A FRAMEWORK TO UNDERSTAND ENGINEERING IDENTITY DEVELOPMENT AND THE SUCCESS OF WOMEN'S PARTICIPATION ON COMPETITIVE PROJECT TEAMS

A Dissertation

by

SHAWNA L. FLETCHER

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Chair of Committee,	Kristi Shryock
Committee Members,	Dilma Da Silva
	Karen Butler-Purry
	Timothy Scott
Head of Department,	Timothy Jacobs

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ABSTRACT

The purpose of this study was to evaluate undergraduate women participating on collegiate extracurricular competitive project teams (PT) in comparison to non-project team (non-PT) female students. The study determined that PT participation significantly leads to an increase in engineering identity development and enrollment in non-traditional majors for women. A five-year retrospective study on PT participants was conducted to analyze participation and draw conclusions for ethnically underrepresented and first-generation (FGEn) populations. Cumulative GPA was used to evaluate differences in academic identity between PT, non-PT female, and college of engineering (COE) populations. A forced Likert survey was designed to determine other factors that influence engineering identity formation between cohorts. A full-factorial analysis of survey data found that the strength of “risk-taking” and “making mistakes” covariates were higher in PT participants than non-PT females ($p<.05$). Information from the data analysis was used to develop a Causal Loop Model (CLM) and Event Tree Analysis for women’s participation and success on competitive project teams.

DEDICATION

This body of work is dedicated to those in my life who have made a difference, kept me motivated, and to those who have loved and supported me. First and foremost, I dedicate this work to my father, who inspired me to desire learning and to ask questions. He who rose from the ashes, a kindred spirit forever, my macushla. To my mother, who also pursued learning and encouraged me to fight for a cause. She taught me to work hard and make the best with what you have. To my sister, Alysun, who said, “you have to finish, you’re so close…just do it”.

And for those closest to me - to my husband, Terrance Patrick, who has supported and encouraged me to hurdle obstacles and meet the challenges that life brings. You are kind and have always loved unconditionally. And to my son, Joshua Patrick, who is wise beyond his years. You are sarcastic and have a wicked sense of humor. To you I encourage to live your dreams, never give up, and go the distance.

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Contributors

This work was supervised by a dissertation committee consisting of Dr. Kristi Shryock, Committee Chair, Department of Aerospace Engineering and Department of Multidisciplinary Engineering; Dr. Karen Butler-Purry, Committee Member, Department of Electrical Engineering; Dr. Dilma Da Silva, Committee Member, Department of Computer Science and Engineering; and Dr. Timothy Scott, Committee Member, Department of Biology.

All work conducted for this dissertation was completed by the student independently. The student acknowledges the efforts and contributions for the project team members themselves, as their active engagement was an important contribution to the pursuit of this work and the completion of this dissertation as a whole.

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NOMENCLATURE

AAUW	American Association of University Women
AERN	Architectural Engineering Major
AERO	Aerospace Engineering Major
ANOVA	Analysis of Variance
AUV	Autonomous Underwater Vehicle
BAEN	Biological and Agricultural Engineering Major
BMEN	Biomedical Engineering Major
CECN	Computer Engineering Major
CEEN	Computer Engineering Electrical Major
CHEN	Chemical Engineering Major
CLEN	College of Engineering General Major
CLM	Causal Loop Model
COE	College of Engineering
Covariate	Characteristics of the participants of an experiment, excluding the actual treatment (Ott, 2016).
CPSC	Computer Science Major
CSCE	Computer Science and Engineering Department
CVEN	Civil Engineering Major
ECEN	Electrical and Computer Engineering Department
ELEN	Electrical Engineering Major
ENGE	General Engineering Designation

Error	Measure of the estimated difference between the observed or calculated value of a quantity and its true value; difference between actual and expected output; failure of a planned action to achieve a desired outcome (Proctor, 2018). For this dissertation, error relates to external factors that lead to gaps in participation of women in various environments.
ESET	Electrical Systems Engineering Technology Major
ETID	Engineering Technology and Industrial Distribution Department
EVEN	Environmental Engineering Major
Failure	Lack of success, deficiency, or action or state of not functioning. Inability of a system or component to perform required function according to its specification (Proctor, 2018). For the purpose of this dissertation, failure relates to internal factors that lead to gaps in participation of women.
Fault	Displacement or discontinuity resulting from fracture between components; condition that causes failure to perform a required function (Proctor, 2018). For the purpose of this dissertation, fault relates to external system factors that lead to gaps in participation of women.
FGEn	First-generation student; students whose parents or grandparents did not attend college and they are first in their family to attend.
IDIS	Industrial Distribution Major

ISEN	Industrial and Systems Engineering
ITDE	Interdisciplinary Engineering
MMET	Manufacturing and Mechanical Engineering Technology Major
MXET	Multidisciplinary Engineering Technology Major
MEEN	Mechanical Engineering Major
MSEN	Materials Science and Engineering Major
NAE	National Academy of Engineering
Non-traditional	Engineering majors that are the least sought out by women and underrepresented populations including mechanical engineering, electrical engineering, and computer science.
NRC	National Research Council
NSF	National Science Foundation
NUEN	Nuclear Engineering Major
OCEN	Ocean Engineering Major
PETE	Petroleum Engineering Major
Recruitment	For the purpose of this dissertation, recruitment is defined as students who have had at least one interaction with a project team discussed in the dissertation and intend to join that project team at the institution where the study took place.

Retention	For the purpose of this dissertation, retention is defined as the number of students who actively engage in at least one project team for a period of at least one semester at the institution where the study took place.
SAE	Society of Automotive Engineers
STEM	Science, Technology, Engineering and Mathematics
Success	For the purpose of this dissertation, success is defined as those students who self-select engineering at the institution where the study took place and persist in engineering majors until graduation or, those who are still active in engineering at the time of the study.
TEAB	Blinn-Team Co-enrolled Cohort with Two-Year Institution
VEX U	University division of VEX robotics
WE	Women in Engineering

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CHAPTER I

1.0 INTRODUCTION

Since the early 1990's, the lack of women pursuing engineering degrees and careers in male-dominated fields has been of interest. Current workforce trends indicate that women working in engineering occupations has increased from 3% in 1970 to 15% in 2019 (US Census Bureau, 2021). Though progress has been made, women continue to remain underrepresented in science, technology, engineering, and math (STEM)-related fields. Less than a decade ago, comprehensive reports from the National Science Foundation (NSF), National Academy of Engineering (NAE), and National Research Council (NRC) indicated a steep decline in the number of students pursuing careers in STEM (NSF, 2010; NAE, 2016; National Academies, 2016). In turn, this has affected the US STEM workforce and our ability to innovate and remain competitive. Experts have concluded that the future economic well-being of our nation will largely depend upon the training of young students within these disciplines and will center upon their ability to be globally competitive with engineers from developing nations (Friedman, 2005; Kenney & Dossani, 2005).

In addition, leaders of major U.S. technology firms have cited the state of K–12 education as a major barrier to filling jobs in the United States (Kenney & Dossani, 2005). Despite current educational trends, it is clear that efforts must be implemented to attract and retain students in critical areas, including STEM. In addition, it is essential that STEM efforts include activities that appeal to traditionally underrepresented students to increase the pool of diverse professionals entering the workforce.

Though the author recognizes K-12 education is of concern, university-level support to retain women and underrepresented students, especially those who self-select engineering majors, is critical. From 1998 to 2018, bachelor's degrees awarded to women in engineering have only slightly increased from 18.61% to 22.2%, respectively (National Center for Science and Engineering Statistics, 2021). Currently, women represent 23.9% of the overall undergraduate engineering population in universities across the US (American Society for Engineering Education, 2021). Disaggregated by gender *with* ethnicity, the percentage of US women in engineering from traditionally underrepresented populations are constituted by Black or African American (1.32%), Hispanic (3.21%), Native American (.07%), Multiracial (10.65%) and White (11.33%). The disparity in overall participation of women in engineering disciplines leads to issues with retention and persistence, as well as inequity in the percentage of degrees awarded. In 2019, the number of undergraduate degrees awarded to women was 22.5% (American Society for Engineering Education, 2021).

Further, many female students continue to be underrepresented in certain disciplines within engineering that are considered "non-traditional", such as mechanical, electrical, and computer science majors (Hill, Corbett, & St. Rose, 2010). For the past decade, US engineering graduation rates for women pursuing mechanical engineering, electrical engineering and computer science have stagnated at 12 - 13% (American Society for Engineering Education, 2021). This low percentage has led to disparity in the workforce, with women currently constituting only 13% of all employed mechanical engineers, 11.1% of electrical engineers (Zippia Career Statistics, 2020) and represent approximately a quarter of workers in computer-related jobs (26%) (US Census Bureau, 2021).

1.1 Contributing Factors for Underrepresentation

With an interest to increase the number of underrepresented students entering engineering majors, universities have developed targeted efforts and interventions. These efforts/interventions have centered on community building (Cairncross et al, 2015; Davis & Finelli, 2007; Dell et al, 2009; Richardson & Dantzler, 2002), remedies for academic conceptual deficiencies (Medina, Gerson, & Sorby 1998; Sorby & Baartmans, 2000; Strong & Smith, 2001), and leadership (McCullough, 2011; Billing & Alvesson, 1989; Dugan et al, 2013). Engineering education research to assess interventions has shed light on multiple contributing factors. Three factors related to this research study include internal factors (identity, stereotype threat, risk-taking), external factors (engineering climate), and availability of opportunities (hands-on, extracurricular). These theories will be briefly discussed in the following sections as they relate to the overall premise of the research. It is important that the complexity of this issue is conveyed as recruitment, retention, and persistence of women and underrepresented students in the engineering profession has yet to be fully understood.

1.1.1 Internal Factors (identity, stereotype threat, risk-taking)

There are many theories and models, coupled with decades of research, that explore internal aspects of underrepresented populations and STEM. The development of internal perceptions and one's own beliefs are explored throughout the literature. However, for the purpose of this dissertation, a few select theories will be discussed.

Further information and the evolution of these theories/models can be found through longitudinal research studies conducted by organizations. A few comprehensive resources include, the National Alliance for Partnerships in Equity (NAPE) reports, such as *CTE and STEM Root Causes and Strategies* (2009), the American Association for University Women (AAUW) reports, such as *Why So Few?* (Hill, Corbett, & St. Rose, 2010), and national reports, such as *STEMMING the TIDE: Why Women Leave Engineering* (Fouad & Singh, 2011). These resources, among others, are a standard for diversity and inclusion practices in engineering and will be briefly included throughout the research study to understand women on competitive engineering project teams.

1.1.1.1 Engineering Identity Theory Overview

Engineering identity is an area that requires further examination within the context of this dissertation. The purpose of including engineering identity as a separate schema of influence is to understand the development of techniques to support underrepresented populations. This dissertation explores how the development of engineering identity can successfully overcome internal and external constraints within the engineering academic environment, especially for women involved in competitive engineering project teams.

As widely adopted in the engineering community, Gee's (2001) external and internal frame of reference for identity has formed the basis for engineering identity theory overall. Science identity and multiple identity theory (Carlone & Johnson, 2007) have been integrated with physics identity models (Hazari et al, 2010). However, the current body of research has theoretically equated engineering identity with 1) academic success or 2) identity to the profession of engineering itself. For research studies that discuss engineering as a professional endeavor, engineering professional identity has been coupled with participation in service learning (Dukhan, Schumack, & Daniels, 2008), personal interests and family (Eliot, Turns, & Xu, 2008), and level of commitment (Chacra et al, 2008; Foor & Walden, 2009).

Within the literature, professional identity has been equated to a gendered experience for men (Rubineau, 2007), with women's identity related to an ability to assimilate to male-dominated cultural environments (Martin & Barnard, 2013; Powell, Bagilhole, & Dainty, 2009). Several studies from the identity literature also examine how professional identity impacts recruitment, retention and preparation (Pierrakos et al, 2009). Though disjointed, engineering identity research has explored the intersectionality of multiple identity factors in professional and academic contexts (Matusovich et al, 2011; Eliot & Turns, 2011; Cass et al, 2011). However, few researchers have explored a relational understanding between factors, or the impact of multiple factors, on the engineering student's identity as a whole.

Within the context of this research, several factors that underlie engineering identity development are explored. Comparison of these factors for women who participate on competitive engineering project teams and non-participants will provide insights to differences in student development and persistence.

