohesion and peer support.

Inspire by sharing stories and making connections. "Telling stories or experiences…Talking about times you've encountered a similar problem, …in FIRST or in your career or at school…[so] students can hear …[how] other people…had similar problems in the real world…I always liked that when mentors did that" was what Anne suggested. Alexis revealed how positive it was that FRC helped her make real world connections. This was an echoed in research by Heilbronner (2009), who found that linking learning to real-world activities was a "powerful motivator" (p. 50). Teachers (and possibly mentors) that connected with students, both personally and with passion were more successful with girls in a science classroom. The National Academies (1997) similarly recommended: "Good mentors are able to share life experiences and wisdom, as well as technical expertise. They are *good listeners, good observers,* and *good problem-solvers* [emphasis present]" (p. 2).

Summing up recommendations for mentors. As noted, mentors should focus on coaching, guiding, and inspiring, not doing. Showing a caring attitude, becoming part of the team's community, helping young people stretch their limits and try new things: those are the recommended mentor behaviors from this group of young women. A mentor training module and collateral describing the benefits could be developed to help a mentor, teacher, coach, or parent learn these behaviors.

Social Cohesion and Peer Support

The category *social cohesion and peer support* has many similarities to the second theme Notter (2010) found in her phenomenological study of females in FLL competitions: "*It's like everyone is rootin' for you*…[a] feeling of camaraderie within the teams and within the experiences" (p. 54). Working together, collaboratively, within a competitive environment is the essence of all FIRST programs: Coopertition. "Even though you are competing against some of these other teams, if you ask for a wrench, somebody is going to go find you a wrench and bring it for you. The coopertition" (Lily). That concept works at other educational or career levels as well, like the engineering classroom (Persaud, Salter, Youder, & Freeman, 2006).

Activities, training, and getting female FRC alumnae more involved in current FRC activities might be the solution path to help grow a more socially cohesive environment. This is an area that needs further research and idea gathering from alumnae, both FRC male and female.

Achieving Critical Mass and Overcoming Stereotype Bias

Stereotypes against females and gender bias continue to exist in many STEM fields. In a double-blind study, both male and female faculty from "Biology, Chemistry, and Physics departments" (Moss-Racusina, Dovidiob, Brescollc, Grahama, & Handelsmana, 2012, p. 16478) were more likely (moderate to large effect sizes) to hire a scientific laboratory manager who was male than a female, offering the male a higher salary and more opportunities for mentoring. More startling at some level was that "female and male faculty were *equally* likely to exhibit bias against the female student [emphasis added]" (p. 16474). This kind of stereotype bias exists outside of academia as noted in the regional competition observations (see Chapter 4, Environmental Analyses) and by some of my study participants.

Women graduating in specific fields within engineering (e.g., mechanical and electrical engineering, computer science) continued to be less than 15% of bachelor's degrees in 2011. This "critical mass" (Hartman & Hartman, 2008, p. 264) percentage, 15%, is significant. Women in those fields where critical mass does not exist are perceived as uncommon or different, compared to other fields (e.g., environmental, chemical, or biomedical engineering) with rates closer to 40%, where women's participation percentages have made a beachhead (NSF, 2012). When higher percentages occur, stereotypes break apart. Hartman and Hartman recommended experiences and female role models to help raise the percentages of female graduates in those fields. Experiences and heroes that help young women see the "people-helping facets" (Hartman & Hartman, 2008, p. 264) are key elements as described above and by the young women in this study.

Another view on causes for the low numbers of women in engineering, physics, and computer science and the impact this low-density has on young women's career decisions comes from Milgram (2011) and her mantra about the importance of messages. "Educators need to repeatedly send a corrective, strong, positive message to women and girls: Yes, You Can!" (p. 5). When young women see a sparse number of women in the engineering, physics, and computer science workplace and also receive “don’t go there” messages from heroes, they conclude those careers are not for them.