1.1.1.2 Stereotype Threat Theory

Though engineering identity is a focus of this dissertation, stereotype threat is a theory that underlies the development of engineering identity for women in professional settings. According to Steele and Aronson (1995), stereotype threat is described as the perception that marginalized groups are "at risk" of representing a negative societal stereotype. Though research in this area has centered on gender differences and math ability (Aronson et al, 1999; Benbow & Stanley, 1980; Pavlova et al, 2014; Steele, 1997; Stoet & Geary, 2012), researchers have explored the effects of stereotype threat on women's performance (Schmader, Johns, & Forbes, 2008), especially when performing visual spatial tasks (Wraga et al, 2006). The body of research also explores individual susceptibility to stereotype threat when subjects proport a strong identity to their social or ethnic group (Davis, Aronson, & Salinas, 2006; Marx, Stapel, & Muller, 2005; Schmader, 2002) and the level to which they value that identity (Appel, Kronberger, & Aronson, 2011; Pavlova et al, 2014; Steele, 1997; Stone, 2002;).

Stereotype threat in male-dominated environments can be attributed to hypervisibility in classroom spaces through peer interactions (Tuitt & Carter, 2008) or invisibility in the context of group projects (Meadows & Sekaquaptewa, 2011), especially for women of color in predominantly white institutions (Neil-Jackson, 2020; Robinson, Esquibel, & Rich, 2013). Though a few studies exist, little research has been conducted to address women of color at the undergraduate level. In theory, many marginalized groups are subject to conform or assimilate to prevailing dominant standards at academic institutions (Solorzano & Bernal, 2001). With assimilation, an underrepresented individual's motivation and performance are found to be impacted within environments under high stereotype threat conditions (Beaton et al, 2009; Cadinu et al, 2003; Leyens et al, 2000; Rosenthal, Crisp, & Suen, 2007; Sekaquaptewa &

Thompson, 2003). For many, the experience translates into the development of anxiety and depression when performing in academic settings (Townsend et al, 2011) and may evoke a negative physiological response (Osborne, 2006).

Though stereotype threat is a relevant theory needed to understand engineering identity formation, there is an absence of research that correlates this theory with undergraduate women participating in extracurricular and competitive engineering project teams. This is an area that warrants further investigation.

1.1.1.3 Risk-Taking Theory

Within the literature, risk-taking theories for women in engineering environments and career choice are briefly discussed. Competition and individualism are two concepts that are intertwined however, they will not be discussed within the context of this dissertation. Experiments show that women are less likely to take risks (risk averse) than men (Bertrand, Ashenfelter, & Card, 2011; Croson & Gneezy, 2009; Gneezy, Niederle, & Rustichini, 2003; Niederle & Vesterlund, 2007). Further, women have been shown to perform equally as well as men in single-sex settings, however, men outperform women when placed in competitive settings (Gneezy, Niederle, & Rustichini, 2003). Researchers have also found that women take fewer economic, physical and intellectual risks (Byrnes, Miller, & Schafer, 1999; Croson & Gneezy, 2009; Eriksson & Simpson, 2010; Jianakoplos & Bernasek, 1998). There are also other intrinsic attributes that may provide insights to gender differences in risk-taking (Eriksson & Simpson, 2010; Fisk, 2016; Fisk, Miller, & Overton, 2017; Nelson, 2015; Scotchmer, 2008) however, these may not fully explain engineering environments.

Within marginalized populations, external schemas and stereotypes often translate into internal schemas. For instance, women have been shown to self-assess lower than men of equal ability in performing male-typed tasks (Correll, 2004). Research has shown that personal belief about success highly influences risk-taking behavior (Krueger & Dickson, 1994) therefore, the lack of women present on male-dominated competitive engineering project teams may be relative to their belief about their success on those teams. These theories inevitably circle back to the concept of stereotype threat and how women decrease their risk-taking when performing under male-dominated environmental conditions (Carr & Steele, 2010). Risk-taking while engaging under single-sex and mixed project team conditions also warrants further investigation, especially through the lens of environmental conditions prevalent or absent under either condition.

1.1.2 External Factors (engineering climate)

Beyond elements that underlie internal perceptions, external factors, such as the engineering environment and climate, have also been shown to influence or deter women. In their groundbreaking report, *STEMming the Tide*, Singh & Fouad (2011, 2013) received survey responses from 3,961 women to explore gaps in the number of women at various stages in their careers. Among their key findings, 1/3 of women surveyed do not enter the engineering profession after earning an engineering degree. Reasons cited were due to their perception engineering was inflexible and the engineering workplace culture was non-supportive to women. Five years after entering an engineering career, women left engineering due to working conditions, low salary, lack of advancement, and other reasons (Singh et al, 2013). For women currently in the engineering field and who stayed longer than 10 years, this study showed the importance of key supportive advocates (supervisors and coworkers) who recognized and valued their contributions. Therefore, the common thread of key findings for each cohort revealed that environment and culture played a large role in women's decisions to stay in engineering or leave. The study also mentions that women who left engineering companies or considered leaving their company were *very likely* to leave the field of engineering altogether (Singh et al, 2013).

Engineering itself is a profession however, workplace and academic climates matter to people. Women and underrepresented students bring to the environment different ideas and methods for working. They also bring a set of values and standards that are regularly dismissed by majority populations. Embracing and embedding these values and standards into academic daily practice would enhance academic/work climates and lead to more diversity as a byproduct. One area for further improvement is messaging. Resources have existed through the National Academies of Engineering (NAE) and other organizations for decades (NAE, 2008, 2013; Pearson, 2008; FIRST, 2020) however, they are not known within the engineering educational community. Incorporating key findings (Mills, 2009; NSF, 2009) into the curriculum itself would help to change *inflexible* engineering environments. Training students on how to engage and providing tools for teaming would also enhance engineering academic environments (Melchior et al, 2005; Kirn et al, 2017; Layton, Ohland, & Pomeranz, 2007). Inevitably, this would lead to a more welcoming atmosphere and a greater appreciation for marginalized groups within the engineering cultural climate.

One messaging best practice is to show visual images of women and underrepresented students in laboratory or manufacturing settings. Visual images of women performing hands-on tasks has shown to increase representation in traditionally male-dominated fields (Kerkhoven et al, 2016; Rosenberg-Kima et al, 2008; Leathwood, 2013). In addition, participation in hands-on learning has been shown to increase confidence and ability in young, underrepresented students yet, limited opportunities exist outside of the classroom at the collegiate level. Once women decide to pursue engineering, there are retention gaps seen in the first two years of college. Primarily, women are subject to assimilate to educational norms that are difficult to dismantle in engineering (Polmear et al, 2018; Bejerano & Bartosh, 2015; Fromm, 2003; Kramer-Koehler, Tooney, & Beke, 1995; Seymour & Hewitt, 1997). Gendered narratives and norms underlie many of the subject areas in the first two years of the engineering curriculum (Danielsson, 2014; Tonso, 1996). For people of color, the presence of racialized narratives (Nasir & Shah, 2011) regarding math ability and perception of lowered standards (Ceglie, 2011) often impact student experiences of belonging and persistence (Seymour & Hunter, 2019; Wee et al, 2011). In fact, documents written in the late 1990's still are relevant to discussions about why students leave engineering and what can be done (Seymour & Hewitt, 1997).

As an educational standard practice, the majority of engineering coursework in the first and second year are courses in math, chemistry, and physics. These courses are traditionally taught, with lectures and examinations, with little to no connection to engineering or application. Though freshmen introductory engineering courses with hands-on application are implemented at some universities (Richardson et al, 1998; Dally & Zhang, 1993), students are often forced to find other educational outlets to practice the engineering profession. One outlet is participating in extracurricular activities, especially those that assist to develop technical skills through hands-on learning and competitive engineering project teams.

1.1.3 Availability of Opportunities (hands-on, extracurricular)

Within engineering undergraduate communities, a wealth of opportunities for hands-on learning and developing engineering skill sets through participation on competitive engineering projects teams exists. The types of teams involved in this discussion are purely extracurricular and voluntary however, some have been integrated into senior capstone design projects (Laguette, 2007; Paulik & Krishnan, 2001; White, McKisson, & Barott, 2007). Many engineering colleges support these teams at a minimal level and rely heavily on student interest and persistence to keep the teams active from year-to-year. Though these teams exist, they are usually made up of majority male members with the participation of women scant or non-existent. Research on engineering project teams at a collegiate level has not necessarily been a focus for engineering education. However, this type of research could give insight into *errors*, *faults* and *failures* within the engineering educational system that affect the development of engineering identity. These ideas will be explored further in Chapter V within the context of this dissertation.

1.2 All-Female Cohorts on Engineering Project Teams

[Section 1.2 contains information originally presented at the 2016 American Society of Engineering Education Conference and Exposition and is reprinted with permission (copyright 2016, ASEE)]. The majority of research on project teams has been conducted at the K-12 level. One area that can be identified and examined for the success of underrepresented students is through Project Lead the Way (PLTW), a national organization that provides learning experiences for preK-12 students and teachers (Fletcher, 2016). This organization provides training and development with hands-on curriculum to develop STEM skills through real-world learning (PLTW, 2021). Recently, several all-female cohorts have been created in Ohio, Georgia, Florida, Alaska and Texas (PLTW, 2012, 2014; Cahill, 2012). Though not widely known, these efforts have been enlisted to significantly increase the number of women entering IED and Electronics courses through PLTW.

In 2011, a partnership between Hilliard Davidson High School in Worthington, OH and the Women in Engineering (WiE) Program at The Ohio State University (OSU) was initiated. Originally, a male math and PLTW teacher was concerned about participation of only two female students in his entire PLTW four-year program. With research-based practices, the Women in Engineering Program suggested that an all-female cohort be piloted for freshman through senior women to get them engaged. With support from the administration, an all-female Introduction to Engineering Design (IED) course called "WiE IED" was offered in Fall 2011. Support from the university was minimal as female engineering students visited the classroom about five times per year.

One of the first events included recruitment from the feeder middle school to bring interested students to the high school campus for a ½ day program. Five OSU engineering student volunteers and the Interim WiE Director assisted the school to create an interactive, hands-on experience with PLTW high school students. The results were positive, and 18 students enrolled in the course. The next year, the program had 30 students enrolled in their PLTW all-female cohort (Fletcher, 2016; Cahill, 2012). By the third semester, the all-female IED course had a waitlist and students were continuing with other PLTW courses. A video was produced and launched on the PLTW national website, with the teacher, current students, former PLTW participants and program administrators from Ohio State.

Due to the success of the Hilliard Davidson group, Alaska's Dimond High School PLTW initiated a similar program. "Smart Girls Rock" increased their PLTW participation from 13% to nearly 35% with a 50-50 split in their Digital Electronics course (Pike & Robbins, 2014). Gulliver Academy Middle School in Coral Cable, FL also showed a significant increase in the number of females in their PLTW courses after opening an all-girls section of IED. Jefferson High School in Cedar Rapids, Iowa also formed the Society of Women Exploring Engineering and Technology (SWEET) to keep girls already studying engineering engaged (Walcerz, 2007; Cahill, 2012). Across the PLTW community, with support from their administration, schools have been offering all-female PLTW cohort classes with great success. However, one question remains, if IED and PLTW courses aren't appealing to females, why do they have as much success when offered as all-female cohorts?

1.3 Case for Single-Sex Interventions

[Section 1.3 contains information that was originally presented at the 2016 American Society of Engineering Education Conference and Exposition and is reprinted with permission (copyright 2016, ASEE)]. There are many reasons why women do not automatically enroll in engineering and technology courses. The absence of role-models, coupled with feelings of isolation, social bias, classroom and environment, and male-dominated teaching methodology are a few (Hughes, Nzekwe, & Molyneaux, 2013). PLTW-specific studies have found that female students in PLTW IED courses lack parental support as well as support from peers and school administrators (Schultz, 2011). Qualitative studies indicate that inequitable classroom interactions, coupled with gender-biased instructional methodologies, deter female students from pursuing engineering career paths. When women are enrolled in single-sex programs or all-girl schools, the results are dramatically different.

In Australia, 40% of the University of Technology, Sydney (UTS) female engineering students previously attended single-sex secondary schools (Tully & Jacobs, 2010). The study found that female students were primarily motivated to pursue engineering due to their self-efficacy in math and females consistently outscored their male counterparts in measures of self-perception of skill and ability in mathematics. They also found that female students benefited from verbal encouragement, single-sex problem-solving groups, engineering problems that were embedded in context, and single-sex classroom dynamics (Tully & Jacobs, 2010).

Development of identity as an engineer for females pursing engineering is important (Hughes, Nzekwe, & Molyneaux, 2013; Wee et al, 2011; Rosenthal et al, 2011). In multiple studies, support from single-sex programs enhanced female engineering students' sense of belonging in their major and the university in their first year (Rosenthal et al, 2011). Single-sex efforts are also found to increase and impact retention of women in STEM. Findings suggest a direct correlation between single-sex programs and identity compatibility for college women in STEM majors (Hughes, Nzekwe, & Molyneaux, 2013; Rosenthal et al, 2011). When stereotype-threat conditions were introduced to male and female students taking math tests, female students from single-sex educational institutions consistently performed higher than their male counterparts. In addition, females from single-sex educational systems outperformed their male and female co-educational counterparts on standardized math or physics tests (Cherney & Campbell, 2011). It was found that girls from single-sex schools had higher intrinsic motivation and self-esteem. The evidence is clear, these factors are important to girls' self-efficacy and self-concept of their math ability, which in turn, affects their educational and career choices (Cherney & Campbell, 2011).

It is important to note the abundance of research that exists on women in engineering majors and self-efficacy (Rosenthal et al, 2011; Cherney & Campbell, 2011; Backer & Halualani, 2012; Marra et al, 2009; Hutchison et al, 2006). However, the abundance of research is usually performed by studying mixed-sex teams, where female and underrepresented students exist in small numbers. The effect of being overpowered has significant effects on university-level students' confidence, identity, self-efficacy, and persistence. Several studies used the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) instrument (Backer & Halualani, 2012; Marra et al, 2009). Overall, women and underrepresented students were found to perceive a “lack of inclusion” in engineering environments. This result was thought to be attributed to negative social cues by fellow students and faculty (Marra et al, 2009; Hutchison, 2006).

Studies on mixed-gendered teams in freshman engineering courses also show that females experience isolation and take on stereotypical roles during projects and team presentations (Felder et al, 1995; Meadows & Sekaquaptewa, 2011, 2013). In one study, males were found to take on more active, technical roles and had better outcomes than their female counterparts (Meadows & Sekaquaptewa, 2013). On equal and male-dominated teams, male students were more likely to answer technical questions and appear more knowledgeable (Ball et al, 2005). Females were found to perform better when on all-female groups or when paired with other females than when they participated in mixed-gendered or male-dominated teams (Meadows & Sekaquaptewa, 2011). While literature suggests creating a team gender balance can improve student performance, the evidence supports that gender balance is not enough to overcome stereotypical team-role adoption (US Department of Education, 2015; Frehill, Benton-Speyers, & Cannavale, 2004; National Women’s Law Center, 2012; Rolison, 2003).

1.4 Research Overview

1.4.1 Summary

The purpose of this study was to evaluate women's participation on competitive engineering project teams and if participation leads to a significant increase in engineering identity development in comparison with other females in engineering. Further, the research study seeks to understand if a significant increase in enrollment exists for non-traditional engineering majors for female students who participate on these teams. Data was analyzed to discern overall experiences and success rates, including overall graduation, major choice, and persistence between team participants in comparison to the general college of engineering population and national statistics. Cohorts were disaggregated for further understanding for the experience of first-generation (FGEn) and traditionally underrepresented women of color populations. Results were used to formulate a model for recruitment and retention of women on competitive engineering project teams by developing a Causal Loop Model and Event Tree Analysis. The model uses Erikson's Eight Stages of Psychosocial Development with *error, fault* and *failure* analysis as theoretical frameworks. The models are coupled with engineering identity theory to provide an understanding of women's participation on engineering project teams and a context to formulate a model for future success.

1.4.2 Purpose

The purpose of this study was to evaluate if participation on competitive women in engineering project teams significantly leads to an increase in student identity to become an engineer as well as increased enrollment in non-traditional majors of interest.

1.4.3 Objectives

- to test the hypothesis that participation in single-sex competitive engineering project teams (CEPT) increases engineering identity
- to understand the relationship between engineering identity development in project team participants and non-participants
- to understand if experience on competitive project teams is related to persistence in engineering for women
- to determine if there are differences in overall experience within the engineering academic environment for CEPT participants and non-participants

1.4.4 Significance

The significance of the study is that women's participation on competitive engineering project teams is rare. This study takes place at a large, Research I university with a program that has fostered an environment for a significantly large number of women to participate in hands-on competitive engineering project teams. These teams are student led and student driven. With the overall number of women in engineering at the university, the researcher has gathered and analyzed data from a large sample size and had an ability to compare women participating in hands-on learning with non-participating engineering students. A systems approach was implemented to determine factors that contribute to success as well as *error*, *fault*, and *failure* analysis within the engineering environment. Statistical analysis was implemented to determine the strength of engineering identity development in project team populations. This information was used to formulate conclusions regarding underrepresented and first-generation (FGEn) populations and develop a framework for women's success.

1.4.5 Benefits to Research

There are multiple benefits to understand the development of identity in female engineering students through participation on competitive engineering project teams. Information gained in this study can give insights to develop strategies for student persistence and retention. The study also provides information regarding how underrepresented students perceive themselves and whether engineering culture is a significant factor (defined as *error*, *fault*, or *failure*) in their overall experience. There are many reports that discuss engineering culture and why female students do not pursue engineering as a career because of their experience with peers and faculty in engineering colleges (Fouad & Singh, 2011; Singh et al, 2013). This study assists to fill gaps in knowledge for the benefit of transforming engineering environments in academic and industrial settings.

To date, formidable studies in student success have not applied identity theory, especially to determine causal factors for participation and non-participation in voluntary, extracurricular competitive engineering project teams. This is a significant study that informs the body of work surrounding engineering identity theory and creates awareness for methods that increase student success.

CHAPTER II

2.0 LITERATURE REVIEW

2.1 Abstract

For two decades, a growing body of research surrounding engineering identity has emerged as an indicator for interest and persistence in engineering. The purpose of this systematic literature review is to identify the scope of work regarding the development of engineering identity as a concept, specifically within undergraduate student populations in higher education. This literature review also provides a special focus on studies that examine underrepresented populations and their ability to navigate multiple identities within engineering enculturated environments. The literature review concluded that research on engineering identity can improve by 1) adopting uniformity across terms and factors that are easily identified; 2) recognizing, understanding and building upon the depth and breadth of research pursued by disciplines other than engineering; 3) correlating engineering identity factors with student success and retention; 4) providing valid measurement instruments specific to engineering identity; and 5) incorporating a standard for robust measures, including control or comparison groups, to inform a greater understanding of engineering identity development. Gaps in literature and recommendations for future research are discussed.

2.2 Introduction

To examine student success factors, research on identity and STEM identity has emerged in multiple disciplines. In psychology and education, identity theory has evolved to reveal three accepted identity style types: diffuse-avoidant, normative, and informational (Berzonsky, 1992; Trede, Macklin, & Bridges, 2012). These identity styles have been used by educational researchers to predict student academic success rates (Adams et al, 2001), especially while transitioning to university settings (Berzonsky & Kuk, 2000). Though these identity styles are widely accepted, engineering identity has grown roots mainly from STEM identity models. STEM identity is understood to contain both internal and external components. This theory includes an individual's ability to identify with STEM and the ability of the larger STEM domain to recognize the individual as a member of their community (Gee, 2001; Stevens et al, 2008). One of the issues with STEM identity models is that researchers are undecided upon defined characteristics that constitute identity and ways to translate these characteristics into valid identity measurement instruments (Carlone, 2017). Consequently, many studies have linked engineering identity to the development of academic identity, especially an affinity towards core subjects such as, math identity (Cribbs et al, 2015; Renninger, Nieswandt, & Hidi, 2015) and physics identity (Hazari et al, 2010). By defining identity solely on academic competence/performance, interest, and recognition; STEM identity models have often excluded the overarching experience of underrepresented populations, including women and women of color (Carlone & Johnson, 2007).

Researchers have only begun to understand the complexity that underlies STEM identity for marginalized populations. This complexity includes intersectionality between multiple identities such as, gender, ethnicity, ability, and socio-economic status (Carlone & Johnson, 2007). Gaps that exist for underrepresented populations include, a comprehensive understanding of connections between internal identity, social identity and the external culture (engineering and other), and models for the underlying complexity within each context (Tate & Linn, 2005). Therefore, for engineering identity to emerge as a holistic theory, defining factors that underlie core identity, coupled with techniques that grow academic and professional identity within underrepresented populations in engineering are crucial research areas.

The purpose of this literature review is to differentiate engineering identity from other disciplinary identities and acknowledge more prevalent research emerging to clarify engineering identity as a singular concept. Examining research that defines engineering identity will assist to expose prevalent themes and provide an idea for future directions in engineering educational research. For clarity, it is important to mention that engineering identity theory is often overlapped, coupled, and confused with other constructs including, self-efficacy, growth-mindset, and grit. While this terminology is accepted throughout engineering educational communities, this literature review will seek evidence for, and use terminology that pertains to, academic persistence and retention. As an added condition, literature focusing on underrepresented populations was deliberately identified.

For the purpose of this review, the term underrepresented is used throughout to indicate students who are not represented in engineering at the same rate as local, statewide, or national population percentages. Reference to underrepresented students in this review specifically indicates women and women of color (i.e.: African American, Hispanic, Latina, Native American), unless otherwise specified.

2.3 Lit Review Research Questions

The systematic literature review and discussion are driven by specific research questions. Though questions served to navigate the engineering education literature, it is acknowledged that the process for the review was not based upon grounded theory (Bryant & Charmaz, 2007). Therefore, references cited do not encompass all research in this area. In addition, due to the particular focus on underrepresented populations, several studies were deliberately excluded that may have provided a broader definition of engineering identity development or other insights. Methods that outline criteria for inclusion are detailed in section 2.4 (Methods). This systematic literature review was guided by the following research questions:

a) What studies have emerged that conceptualize engineering identity as a singular concept?

b) What factors have been linked to engineering identity development, specifically in women and underrepresented populations?

c) Is the literature on engineering identity correlated to student success and retention?

d) Do valid measurement instruments exist that are specific to engineering identity?

e) How are engineering identity studies conducted and are there recommendations for improvement?

2.4 Methods

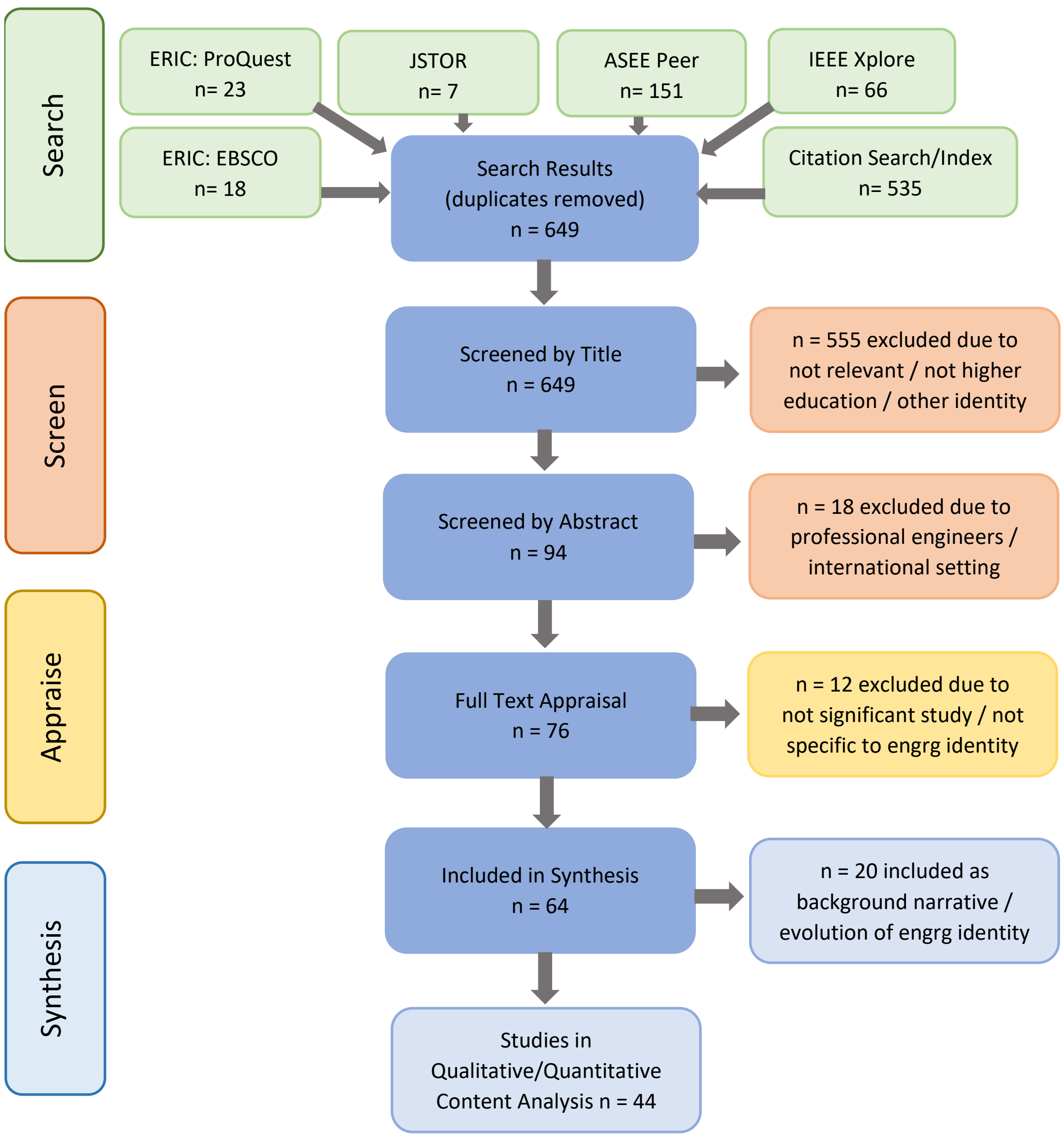
The following sections describe methodology used to synthesize the systematic literature review and iterative process to obtain scholarly works and examine research.