Conceptually, this critical mass idea suggests the posse effect mentioned earlier has merit. Young women in mixed-gender teams that have only one or two females in them might experience external stereotypes more frequently than those with a larger number of females in them. The comments by a few of the young women in this study suggested that conclusion; however, more research on mixed-gender teams with those challenges is necessary to better explore that conclusion.

Further Research and Next Steps

As Betz and Hackett (1997) and others have stated, young women may be avoiding traditionally male dominated careers, such as engineering, physics, and computer science, because they have low self-efficacy in skills needed in those fields. Or as Eliot (2013) suggested in *Pink Brain, Blue Brain*, socialization and bias patterns in society influence females to avoid engineering, physics, and computer science careers. As noted at the beginning of this chapter, Bandura’s theory of self-efficacy suggests that certain precursors affect a person’s self-efficacy perceptions. Self-efficacy levels in turn influence behavior and interests, which leads to career decisions (Lent & Brown, 1996). If self-efficacy in engineering or computer science can be increased for young women, ultimately the numbers of women entering those careers should increase (Betz & Hackett, 1997). Recent research with both CS and engineering majors using SCCT instruments demonstrated the viability for investigating career decisions and persistence of students in those majors (Lent, Lopez Jr., A.M., Lopez, F.G. & Sheu, 2008; Lent, Miller, Smith, Watford, Lim, Hui,…& Williams, 2013). Using those career theory instruments specifically with young college women who are FRC alumnae could be instructive.

Repeating this study with male FRC alumnae in college might bring forth dissimilar views, or not. Males and females have different expectations from a mentor and the mentor's influence has been shown to have gender nuances (Lockwood, 2006). Nonetheless, the causes for this difference are not well understood (Bogat & Liang, 2005). If a comparable model did result after exploring young male's ideas about this study's research questions (i.e., influences of FRC experiences and heroes on their career decisions), then my study's model may not be helpful in solving the problem of low numbers of women in engineering, physics, and computer science. However, if the results are completely or partially different, the deltas or variations could be even more useful for improving intervention programs. The young women in this study identified social cohesion and peer support from the FRC experience that were a major influence, consistent with other research (Bogat & Liang, 2005; Notter, 2010). Whether young men would remember or identify these factors in the same way is a question worthy of exploration. Also, since most FRC heroes were indeed male, will this paucity of women mentors have an impact on the results for male and female FRC alumnae, in particular for mixed-gender teams? Further research is needed.

While my study did not explore through any filter of race or ethnicity, research suggests that robotics programs can positively influence interests of underrepresented minorities in engineering, physics, and computer science. Intersections of gender and race or ethnicity will likely not have the same influence or outcome (Riegle-Crumb, Moore, & Ramos-Wada, (2011). Certain related studies suggest unique or somewhat different results. In one quasi-experimental quantitative study (Klein, 2009), Native American middle-school students built robots as part of their science class. Their attitudes about science improved, with interested and energized students; the activities had a side effect of minimizing classroom behavior issues. Lyon (2013) in her qualitative study of young college age women in computer science explored the intersections of ethnicity and gender within CS, finding "the constellations of race, class, and culture…created different experiences" (p. 119). Asian-American females (and males) also have a different career decision making model in several respects (Tang, Fouad, & Smith, 1999), selecting careers more from family or culture influences. They may have more technology heroes in their family lives, one possibility for their higher percentages in STEM than other underrepresented females. In a final example, Latina career self-efficacy is negatively impacted by perceived obstacles (Rivera, Chen, Flores, Blumberg, & Ponterotto, 2007). The influences explored in my study may not apply to all cultures, races, or ethnicities and new or different influences may indeed exist. I did not explore race or ethnicity and it did not arise in the dialogues. It is an area worthy of significant future research and exploration as the participation by women of color in engineering, physics, and computer science is significantly lower than that of European-American or Asian-American women.

Implications for Social Change

Resolving the overarching problem, the gender gap in engineering, physics, and computer science fields, requires changes in those fields. Many see this. For example in academia, “the (remaining) barriers to women’s progress…are systemic and rather than trying to change women to fit the sciences and engineering, *these fields need to be changed in order to accommodate women* [emphasis added]” (Bystydzienski, 2004, p. ix). To affect this kind of social change, many universities have recognized this and with the support of NSF ADVANCE grants have been finding solution paths to change their cultures, recognizing that culture change is needed. Many companies, large and small, have embraced the need for culture change, though many have not. Intervention programs, such as FRC, that are successful for males may need to change to grow an environment more welcoming to young women to garner more young women in them.

This organizational social change could be as simple as changing the theme of competition games or providing training to mentors (much like what academia has been pursuing with ADVANCE grants) as described in the recommendations paragraphs. In an *Electronic Engineering Times* interview with John Escobar, a parent and techie involved with elementary STEM programs, he stated “the most important part of the solution is the hands-on education. They need to play with it to really get involved. Students get theory all the time but limited action” (Price, 2012, p. 48). Likewise, Vogt, Hocevar, and Hagedorn (2007) in their study of male and female university engineering students concluded that “special interventions that focus on self-efficacy…might give women more confidence" by helping develop their critical thinking abilities in engineering subjects (p. 358). A longitudinal study (Schumacher, Stansbury, Johnson, Floyd, Reid, Noland, & Keukefeld, 2009) demonstrated that a 3-year intervention (summer camps and school year activities) aimed at improving adolescent female's self-efficacy remained effective long-term (five years later) with retained STEM interests. However, real or perceived barriers are connected to "women's outcome expectations for specific career domains" (Lindley, 2005, p. 283) and to self-efficacy as Aria, Lexi, and others noted in Chapter 4 data analysis section. Research continues to point to the need to improve young women's self-efficacy and help them grow their determination to persist, to result in any social change, like growing beyond critical mass in certain engineering, physics, and computer science fields.

In other words, when young women have high self-efficacy and outcome expectations in a career domain, they are more likely to pursue a career in that domain. Although, young women might need support to understand what has been a male culture and how to operate in it, (Burack & Franks, 2004) as Alexis described in Chapter 4 (obstacles to a decision). Alternatively, programs could shift their cultures to develop a potentially broader appeal to females and underrepresented groups (NAE, 2008) and provide training (e.g., mentor training) to help its adult leaders understand their influence on young women's career decisions.

Either way—young women benefiting from existing programs or programs changing their culture to accommodate more diverse interests—if the result is more young women entering engineering, physics, and computer science careers, society benefits. With no exception, all the young women in this study indicated that the FRC experience influenced their college major and career decision. Who they have become had roots in the FRC experiences and heroes generators, acted upon by the knowledge making processes, though some of these elements were shaded by gendered influences.

Conclusion

The FRC program provides many opportunities to nurture an interest in engineering, physics, and computer science skills and careers. Learning computer programming early, having to take risks, and acquiring engineering skills in a drive team or building a complex robot, have all been shown to help young women nurture these interests (Eliot, 2013). The model developed in this, as seen earlier in Figure 8, suggests a framework or system for growing these interests. The two generators, FRC experiences and supportive relationships, evolve through an intense six week journey, collaborating to design and build a robot, competing with it, in a nurturing environment of social cohesion and peer support via their heroes. These generators to the career decision pathway feed the learning, connecting, and knowing processes to decisions. Ultimately, FRC helps young women answer the question, “Who have I become?”

Gendered memories can create obstacles or barriers to young women choosing engineering and computer science careers. Recommendations made by the young women and by me might help the FRC experience become more welcoming to young women and potentially encourage more young women to engage in this worthwhile activity.

Moreover, “robotics fosters creativity” (Notter, 2010, p. 84). A source for innovative engineers and computer scientists could be inside these kinds of programs. A more diverse group of engineers and computer scientists with more females has the power to fuel higher innovation levels for the United States.