2.4.1 Framework

Framework for the systematic literature review was primarily informed by Borrego, Foster et al. (2014). Relevant to engineering education, Borrego, Foster, and Froyd (2014) argued that seminal publications, important works that provide new insights and research directions, could be better informed by systematic reviews that utilize interdisciplinary sources. Systematic reviews differ from other literature reviews by offering a process that can be replicated and is highly documented. In this literature review, a scoping review (Sucharew & Macaluso, 2019) was first implemented to assess the breadth of multidisciplinary research performed over four decades. Due to the number of sources initially found on ERIC via ProQuest (24,913), a systematic review process was applied to narrow sources for relevance (Munn et al, 2018). Within this iterative process, the search-screen-appraise-synthesis method was implemented to provide a comprehensive search and identify literature that specifically focused on research questions of interest (Borrego, Foster, & Froyd, 2014). Further, systematic reviews that are "state-of-the-art" contain four types of complimentary methodologies: search (retrieval), selection (apply criteria), coding (quality evaluation), and synthesis (analyze results) to further refine results (Borrego, Foster, & Froyd, 2015).

Qualitative content analysis was applied to identify research themes and to understand borrowed elements from identity instruments in other fields to develop separate instruments within engineering education over time. Finally, citation searching or citation indexing (Klavans & Bovack, 2017) was employed to further identify research frequently referenced by authors performing larger, longitudinal studies within engineering education. As described in subsequent sections, multiple criteria were applied at each step to determine the quality and relevance of individual scholarly works. Figure 1 represents the overall framework and process for the systematic literature review. The following sections describe that process in detail.

Figure 2.1 Flowchart for Systematic Review Process



2.4.2 Search

2.4.2.1 Databases, Refined Terms

Scoping was used as a primary technique to probe databases, narrow specific search terms, and survey multidisciplinary literature to encompass engineering identity as a topic. Initially, search results on ERIC via ProQuest revealed over 24,900 (24,913) sources relevant to identity (only) and showed to be too comprehensive. After scoping, search terms and databases were refined to include only those most relevant to engineering and engineering education. At this stage, it was observed that researchers from multiple disciplines used convoluted terminology (different language) to describe "engineering identity" as well as relate engineering identity to specific theories or concepts within those disciplines. Given that engineering identity is a burgeoning concept, further work was done to eliminate complexity and look for salient themes that appeared across the engineering literature when addressing identity. For this review, the final search terms were: "identity" AND "engineering". More refined search terms included "women", "women of color", "underrepresented" and "NOT STEM". Databases used in the search:

a) ERIC via ProQuest

b) ERIC | EBSCO

c) JSTOR

d) ASEE peer

e) IEEE Xplore

It should be noted that after citation searching/indexing was performed, references were gathered in additional databases as they did not appear as complete works in the databases listed above. Other databases/search engines used were:

f) ResearchGate

g) Academia

h) Google Scholar

i) Wiley online library

2.4.2.2 Criteria and Inclusion

To narrow the scope of the study, search criteria were used to further focus topics and provide viable references. As a common research practice, sources were restricted to those that were full text, peer reviewed, and written in English (Cooper et al, 2018). Therefore, the majority of sources were found in Journal publications and/or conference presentations, with a significant number of studies presented as conference papers within the past five years. While testing search criteria, the year of publication was initially restricted from 2010 to February 2020. However, the final list of literature reviewed contains up to 20 references written prior to 2010. These sources were included as they provided relevant information and a historical context for the evolution of engineering identity and measurement instruments. Two book titles were also included as references due to their numerous mentions by authors in current engineering identity literature. It should be noted that though books and book chapters are included in this literature review, full texts were not retrieved or reviewed in this study.

2.4.2.3 Exceptions

After the initial search, it was recognized that the search criteria were too narrow. Further data mining found well-published authors in this area or studies mentioned by multiple engineering educators. Citation searching/indexing was used to find significant studies or commonly cited references that could also be included for the purpose of this literature review. This process stage used modified criteria from scoping but yielded several cross-referenced sources. Exceptions to the search criteria were made to reveal sources that did not contain "engineering identity" in the title and were either 1) mentioned by multiple authors; 2) significant studies; 3) notable book references from well-known authors in fields other than engineering; 4) contained more complete definitions of identity and development of identity theory; and 5) included a close variation to "engineering identity" as a search term (ie: "engineer identity" and "engineering identities"). Other descriptors found that were included (not limited to) were: "affect", "agency", "belonging", "communities of practice", "gendered identities", "multiple identities", "representation", "self-efficacy", "self-presentation", "self-concept", "social norms", etc.

After searching databases and expanding criteria for inclusion with citation searching/indexing, 649 references were found. These references were further narrowed by performing the next steps.

2.5 Screen

For a reference to be included, the study population had to specify undergraduate students in higher education, attending US institutions. By applying these criteria, approximately 32 studies were eliminated as they focused on K-12 populations or professional engineers. Preliminary screening indicated the most relevant articles included titles containing “engineering” and “engineering WITH identity” as a specific study focus. In addition, the reference had to fit within one of the parameters specified by the research questions. To reiterate, research questions may be paraphrased as: a) was the study specific to engineering identity?, b) was the data disaggregated and contain noted differences for women and underrepresented populations?, c) were the studies in anyway correlated to student retention at their particular institution?, d) were researchers using a validated measurement instrument?

During this stage, article titles and abstracts were reviewed for relevant study subjects and academic environments. Of the 649 references, 555 were excluded due to irrelevant study focus, or not relevant in higher educational contexts. It was noted that many of the references eliminated in this phase were qualitative studies conducted by researchers in other disciplines that gave a historical basis or context for defining engineering identity. Though these may have been viable sources of information, they were eliminated during the screening stage to remain focused on the research questions at hand.

Of the 94 abstracts that were reviewed, 18 were eliminated due to study subjects consisting of either professional engineers or the study was conducted in an international setting (6 total). At this stage, conference papers that were works in progress or did not present a significant research study contribution were also eliminated, including those that described program interventions with small populations of students involved as “engineering identity building activities” (12 total). Though eliminated references may have provided beneficial information, they were not included due to the primary focus of this particular literature review.

2.5.1 Coding and Filtering

To ease the process of reviewing titles and abstracts, an excel spreadsheet was created to provide quick access to the following information:

- Publication year
- Authors / Author contact information
- Title of reference
- Website or citation link / where source found / date found
- Abstract
- Conclusions / Results
- Noteworthy mentions (with page numbers)
- Category Type 1 (ie: Journal Article, Primary Source/website, Book/Publication, Dissertation, Conference Paper)
- Category Type 2 (ie: Research Study, Definition, Report, Literature Review, Identity Scale Instrument)
- Themes for three subject areas (ie: identity types, multiple identities, STEM identity, academic identity, etc.)
- Population studied (number of study participants / gender disaggregated, or no? / Ethnicity disaggregated, or no?) / Additional Themes
- Notes and Categories

At this stage, 76 full articles were retrieved and catalogued into the spreadsheet to provide easy access and an ability to appraise relevant sources. Multiple screening attempts were conducted to ensure that sources included in the full-text appraisal phase were the most significant and relevant. Again, several sources from the citation searching/indexing phase were ambiguous and were retained to be analyzed in the full-text review phase to ensure a comprehensive list of references were obtained. It is important to mention that during the title and abstract review phase, a few articles related to the development of academic identity or identity types were eliminated. Though not specific to engineering identity, a few studies were retained (briefly mentioned) to provide a historical context for engineering identity as a concept and for background to develop valid measurement instruments.

2.6 Appraise

Full texts were retrieved and compiled from a variety of database sources. The majority of references that were conference proceedings were retrieved from ASEE Peer (25) and IEEE Xplore (10). Other journal articles were retrieved from Academia/ResearchGate (12), ERIC: EBSCO (5), JSTOR/JEE (7), SAGE (5), and Google Search/Misc. (12). At this stage, 10 references were eliminated due to not meeting criteria of being specific to engineering identity, convolution of identity with other concept (ie: confusing identity with self-efficacy or other related concept), and other factors including: small populations, authors extremely unaware of previous research, or authors did not build upon previous results.

2.7 Synthesis

2.7.1 Qualitative/Quantitative Content Analysis

A total of 64 studies were included in the synthesis stage and a total of 44 studies were used in qualitative analysis. Twenty (20) references were found to be useful to explain background narrative for the development of engineering identity theory and the evolution of measurement instruments. Many of these references were most likely gleaned during the citation searching/indexing phase. As a primary measure, references were catalogued according to research method used (qualitative, quantitative, mixed) and the instrument used to gather data. The number of subjects in the study was also tracked to indicate the breadth of the study and determine significance.

2.7.2 Coding

During synthesis, 44 studies were categorized and coded according to their research methods. Each text was reviewed and organized research techniques into three distinct categories: qualitative, quantitative, and mixed methods. This stage revealed that the majority of studies included in this literature review contained quantitative methods (24 studies). Further, several quantitative studies included a large number of subjects, with study populations ranging from n=184 to n=6772. It was also observed that many of these large-scale studies occurred across multiple institutions and contained longitudinal information, though not specifically tracked at this stage. Also, the majority of these studies (18/24) have been conducted since 2015 and include much of the work on developing measurement instruments specific to engineering education. Qualitative studies (14) were conducted mostly from 2005 – 2011, with two exceptions. These studies seemed to have a much smaller number of subjects and one study provided a case-study narrative for a single student. Though subject numbers were small and usually were conducted at a single location, these qualitative studies were important in the development of current engineering identity theory. Finally, six (6) studies used a mixed methods approach (qualitative and quantitative). These studies ranged from 2008 – 2019 and contained both small and large number of subjects. Appendix A, Table 1 describes research methods used by each of the studies in the synthesis stage.

To deeper understand study populations and how data was disaggregated, a spreadsheet was created to track the author/year, number of subjects and whether or not data was disaggregated to study populations of interest (FGEn, socio-economic status (SES), gender, race/ethnicity, ability, military, LGBTQ+). This allowed for deeper understanding and an ability to quickly assess gaps in literature and future research directions. Subsequent sections discuss the relevance and importance of studies to disaggregate data and it was observed that although many studies were aware of the need for this type of information, they failed to include disaggregated data in their results. Appendix A, Table 2 describes the populations studied and how/if populations of interest were disaggregated and presented in the final results.

Finally, to track the quality of research findings in engineering educational contexts, studies were examined and coded for their different identity types and themes. Again, a spreadsheet was created that tracked the author/year, number of subjects, and each study was categorized for its concentration on certain identity types (self-perceived identity, academic identity, professional identity, peer/social identity, engineering cultural identity/belonging, and multiple identity). Studies were also examined and categorized for their major themes and findings. As mentioned in the discussion, this clarified how researchers were defining identity and the qualities that they deemed important to develop identity in engineering. Further, categorizations were difficult to determine as studies referred to engineering identity as an all-encompassing term yet, they seemed to refer more specifically to a professional identity or academic identity.

It is important to note that categorization of identity types and themes were constructed on the basis of one person's opinion. Therefore, coding was subject to interpretation and may not be reliable. For a valid systematic literature to have been conducted, it would be important that several individuals evaluate the studies in depth and come to similar conclusions regarding coding and categorizations. Appendix A, Table 3 includes identity types and themes present in the literature examined.

2.8 Limitations

This review is limited for several reasons. First, bias could have been introduced through the concentration of literature from Journal articles and conference presentations. Though these sources were peer-reviewed, the reviews themselves may not have been rigorous. As a novel concept, reviewers in the engineering community may have had a limited scope of knowledge regarding engineering identity and identity theory, in general. It is also noted that this literature review provides limited reference to books, book chapters, and other sources (i.e.: theses or dissertations were not considered). Therefore, the literature review may only provide a superficial understanding of engineering identity and its theoretical basis. Including a wider range of published sources may have provided a deeper understanding for the evolution of engineering identity as a concept, rather than information gleaned solely from journal articles and conference proceedings.