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Appendix A: Dissertation Process Information

The online focus groups were conducted over two months, with most interviews conducted over a 30-day period. Two interviews were held about three months later. Details on the scheduling are found in Table A1.

Table A1

FRC Alumnae Study Meetings

Process Type	Timing	# of Meetings
Focus Group One	April 2013	5
Focus Group Two	May 2013	3
Interviews	July 7 – August 1, 2013	7
Interviews	October 23 – 29, 2013	2

Housekeeping Posts in Online Focus Groups

First Housekeeping Post

1) Respect others' ideas. The discussion will not be moderated. What is discussed here is between us and other's posts or comments should not be shared outside the focus group.

2) Respect other people's privacy. Everyone has an alias or pseudonym to protect their privacy (except me, Ceal). Same for the team names. If you share personal contact information, understand others in the group can see it. Either way, I will delete your personal data from the study data I keep. I will likely use quotations

and ideas from our discussions here in my study analysis and dissertation, using only pseudonyms. Let me know if you want something kept more private.

3) Heroes: I am using this word as a collective one, defined as a supportive relationship, a role model, teacher, parent, coach, or mentor that inspired you in some way.

4) Answer questions as a reply to the post made with it. This will keep the discussions threaded. Feel free to respond to anyone else's post. Think of this as a chat in a physical room.

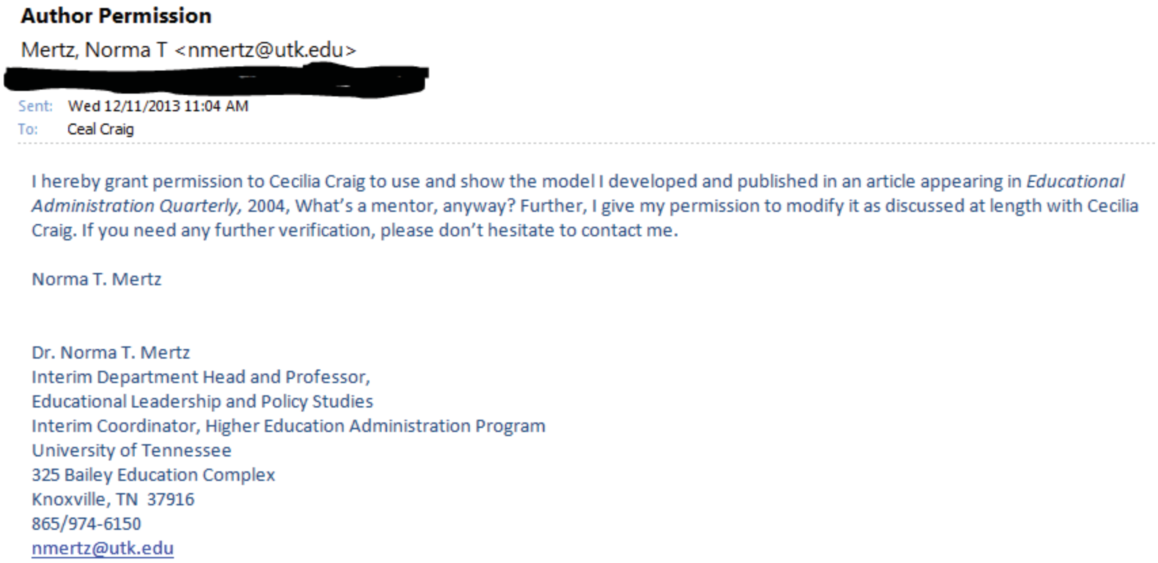
5) Ask questions if you are confused or have a suggestion. Remember, you can withdraw from this study at any time and I will not include you in it after that. Depending on the timing of any withdrawal, I may not be able to delete your specific online posts in the Focus Group discussions.