Second, when scanning initial sources and citation searching/indexing, it was observed that authors were not especially versed in the body of research performed by identity theorists in psychology, education, or health/medicine, for example. Also, researchers were not especially aware of well-known, longitudinal and multi-institutional studies from the 1990's that have been conducted to understand persistence and retention issues in underrepresented populations. In addition, disciplines tended to use idiosyncratic language, particular to that discipline, to describe identity characteristics that are similar in multiple fields. Due to the disconnect between research on identity, STEM identity, and engineering identity, engineering identity literature may offer parallel concepts without drawing connections. Therefore, research on engineering identity, as a whole, remains segregated and limited. For the purposes of this literature review, information has been restricted to knowledge gleaned by the engineering educational community and it is recognized that this may not contain the broadest understanding of identity constructs or concepts.

As an added note, the technique of screening by title, prior to screening by Abstract, may have provided limitations for the number and quality of references included in this literature review (Morelock, 2017). Screening for the inclusion of terms, such as "engineering" and "identity", or "engineering identity", may have provided a false representation of studies, especially those specifically dedicated to engineering underrepresented populations. Generally, engineering researchers are concerned with supporting and retaining underrepresented populations. Therefore, studies that focus on underrepresented populations are usually entitled as such to draw special attention to research involving said populations. To clarify, studies may have included valuable information on engineering identity development for underrepresented populations but were missed due to absence of the words, such as “engineering” or “identity” located in their title alone.

Finally, studies conducted on international populations, or written in different languages, were not considered as differences in culture and demographics exist between countries (European, Asian, Scandinavian, or N. American populations including Canada). Though this literature review retains a few references from international populations for the purpose of discussion, it is acknowledged that many of the studies that examine gender differences in engineering contexts are still influenced by cultural nuances that may or may not be present in US universities. Further, cultural differences found within study populations in the US were not considered as part of the study questions at hand. For example, differences in Western-American cultures, Southern-American cultures, Eastern, etc. For the purpose of this literature review, external culture found in US universities was generically framed as “engineering culture” and considered to be understood as uniform across studies and their research subjects.

2.9 Results

This section reviews major findings and provides information on the inclusion of literature to answer specific research questions. There are significant studies that have led to the development of engineering identity, however research depicting identity in other fields was not widely included. Significant works commonly mentioned in the engineering education literature (Hazari et al, 2010; Tonso, 2014; Cribbs et al, 2015) are not included in the results as they did not meet the narrow criteria set for this particular literature review, nor did they meet criteria set for publication type. However, some research studies may be discussed in section 2.10 (Analysis) as they contain information relevant to key discussion points and provide useful conceptual connections.

2.9.1 Literature Reviews, Groundwork for Engineering Identity

There are three notable literature reviews, included as references used for historical purposes (3/20), which are specifically dedicated to engineering identity. The first literature review was presented as a conference paper and provided a broad overview of the development of identity theory in social science (psychology, sociology, anthropology), education, and STEM (math and physics) (Patrick & Borrego, 2016). Two other literature reviews located provide an overview of contributing fields and development of identity in engineering education. Morelock's (2017) systematic review of identity in engineering education (definition, factors, interventions, measurement) and Rodriguez, Lu, & Bartlett's (2018) systematic review of engineering identity in higher education literature. These works are seminal and present a broad understanding for research and groundwork laid to conceptualize engineering identity.

Due to the narrow scope and constraints of this literature review, the author defers to citations located in each previous literature review to provide a more comprehensive understanding of the body of work surrounding identity and STEM identity. Further, literature that pertains to the development of math identity and physics identity is relevant, though not heavily explored in this review. Each academic identity theory plays a significant role in the development of engineering identity as it is currently understood.

2.9.2 Studies that Conceptualize Engineering Identity as a Singular Concept

Of the 44 total articles that met multiple criteria for full analysis (higher education, engineering undergraduate student population, etc.) for this literature review, 30/44 (68.2%) made reference to "engineering identity" or "identity" within their title or sought to define engineering identity as a singular concept. Though categorization during the literature review was subjective, 8/44 (18.2%) provided reference to engineering identity as "professional identity" and one (1/44 = 203%) as "academic identity" directly in their title. It was noted that the remining studies (5/44 = 11.4%) referred to engineering identity in conjunction with another concept or area of significance.

2.9.3 Methods for Conducting Engineering Identity Studies

Forty-four (44/64) research studies were categorized according to their research methods. Three distinct categories emerged: qualitative, quantitative, and mixed methods. Of the 44 studies categorized for research methods, (24/44 = 54.5%) used quantitative methods. As previously mentioned, several quantitative studies contained a large number of subjects (populations n=184 to n=6772). Many large-scale studies contained longitudinal data across multiple institutions. The majority of quantitative research studies (18/24) were conducted since 2015. Qualitative studies (14/44 =

31.8%) were conducted from 2005 – 2011, with two exceptions. Qualitative method studies consist of smaller subject numbers and one study provided a case-study narrative for a single student. Though subject numbers were small and usually were conducted at a single location, these qualitative studies were important in the development of current engineering identity theory. Finally, six (6) studies used a mixed methods approach (qualitative and quantitative). These studies ranged from 2008 – 2019 and contained both small and large number of subjects. Table 1 describes research methods used by each of the studies in the synthesis stage. [Appendix A, Table 1]

2.9.4 Engineering Identity in Women and Underrepresented Populations

Primary review of literature indicates that 16/44 (36.4%) articles mentioned gender, “minority”, or provides reference to an underrepresented population in their titles. However, full text review identified a significant number of researchers were concerned with the development of engineering identity in underrepresented populations and provided disaggregated data for special populations. Of the 44/64 research studies examined, 16/44 (36.4%) disaggregated data based on gender alone (*note: not necessarily the same 16 articles listed above that mentioned underrepresented populations); thirteen (13/44 = 29.5%) studies disaggregated and reported data based on gender and race/ethnicity; one (1/44 = 2.3%) study disaggregated and reported data based on gender, race/ethnicity, and other factors (FGEn and SES); other studies disaggregated data based on FGEn status (1/44 = 2.3%), veteran/military status (1/44 = 2.3%), race/ethnicity only (1/44 = 2.3%); and eleven (11/44 = 25.0%) studies did not disaggregate data to distinguish differences between any population of interest.

However, two (2/11) studies that did not disaggregate data, collected data on gender and race/ethnicity and one (1/11) collected data on gender that could have been disaggregated to explore population differences in engineering identity. Table 2 describes the populations studied and categories representing disaggregated data elements. [Appendix A, Table 2]

2.9.5 Engineering Identity Literature Correlated to Student Success and Retention

Though many studies mentioned the need to tie engineering identity into student success and retention. Only two studies (2/44 = 4.5%) tied engineering identity to recruitment and retention (Beam et al, 2009; Pierrakos et al, 2009). In fact, both studies defined engineering identity as a “professional identity” and contained the same research teams, presenting two different papers at two different engineering education conferences. The first paper centered on freshmen engineering student populations and the implications for recruitment and retention (Beam et al, 2009), while the other study examined engineering persisters vs. engineering switchers and focused on a broader age-group for engineering undergraduate students. Again, full text review revealed that although many of the studies understood the importance of engineering identity on persistence and retention issues, very few studies made a direct correlation between their findings and actual observed recruitment and/or retention data.

2.9.6 Measurement Instruments Specific to Engineering Identity

Some studies included in this literature review borrowed measurement instruments that were previously developed from other fields. However, most studies were unaware of these identity instruments and failed to utilize instruments already developed. One such instrument, only mentioned by one study when citation searching/indexing was Berzonsky's Identity Style Inventory (ISI3) (Berzonsky, 1992).

The Sustainability and Gender Engineering Survey (SaGE) developed by researchers from Clemson University (Klotz, Potvin, & Hazari, 2011) was used for several studies (5/44 = 11.4%) and was most noted by authors that were familiar with the survey and its development (Godwin, Potvin, & Hazari, 2013; Godwin, et al, 2013; Godwin et al, 2015; Godwin, 2016; Patrick, Prybutok, & Borrego, 2018). For studies that utilized the SaGE survey, elements from SaGE were modified in order to develop a comprehensive measurement instrument which was later developed specifically for engineering identity (Godwin, 2016). Other notable measurement instruments were developed including the Engineering Identity Factors Survey (Meyers et al, 2012) to examine professional identity and engineering cultural identity, however, does not appear to be widely used. One study previously mentioned used a combination of Meyers et al (2012), SaGE (2011), Hazari's physics identity questionnaire (2010) and APPLES I (2007) or APPLES 2 (2008) survey from the University of Washington to construct a comprehensive engineering identity survey (Patrick, Prybutok, & Borrego, 2018).

Another instrument specific to engineering identity that has emerged is the Engineering Student Identity Scale (E-SIS). The E-SIS is constructed from multiple instruments to measure identity and consists of 38 items (Curtis, Anderson, & Pierrakos, 2017). Researchers based the instrument heavily on social and identity role theory in the literature. Another notable instrument developed to measure engineering affect and identity in engineering professional practice-based survey questions on ABET learning outcome engineering criteria a-k (Patrick et al, 2017). Finally, a few instruments have been developed since 2018 that seek to validate questions and measure engineering identity with the use of identity scales (Borrego et al, 2018) to predict engineering persistence (Patrick, Prybutok, & Borrego, 2018) and overall engineering identity (Choe et al, 2019).

It is notable to mention that other engineering identity instruments exist, such as the Engineering Identity Development Scale (EIDS), for example. However, these instruments are geared more toward understanding identity development in K-12 populations than engineering students in higher education (Capobianco, 2015).

2.10 Analysis

2.10.1 Disconnected Models for Engineering Identity

From the research findings in section 2.9 (Results), it is evident that engineering identity is not understood as well as psycho-socio or STEM educational models for identity theory. Thus, the body of work surrounding engineering identity theory has relied heavily on definitions for STEM identity, especially physics and/or math identity. Again, the three literature reviews mentioned in section 2.9.1 provide a comprehensive understanding of identity, STEM identity, math identity, and physics identity as the basis for engineering identity theory.

Within emergent engineering identity models, survey questions regarding STEM identity, including factors that distinguish science identity from math identity and physics identity, appeared to be prevalent in qualitative studies up until 2011. These factors appeared to be included, interchanged or separated at random, with the addition of a host of other external traits. For example, two early studies theorized engineering identity consisting of "three types" of personalities: academic, social and intellectual (Tate & Lin, 2005) another defined personalities as Nerds, Academic-achievers, and Greeks (Tonso, 2006). Some studies argued that engineering students associate engineering with a professional identity that consists of academic, institutional identities coupled with gendered identities, which can be influenced by positive role-models (Capobianco, 2006).

Many of the studies defined engineering identity as either identity with academic success or identity to the profession of engineering itself. Though categorization of research for this review was subjective, those studies that discussed engineering as a professional endeavor, coupled engineering professional identity with participation in service learning (Dukhan, Schumack, & Daniels, 2008), personal interests and family (Eliot, Turns, & Xu, 2008), or explored alignment of professional identity with gendered experience for men (Rubineau, 2007), or gendered experiences for women and level of commitment (Chacra et al, 2008; Foor & Walden, 2009). Several studies also examined how professional identity impacts recruitment and retention (Beam et al, 2009) and preparation (Pierrakos et al, 2009).

As indicated in section 2.9.5, these were the only two studies that tied recruitment and retention findings to engineering identity data in their study population. This was an area of concern as many of the studies mentioned the importance of recruitment and retention of students however, did not discuss actual recruitment or retention factors with their findings. More about the importance of correlating recruitment and retention data to these studies will be discussed in Section 2.11.3.3. Further qualitative studies in 2011 relied heavily on engineering theory from Gee (2001) and explored students' engineering external and internal frame of reference for identity in professional and academic contexts (Matusovich et al, 2011; Eliot & Turns, 2011; Cass et al, 2011).   Though disjointed, research from 2005 until 2011 explored the intersectionality of multiple identity factors that may contribute to and influence the experience of individual students. Up until 2012, these factors were viewed as separate and few researchers explored a relational understanding between factors or impact of multiple factors on the student as a whole.