Second Housekeeping Post

(1) Thread/message/Topic management

If you have not participated in an online threaded discussion before, sometimes the posts can be overwhelming. I hoped to ameliorate that issue a bit by limiting the focus group to five plus me. Sometimes it helps to read the posts in threaded or TOPIC order. When you highlight “messages” on the left hand side of the screen (in my view anyway), you have options. Messages, Topics, Hot Topics. By reading in Topic view, it starts first with the “question or topic” and then shows the messages with indented order to show the “sub-threads.” In Summary view, the first couple of lines of the message are shown. Expand Messages to see the whole thread with all the details. Hope that helps!

Appendix B: Permissions



Author Permission

Mertz, Norma T <nmertz@utk.edu>

[redacted]

Sent: Wed 12/11/2013 11:04 AM
To: Ceal Craig

I hereby grant permission to Cecilia Craig to use and show the model I developed and published in an article appearing in *Educational Administration Quarterly*, 2004, What's a mentor, anyway? Further, I give my permission to modify it as discussed at length with Cecilia Craig. If you need any further verification, please don't hesitate to contact me.

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Curriculum Vitae

Education

PhD in Education, Walden University, 2008 – 2014

MSE in Mechanical Engineering, California State University, Fullerton, 1978

BSME in Mechanical Engineering, The Ohio State University, 1974

Coursework in D.E. (Engineering Management) program, Southern Methodist University, 1980-1986

Coursework in CLAD Teaching Credential program, National University, 2000-2001

Professional Experience

IBM Corporation/BLADE, 2011

- Executive Project Manager: Program management for next generation products.

Blade Network Technologies, 2006 – 2010

- Senior Director, Program Management; Senior Director, Special Projects; Senior Director, Program Management; and Director, New Product Introductions.

Druai Consulting, 2001 - 2006

- Provided consulting services for high-tech and education communities (project management, process development, problem solving, interpersonal skills training and development). *Pro bono* support to local high school: robotics club, Academy Advisory Boards, mentor programs.

Siemens Information & Communication Products, 1996 - 2000

- Director, Operations; Y2K operating company representative

Tandem Computers, 1994-1996 and 1989-1992

- Senior Program Manager; Manufacturing Engineering Manager; Senior Technical Staff to Development Vice-President

C^2 Consulting, 1994

- Provided program management and process development leadership for software engineering and engineering operations group projects.

Maxtor Corp., 1992 - 1994

- Director, Manufacturing Operations & Program Management; Responsible for direct labor (clean-room and test) as well as manufacturing program management teams charged with transition of new products from pilot build to volume production in Singapore.

Xerox Corp., 1979-1989

- Senior Manufacturing Program Manager, Contract Manager; Manager of Quality Assurance; Materials Manager: Manufacturing & Quality Systems Manager.

Rockwell International, 1974 - 1979

- Quality & Reliability Data Systems Manager. Operations Engineer. Process QE & QA Supervisor.

Teaching Experiences

University of Phoenix Online, 2002 - Current

- Certified Advanced Facilitator: college algebra, math history, and project management classes.

Johns Hopkins University, Center for Talented Youth, Summers, 2002 - 2005

- Instructor, Engineering & Science: Created and delivered two three-week Engineering & Science sessions for fifth and sixth grade students in residential program. Taught Newtonian physics with hands-on, team-based activities.

Milpitas Unified School District, 2000 – 2001

- Math Teacher, K-12 Public School District: Taught high school level Geometry and Algebra II classes for school year.

Professional Organizations

- American Educational Research Association
- Golden Key Honorary
- Kappa Delta Pi (Education Honorary)
- National Career Development Association
- Society of History & Technology
- Society of Women Engineers
- Women in Engineering ProActive Network (WEPAN)

Publications & Papers

Single Authorship (Craig, C. D.)

(2014). Robotics Programs: Inspiring Young Women in STEM. In J. Koch, B. Polnick, B. Irby (Eds.), *Girls and Women in STEM: A Never Ending Story (*pp. 175-192). Charlotte, NC: Information Age Publishing.

(2013). *Volunteer management in small Not-For-Profits* [White paper]. Available by email to author.

(2013). *Not-for-profit organizations as learning institutions: Management of volunteers* [Unpublished paper]. Walden University

(2013). *Pre-teen female motivations after the loss of a father while in elementary grades* [Unpublished paper]. Walden University.

(2011, July 1). *Can high school robotics increase female interests in engineering & computer science careers?* [Roundtable paper]. National Career Development Association 2011 conference, San Antonio TX.

(2010). *Principles of organizational and social systems in product development organizations and decision making* [unpublished paper]. Walden University.

(2009). *Societal influences affecting teens entering high-tech fields* [unpublished paper]. Walden University.

. (2009). *Teen career influences & STEM—science, technology, engineering, & mathematics or can FIRST programs help improve availability of STEM graduates in US?* [Presentation & Paper]. 2009 FIRST Conference, Atlanta GA.

(1988). *Secrets of Japanese manufacturing: Strategy or culture based*. 1988 Society of Women Engineers Convention & Proceedings.

(1984). *Controlling multinational electronic typewriter manufacturing*. 1984 International Council of Women Engineers & Scientists Convention.

(1976). *Control corrective action costs*. 1976 ASQC conference.

With Rebecca Wright, Co-Editor & contributing author

(1989, March/April). *U.S. Women Engineer*. Issue theme: Manufacturing Competitiveness in the 1990s.

Presentations

(2013, February). *Become a mentor in high school robotics programs: Inspire! Have fun* [Presentation]. Society of Women Engineers, Santa Clara Valley section.

(2012, December & other dates). *Making effective decisions* [Workshop]. Western Region Robotics Forum (WRRF) workshops.

(2012, October). *Become a mentor in high school robotics programs: Inspire! Have fun* [Presentation]. Society of Women Engineers 2013 Annual Conference.

(2012, October). *Does robotics inspire young women to seek engineering and computer science degrees*? [Presentation]. American Educational Researchers Association, Research on Women and Education Special Interest Group Annual Conference, Coeur d'Alene ID.

(2012, June). *Career theory connections to women's STEM career choices* [Poster session]. WEPAN 2012 Conference, Columbus, OH.

(2012, July). *Learn how engineering can be an exciting career via robotics* [Poster session]. National Career Development Association 2012 conference, Atlanta GA.

(2009). *Principles of societal development; societal influences affecting teens entering high-tech fields* [Presentation]. December 2009 Western Region Robotics Forum Workshops. (2006, April 28). *Why Companies should want to help you: Engineering enrollments down, global pressures, ideas* [Presentation]. 2006 FIRST Conference, Atlanta GA.

Community Support Experience

Board of Director Memberships

Western Region Robotics Forum (www.wrrf.org) 2006 - Current

- Recognized by WRRF community with special service award in 2006. BOD Member since 2006; Secretary/Treasurer 2006 – 2009; Treasurer 2009 - Current
- Each fall, WRRF organizes on an off-season robotics competition for 30-36 high school teams. CalGames is a significant volunteer event for the high school robotics community, involving 80-100 volunteers, showing thousands of the public how exciting technology can be.

San Francisco Bay Wildlife Society (www.sfbws.org), 2005 – Current

- BOD Member; President, 2010 – current; Secretary 2007 – 2010

Mission Chamber Orchestra (www.missionchamber.org), 2003 - 2008

- President 2006 – 2007; Treasurer 2003 – 2006; BOD Member from 2003 – 2008

Volunteer Efforts

- Women in Engineering ProActive Network, 2012 – Current, Co-Chair, WEPAN STEM Knowledge Center Committee
- San Francisco Bay National Wildlife Refuge support, 2002 – current.
- Society of Women Engineers (1972-95): Management and support positions at local, regional and national levels.
- Graduate of San Jose Community Leadership, Class of 1993.

High School Support

- Co-lead For Inspiration and Recognition of Science and Technology Robotics Competition (FRC) mentor, 2002 – 2009.
- Academy Advisory Boards, 2001 – 2005