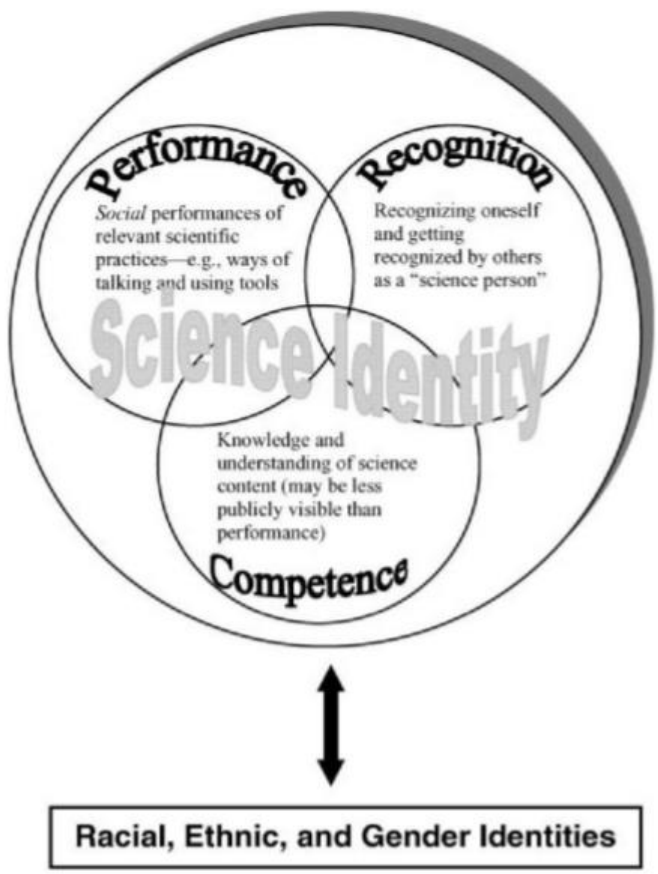
It was evident in the literature that after 2011, researchers began to better incorporate identity theory (Gee, 2001), with science identity and multiple identity theory (Carlone & Johnson, 2007) with physics identity models (Hazari et al, 2010) that were established and built upon one another. This gave researchers a comparable model to inform research directions and define factors within engineering identity.

2.10.2 Basis for Engineering Identity Model Development, Notable References

Full text review of literature and citation searching/indexing revealed that numerous researchers frequently cited three significant contributions to form a basis for the engineering identity model. Though not included in the literature review, Gee's (2001) model for identity factors can be paraphrased as 1) self-recognition and 2) recognition by others as competent. This idea was not expanded upon significantly until six years later, when a science identity model was discussed for women of color.

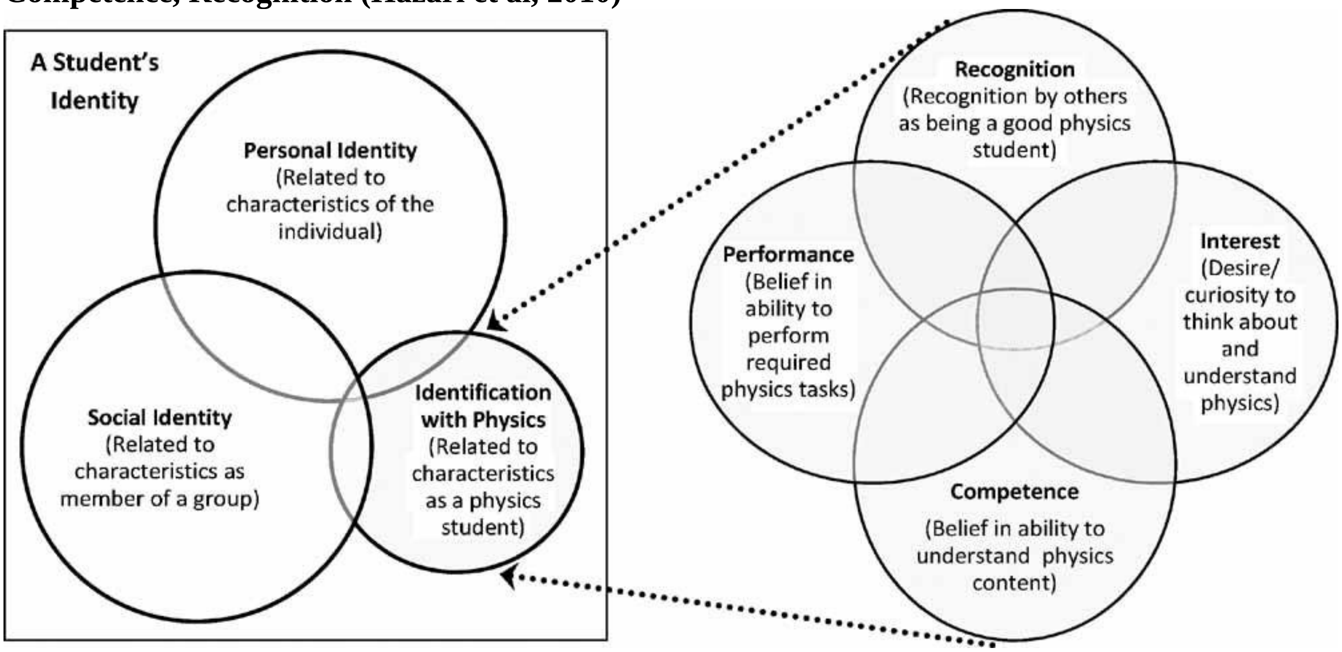
Carlone and Johnson (2007) is widely referenced in engineering identity literature as it may have been the first study to disaggregate data based on gender with ethnicity and examine social factors. In addition, researchers defined science identity as a professional identity with triangulated traits of performance, competence, and recognition. Researchers argued that these three factors interact with other gendered, racial/ethnic identities as a basis for forming science identity (Carlone & Johnson, 2007). Figure 2 depicts three factors that comprise science identity and their interaction with multiple identities that are of significance to women of color.

Figure 2.2 Three Factors for Science Identity: Performance, Competence, Recognition (Carlone & Johnson, 2007)



Researchers in physics identity then built upon this framework by adding interest as a dimension and examined relationships between factors of performance, competence, recognition, and interest (Hazari et al., 2010). As a sidebar, adding interest to the model added some depth to STEM identity however, science identity researchers were apparently unaware of the body of research being developed concurrently in psychology to understand the dimensions of interest in conjunction with engagement and participation. Around that time, a widely known four-phase model of interest development (Hidi & Renninger, 2011) was constructed and to date, has not been integrated into the body of science identity models. This is a shortcoming of science identity research that dimensions of interest (emotional, cognitive, behavioral) and dimensions of engagement (affective, behavioral, cognitive) have not been added to reveal a more comprehensive, in-depth understanding. Also, please note that Hazari's notion interest is interchangeable with motivation lacks a clear understanding that these are separate concepts, each with different attributes and definitions. Figure 2.3 shows the Hazari model of physics identity with added factor interest.

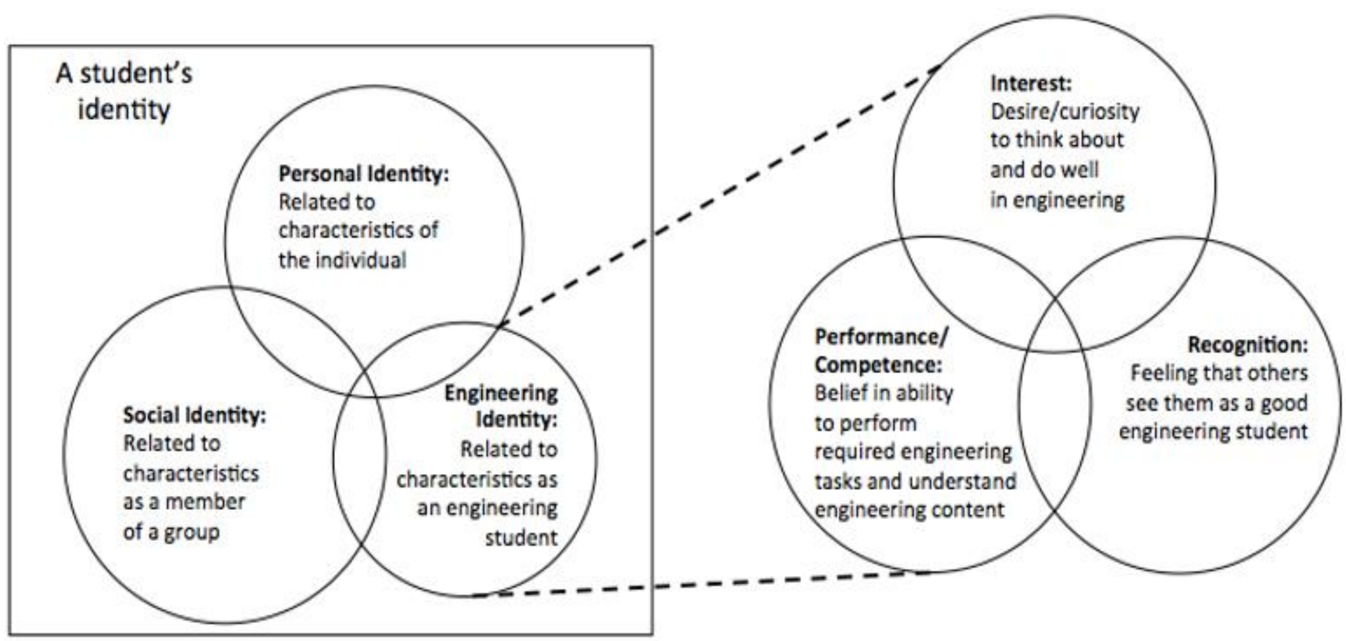
Figure 2.3 Four Factors of Physics Identity Model: Interest, Performance, Competence, Recognition (Hazari et al, 2010)



From these three notable studies, factors of performance (student's belief in ability to succeed academically or during engineering tasks), competence (student's belief in ability to understand material), recognition (viewed by others as good at academic subject matter) and interest (affinity towards engineering tasks and defining factor in persistence) were refined. Subsequent works co-authored by Hazari found that performance and competence were theoretically equivalent and began to combine performance/competence into one construct. These factors were further integrated with math identity models to understand engineering career choice (Cass et al, 2011; Godwin, et al, 2013), academic persistence (Cribbs et al, 2015; Cribs et al, 2016) and develop structural equation models to inform engineering identity measurement instruments (Godwin et al, 2013).

Finally, Patrick, Prybutok, & Borrego (2018), built upon Hazari physics identity model to develop an engineering identity model that replaced "physics" with "engineering" to define the three factors of a student's identity as personal, social and engineering (Patrick, Prybutok, & Borrego, 2018). This study also combined performance/competence into one category as data analysis indicated there was not a significant difference between categories and the factors could be combined. In the course of discovery for the literature review, this was the only study that sought to build upon previous research and provide a new dimension to engineering identity theory. Figure 2.4 depicts the Patrick model for engineering identity, based upon Hazari's previous work.

Figure 2.4 Three Factors of Engineering Identity Model (based on Hazari's Physics Identity Model): Interest, Performance/Competence, Recognition (Patrick, Prybutok, & Borrego, 2018)



2.10.3 Evolution of Engineering Identity Factors

Section 2.10.2 describes the evolution of models that have been used to understand engineering identity in its current state. However, as described in section 2.10.1, the emergence of engineering identity as a singular concept grew from a variety of factors that researchers explored to describe different aspects of identity and its variations. Meyers et al (2012) was a significant study that defined engineering as a professional identity, one where there is both belonging of self and organizational recognition, compounded with factors essential to become an engineer. These factors included making competent design decisions, working with others, and accepting responsibility (Meyers et al, 2012). Though researchers did not recognize engineering identity theories to date, this study was significant due to its large sample size (n=701) and variety of engineering students (freshmen through senior) used to quantitatively predict engineering identity by using a linear regression model. As the bulk of previous engineering identity research relied on qualitative methods with small sample size, the use of quantitative methods with larger sample size became a new direction for engineering identity research.

After 2013, it was apparent that researchers began to explore a broader definition of engineering identity. One that not only included an internal identity with academics or the engineering profession but, one that included other variables, especially those of interest to supporting underrepresented populations. These studies presented a myriad of experimental conditions researchers used to further understand nuance and complexity within external identity structures in engineering environments themselves. Researchers explored the impact of factors including, shaping identity through attending minority serving institutions (MSI's) on underrepresented populations (Fleming et al, 2013); developing a sense of cultural belonging within the profession through 'familia' within Hispanic/Latinx populations (Revelo, 2015); or creating academic and professional identity through access, performance, and retention via participation in special programs (Knight et al, 2013).

A few studies began to explore the impact of gender stereotypes, especially stereotype threat (Jones, Ruff, & Paretti, 2013), or highly gendered environments on women entering the engineering profession (Cech, 2015). As each study prescribed different attributes to explain engineering identity, it was apparent that researchers created their own measurement instruments in isolation. Further, research up until this point was highly scattered and indicated that the engineering educational community did not fully comprehend salient factors that comprise the concept of "engineering identity", nor were they in consensus.

Research after 2015 began to provide some pattern of common understanding and studies began to build upon previous results. Research teams began to develop that began large-scale quantitative studies to validate instruments developed from physics and math identity models. These instruments are discussed further in Section 2.10.4 (Development of Engineering Identity Instruments). However, factors included in these instruments revisited a combination of internal and external identity variables that appeared to be related to three common themes. Therefore, with the development of identity instruments, engineering identity research can be better examined by dividing studies into common factors to explain development of 1) academic identity, 2) professional identity, or 3) holistic self-identity.

2.10.3.1 Academic Identity Factors

Though not as prevalent after 2015, there were still studies that relied on the definition of engineering identity as solely an academic identity, heavily related to math and physics. Several studies used elements from instruments developed by Hazari et al (2010) to examine factors such as, interest, recognition, performance/competence (math), agency, and physics identity (Godwin et al, 2015; Godwin, 2016). Though maintaining an overall academic theme, factors such as, grit in populations of women (Verdin et al, 2018, March) or grit in FGEn populations (Verdin et al, 2018) may have been added to connect engineering academic identity with other recent developments in engineering education literature.

2.10.3.2 Professional Identity Factors

As previously discussed, a large body of research understands engineering identity as a professional identity, affiliated with a set of workplace skills and hands-on ability. Though engineering educational outcomes are well-established, only one study in the entire literature review tied engineering identity to developing factors associated with ABET educational outcomes a-k. These factors include framing and solving problems, design, project management, analysis, collaboration and tinkering (Patrick et al, 2017). This study was echoed a few years later to measure similar identity factors (Choe et al, 2019; Kendall et al, June 2019) and examine these factors within underrepresented populations (Kendall et al, August 2019). Though surprising, a limited number of studies examined the development of professional identity through hands-on design experiences as professional practice (Borrego et al, 2018) or in maker spaces (Torralba & Rouse, 2019).

It is important to note that though studies mentioned concepts, such as tinkering and self-efficacy, engineering educational literature does not contain a comprehensive understanding for these longstanding research areas prevalent in psychology and education. As noted by one author, performance/competence is akin to self-efficacy in social science literature and is important to understanding the development of identity in engineering (Patrick, Prybutok, & Borrego, 2018). Though outdated, research on tinkering could have been utilized to further establish professional identity factors that underlie engineering identity within project-based or hands-on settings as well.

2.10.3.3 Holistic Self-Identity Factors

Studies that used either academic identity, professional identity, or a combination of both also included an expanded view of factors to encompass an individual's self-identity with engineering. These factors included, design efficacy, creativity, and global agency (Prybutok et al, 2016), with an addition of growth mindset (Henderson et al, 2017). As the concept of agency begins to appear in the literature, it is apparent that engineering identity research may include factors that describe an individual's sense of "purpose" or "ability to act" as important to connecting with engineering and/or becoming an engineer. Though not referred to as agency, studies also began to couple self-concept identity with personality traits (agreeableness, conscientiousness, extroversion, neuroticism, openness to experience) and authenticity (Stoup & Pierrakos, 2016). Self-determination theory was also utilized to establish a sense of developing competence and interpersonal relationships, managing emotions, autonomy towards interdependence, developing purpose, establishing identity, and developing integrity (Tartar, Van Beek, & Lilienkamp, 2016; Curtis, Anderson, & Pierrakos, 2017). These self-concepts were further developed through measuring identity through distinctiveness, participation, self-enhancement, visibility of affiliation and citizenship (Pierrakos, Curtis, & Anderson, 2016).

With the inclusion of interest in measurement instruments, studies holistically used a combination of academic and professional descriptors to better understand affinity towards majors, such as electrical engineering and computing (Rohde et al, 2019). However, academic and professional factors were further enhanced by expansion into social identity construction theories and the impact of communities of practice (Godwin & Potvin, 2017). Social peer interactions within special populations were observed in Hispanic serving institutions (HIS's) compared with predominately white institutions (PWI's) (Kendall et al, 2018) and found that underrepresented students develop stronger engineering identity in HIS settings. Though some work has been carried out to understand the impact of social identity on engineering identity development in underrepresented minority populations (Cross & Paretti, 2012; Rodriguez, Cunningham, & Jordan, 2019) and women (Faulkner, 2007), more work needs to be done; in academic and other settings (Ross & Godwin, 2016).

The impact of social constructs on developing engineering identity has expanded in the last few years with the understanding that environmental settings and social status are salient factors that determine student identity formation. Researchers have begun to understand the importance of belonging (Sax et al, 2018; Taheri et al, 2019) and have included belonging as a holistic factor to develop survey instruments (Patrick, Prybutok, & Borrego, 2018). Though work has been done that has evolved the understanding of engineering identity factors, more work needs to be done to develop reliable and valid survey instruments that can be used in a variety of settings.

2.10.4 Development of Engineering Identity Instruments

As previously mentioned, engineering identity research is disjointed and many of the studies have independently developed their own surveys, tailored to their specific area of interest. However, as mentioned in Section 2.9.6, engineering identity instruments that warrant analysis include use of the Engineering Identity Factors Survey (Meyers et al, 2012), Sustainability and Gender Engineering Survey (SaGE) (Godwin, Potvin, & Hazari, 2013; Godwin, et al, 2013; Godwin et al, 2015; Godwin, 2016; Patrick, Prybutok, & Borrego, 2018), and Engineering Student Identity Scale (E-SIS) (Curtis, Anderson, & Pierrakos, 2017).

The first survey that warrants a closer look is the Engineering Identity Factors Survey (Meyers et al, 2012). This survey examined professional identity and factors that determine engineering cultural identity. As previously noted, this survey has not been widely disseminated or used in the literature. Examples of statements students must indicate they identify with are:

1) Being able to make competent design decisions
2) Being able to teach engineering content to another person

3) Speaking/communicating using accurate technical terminology
4) Feeling confident in engineering work without confirmation from others that the approach is technically sound
5) Making moral/ethical decisions considering all factors

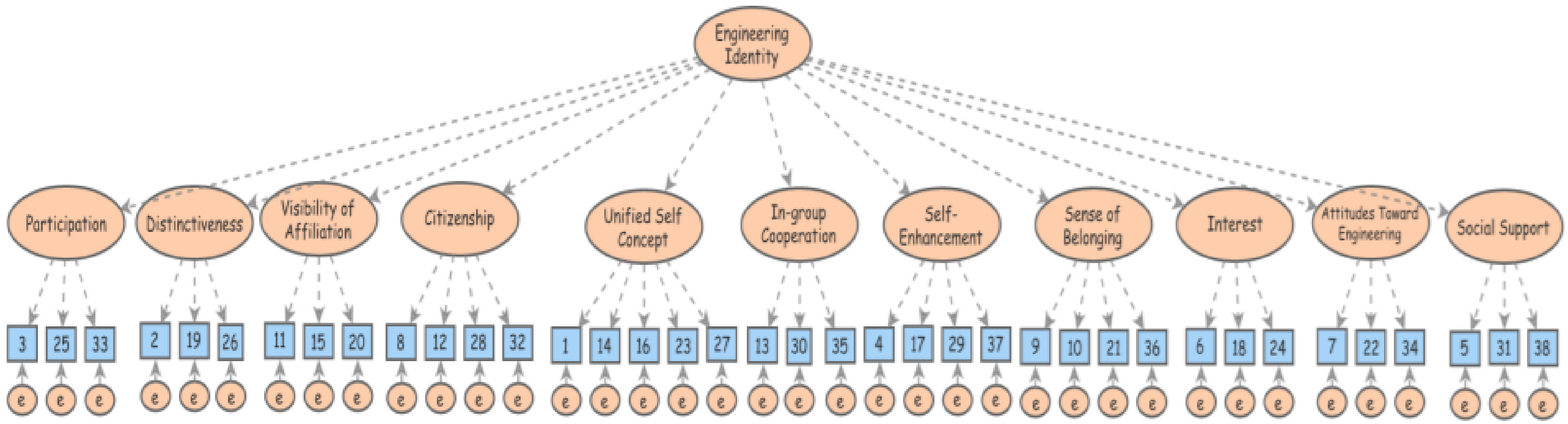
Though these "statements" evoke a sense of identity, the language used throughout the survey warrants improvement. To ensure identity statements are not misleading, wording should be tailored to reflect a sense of active engagement with, or ownership of, rather than passive compliance with, each factor. For example, rewording and replacing, "being able to make competent design decisions" with "I am able to make competent design decisions" or simply, "I make competent design decisions", evokes a stronger sense of awareness and personal reflection within each individual person. Again, this survey has not been widely used in the literature but, could be used in the future if improvements to the language are explored and validated.

The next survey is Sustainability and Gender in Engineering (SaGE) and has been widely used by a team of authors involved in its development (Godwin, Potvin, & Hazari, 2013; Godwin, et al, 2013; Godwin et al, 2015; Godwin, 2016; Patrick, Prybutok, & Borrego, 2018). From published works, authors recommend this survey as a valid measurement for science, math and physics identity, as well as engineering identity. Several studies in the literature review indicated this survey was administered to college-level engineering students and they were asked to recount their high school experience in math and physics courses. In addition, this survey asks questions about interactions with high school teachers and their enthusiasm for subject matter as well as parents' level of education and interest in academic subjects. Reviewing questions on the survey, areas are identified that can relate to interest, recognition, confidence, self-efficacy, performance, and more. However, language in this survey could also be more concise as many of the survey questions may have been indicating one or more results.

Since the survey was interested in comparing differences in experience between genders, questions should have been written with gender and bias at the forefront. Again, language could have been more specific to each students' experience to inform researchers of gender differences when data is disaggregated. For example, questions to indicate experience with teachers could have been asked as "treated me with respect" instead of "treated all students with respect". Another question could have asked the gender of the physics or math teacher to indicate a holistic perspective of the environment that could have impacted the student experience. An observation of the types of questions asked, it appears that the SaGE authors compound ideas that may not identify clear concepts in the results. For example, the "teacher was able to, 'handle discipline and manage the classroom'" articulates two separate concepts that could be clarified into "handle discipline" and "manage the classroom".

Finally, the Engineering Student Identity Scale (E-SIS) instrument based heavily on social and identity role theory. The E-SIS was a hybrid constructed from multiple instruments to measure identity with 38 items (Curtis, Anderson, & Pierrakos, 2017). The sole measurement in the study was to gauge identification with being an engineering student. Questions are grouped in sets of three items designed to represent larger themes of distinctiveness, participation, sense of belonging, interest, attitudes, in-group cooperation, and others. Responses for the 38 items were recorded on a 6-point Likert scale from 0 - strongly disagree to 6 - strongly agree. By condensing and grouping factors, researchers were able to identify core value structures that underlie engineering identity. Structural equation modeling also opened the door for other studies to follow suit with simplified versions of questions found to be reliable and validated instruments (Godwin et al, 2015; Godwin, 2016). Figure 2.5 provides a visual representation of 11 overarching factors.

Figure 2.5 Engineering (E-SIS) 38 Factors and 11 Overarching Themes (Curtis, Anderson, & Pierrakos, 2017)



2.11 Discussion

2.11.1 Constraints

This literature review was performed under significant constraints: gender and ethnicity in US higher educational institutions. Specifically, literature was sought that described engineering identity formation from the perspective of women and women of color. Though only a few engineering identity studies exist in this area, historically, the engineering education community has recognized the disparity of black and Hispanic/Latinx populations' participation in engineering. More work can be done to study underrepresented students and their identity development. Moreover, information on women's participation in specific engineering majors (computer science, electrical engineering, mechanical engineering) was also sought to further identify strategies to build identity in non-traditional, male-dominated disciplines.

There were even fewer studies found that tied in majors with identity formation in these populations. Using constraints narrowed the breadth of the literature review and allowed the reviewer to identify individual studies dedicated to understanding the experience specifically for women and women of color. The reviewer also recognizes that discussing engineering identity in a vacuum, without providing a context for engineering culture and the overall environment in higher education, is deficient. Several studies mentioned "gendered experiences" however, literature included in the review that mentions development of engineering identity in conjunction with the impact of a gendered engineering environment remains sparse.

2.11.2 Gaps in Literature

There are several gaps that exist in the literature and our understanding of the engineering identity development process, especially in underrepresented populations. Although researchers have assembled multiple factors that describe the engineering experience, engineering identity development is not fully understood in itself, nor is it understood within the larger context of higher education. To provide a more robust discussion, engineering identity development in underrepresented populations should contain information on core identity development, intersectionality of multiple identities, and strategies to navigate engineering environmental contexts. The majority discussion regarding engineering identity development is generalized, especially towards an academic or professional identity, not from a holistic perspective. Therefore, the body of research contains within it a structure of bias, stereotypes and assumptions that should be disaggregated and addressed.

In particular, scholars should recognize that core identity overshadows the formation of engineering identity. Examination of a baseline for identity in all student subjects is necessary to understand how they will develop over time. Therefore, with engineering identity "factor" questions, researchers should ask for demographic information and historical context for core identity formation, which few include in their research. For example, the impact of cultural differences in various regions of the US; influence of family and familial values on core identity formation; exposure to and acceptance of social norms and values; etc. In addition, student development models should be incorporated that view identity as a longitudinal, ongoing process.

Development of engineering identity is dynamic however, the majority of studies modeled identity as a static endeavor. Within the literature there also was a lack of evidence supporting a correlation of identity formation with retention in engineering. Without connection to student development and retention models, engineering identity research only seeks to understand a singular point in time.

Large-scale, long-term studies were not found therefore, many of the surveys administered in higher education settings were already for students that had 1) self-selected engineering, 2) had been retained at least one semester in engineering, and 3) were currently experiencing the engineering environment that may have had an influence on their opinions. Even when sample sizes were large, the pool of student subjects was found to be narrow. Unless expressly specified, researchers were not examining differences in experience between students from majority vs. underrepresented backgrounds, students with “double-bind” effects, or the impact of gender differences, in general. They also didn’t examine experience in engineering, coupled with determining factors (ie: academic success vs. involvement level). The body of literature seemed to pick and choose to examine one or two factors, not fully examining or appreciating the complexity of engineering identity.

From benchmark identity studies found in the literature, further engineering identity research should examine majority student and faculty attitudes regarding “recognition”. Identity research in multiple disciplines seemed more geared toward examination of an “internal” identity component within students themselves however, researchers understand internal identity is impacted by the external. Gee (2001) found two important factors. First, students must view themselves as engineers and second, others must view them as engineers as well. In an external context, it is important to examine the impact of biased beliefs in everyday settings. In university settings, faculty should be well-versed on the importance of viewing their students as “engineers in training”, who will soon lead industry with their ideas and skill sets. Currently, engineering faculty have little (if any) training as educators. Their ability to retain students and create future engineers is of vital importance. More should also be done to examine masculine social norms (Akpanudo, Huff, & Godwin, 2017) in engineering student contexts of “who” looks like an engineer and seek to expose bias against non-traditional students. Further, future research should explore how traditionally male fields can change and grow to accommodate other ways of thinking to present educational content and techniques that will enhance delivery to a broader engineering student audience. Involving majority student and faculty populations in finding solutions will be significant to resolve hydrophobic engineering environmental factors.

For the literature to be comprehensive, more needs to be done to craft experimental conditions that students would be subject to outside of the classroom experience. As an engineer, students are required to propose novel ideas, solve grand challenges, and work with teams that are fluid and vertically matrixed. To provide a real-world setting, academia should do more to evaluate situations that demand project-based learning, capstone design or freshmen design projects, and especially, competitive project teams that require team-based skills as well as technical knowledge.

During the literature review process, only one study was found that examined the development of engineering identity by participation in a design project to build an electric bicycle in 8th grade students (Fidai et al, 2018). Another international study found that gendered, problem-based learning environments impacted women (Du, 2006). However, these studies were not included within this literature review due to constraints. Further, only one study even mentioned tying results to ABET student learning outcome criteria a-k (Patrick, Prybutok, & Borrego, 2018). Again, more work needs to be done to examine the hands-on aspect of engineering, as well as tie into ABET accreditation student learning outcomes 1 – 7 (a-k revised in 2019) (ABET, 2019).

Future scholarship should also examine subdisciplines and how students develop within these contexts. There is a large body of research regarding student development of women in computing and computer science. However, few studies examined the development of identity within a subdiscipline context. One study examined gendered professional identities in industrial engineering context (Cech, 2015) and another belonging in computing for underrepresented students (Sax et al, 2018). However, information regarding identity towards subdisciplines is needed to better inform recruitment and retention efforts. Especially for women's participation in non-traditional engineering fields such as mechanical or electrical engineering.

2.11.3 Recommendations

The following recommendations are further explained to enhance future engineering identity research with emphasis in 1) adopting uniformity across terms and factors that are easily identified; 2) recognizing, understanding and building upon the depth and breadth of research pursued by disciplines other than engineering; 3) correlating engineering identity factors with student success and retention; 4) providing valid measurement instruments specific to engineering identity; and 5) incorporating a standard for robust measures, including control or comparison groups, to inform a greater understanding of engineering identity development.

2.11.3.1 Uniformity Across Terms and Factors

As previously mentioned, the initial difficulty to assemble relevant research came from the use of numerous terms and descriptive language for engineering identity across fields. The majority of variation came from the field of engineering research itself. An initial search of "identity" was not sufficient to focus on engineering identity. A search for "engineering identity" revealed that although researchers were intent on describing engineering identity, they used other terms, or variations of terms, to describe their work (i.e.: "engineer identity" and "engineering identities").

Citation searching/indexing revealed other descriptors were included and convoluted with engineering identity such as, "affect", "agency", "belonging", "communities of practice", "gendered identities", "multiple identities", "representation", "self-efficacy", "self-concept", "social norms", etc. Some of these references provided valuable information, however, were not easily accessible during initial search efforts. In addition, there is not a clear agreement between researchers regarding engineering identity factors. By borrowing factors from other disciplines (science, math and physics), researchers were able to create a starting point. This starting point has led to multiple theories, with various tangential directions, within engineering that have led to confusion and lack of adoption of existing knowledge. Therefore, there is a need to create uniformity with terminology and some consensus of factors that constitute engineering identity.

2.11.3.2 Cross-Disciplinary Understanding of Engineering Identity

From initial search attempts, it was clear that the field of psychology and education had vast knowledge in the area of identity. However, many of the engineering identity studies failed to recognize, cite, or build from these studies. From an academic identity perspective, Berzonsky was one well-known and prolific researcher in educational psychology that was hardly mentioned in the engineering identity literature. Further, absence of the Identity Style Inventory (ISI3) as a starting point for engineering identity scale instruments was interesting (Berzonsky, 1992). Though briefly mentioned in one or two studies, engineering identity research did not correlate known academic identity indicators (diffuse-avoidant, normative, informational identity styles) with retention or "prediction" of maladjustment (Adams et al, 2001). Nor did engineering literature indicate how academic identity could be influenced by other factors, such as value orientation (Berzonsky et al, 2011). Many of the studies widely accepted the definition provided by Gee (2001) without realizing the depth of understanding for identity in other fields.

Further, the majority of studies disregarded the body of work available to assist underrepresented populations in engineering and other fields. Due to societal norms, there are a variety of barriers that women and underrepresented minority students face that are distinct from their majority peers. These barriers exacerbate engineering identity construction through marginalization, stereotypes, feeling like an outsider and "code-switching" to navigate various engineering contexts (Downey & Lucena, 2004). Interventions recommended by researchers centered on classroom or instructional aids. Only a limited amount of research focused on a holistic student perspective to better inform teaming and social interactions (Tonso, 2006; Rubineau, 2007), belonging and engineering cultural identity (Foor, Walden, & Trytten, 2007), the impact of minority serving institutions (Fleming et al, 2013) or inclusive excellence programs (Knight et al, 2013). Therefore, the body of scholarly works published on engineering identity should contain a breadth of understanding for cross-disciplinary interventions to develop well-informed theories.

2.11.3.3 Student Success and Retention

Though the importance of student success and retention was mentioned in several studies' introductions, significant results found from the studies did not correlate identity factors with overall student success and retention. One study examined identity and retention but, only from a first-year perspective in freshmen students (Beam et al, 2009). Since many of the studies examined first-year students, longitudinal studies to follow-up on surveyed populations could be implemented to better inform whether identity factors truly indicate students will persist or switch from engineering. Further, longitudinal studies could better inform how preference for individual identity factors change over time. Known student success and retention models could be incorporated to engineering identity research to allow students to further reflect on their experiences. The acquisition of engineering-related experiences, whether academic or professional, is important however, little is known about how students personally connect with those experiences. Again, a holistic view of how individuals interact with the engineering environment and how the environment impacts their experience would be valuable.

Individual reflection regarding how students "feel" about the experience, not just a Likert rating of how they identify with the experience on a survey, would add another dimension. For hands-on or project-based learning, one student success technique that has been used is portfolio construction (Eliot, Turns, & Xu, 2008). Though difficult to evaluate, portfolios provide a record of student progress and an opportunity for deep reflection throughout an entire experience. Thereby, better informing educational practices to develop identity in engineering students.

2.11.3.4 Valid Measurement Instruments

Whether data was presented as qualitative or quantitative, many of the studies consisted of survey instruments or questionnaires that were independently designed by researchers. Because many of the questions were not mentioned in the literature, it is assumed that they varied widely. Within the literature there was little evidence that instruments were developed to ensure reliable or valid measures. In addition, it was apparent that researchers were not necessarily utilizing instruments that were previously developed to determine identity. Therefore, whether or not significant results were found, it is questionable that researchers' claims are warranted.

As discussed in section 2.10.4, of the studies that used factorial analysis to check validity, further examination of factors indicated that statements were convoluted and contained multiple ideas that should have been disaggregated. Few studies also examined the relationship between factors, strength of factors in identity development, or differences in the pattern of identity factors within majority and underrepresented populations. In many of the studies that used SaGE (Klotz, Potvin, & Hazari, 2011) or physics identity instruments (Hazari et al, 2010), they assumed validity and reliability. Again, there is not consensus for the factors that constitute a well-rounded understanding of engineering identity. Therefore, future work should further develop and refine instruments designed to interpret engineering identity (Meyers et al, 2012; Godwin et al, 2015; Godwin, 2016; Curtis, Anderson, & Pierrakos, 2017; Borrego et al, 2018; Choe et al, 2019).

2.11.3.5 Improvements for Experimental Design

Across the literature, significant improvements to experimental design could be made. Experimental design requires a strong understanding of the engineering "system" as a whole to make predictions for engineering identity factors that are specific and testable. Again, many of the studies made assumptions about the engineering educational environment, usually from the viewpoint of a majority perspective (Stevens et al, 2008). Research questions were not well defined. In addition, overall study populations were limited to engineering students, without the inclusion of comparison groups in other engineering majors, other majors across the university (non-engineering students), or during different stages in their academic development (first-year vs. graduating senior).

Quantitative studies should incorporate larger data sets for comparison across institutions. Again, this would require consensus on instruments used and factors indicated within those instruments. Of the 44 studies reviewed, only six (6/44 = 13.6%) of the studies reviewed utilized a mixed-methods approach to understand student identity development. Future research in engineering education should focus on quasi-experimental design, and incorporate a mixed-methods approach, to ensure a robust understanding and validity of findings.

2.12 Conclusion

The importance of this literature review is that it examined past and present research to better understand the evolution of engineering identity as a concept, establish significant engineering identity factors, and spotlight the need for reliable and valid survey instruments. The field of engineering itself is ambiguous therefore, knowledge of factors that interest and motivate students to pursue engineering fields are of value to the engineering educational community. Though it was difficult to determine concrete thematic patterns in the literature overall, it was observed that engineering identity work is in its infancy and researchers have an opportunity to apply knowledge in several areas and add to the body of work. A systematic review of the literature was effective to further understand windows of opportunity within engineering identity research and the importance of support strategies needed to retain underrepresented populations.

CHAPTER III

3.0 RESEARCH

3.1 Introduction

The following research was conducted at the sixth-largest public university in the US and the largest university in Texas. This university is regarded as a Tier 1 research institution, with nationally ranked colleges in engineering, agriculture, and life sciences (US News and World Report, 2021). At this university, within a specific college of engineering program, there has been a concerted effort to provide opportunities for informal hands-on application and to encourage female engineering students. Since 2015, this program has developed and supported three student-led competition engineering project teams. These teams were created to address the issue of underrepresentation of women on collegiate competitive engineering project teams, as well as to increase an interest for mechanical engineering, electrical engineering, and computer science disciplines. These disciplines are commonly referred to as 'non-traditional', due to the lack of participation and low percentage of women and other underrepresented student populations. Underrepresented populations in engineering disciplines traditionally include Hispanic/LatinX, Black/African American, Indigenous/Native American, and first-generation (FGEn) students; defined as students who are first in their family to attend college.

As previously mentioned in Chapter I, women overall are underrepresented in engineering disciplines. The American Society for Engineering Education (ASEE, 2021) reports that women represent only 22.5% of undergraduate students that graduated with an engineering degree in 2019. Nationally, women constitute only 12.7% of the engineering workforce overall (US Bureau of Labor Statistics, 2021) and are less likely to be employed as electrical or mechanical engineers. Further, women currently constitute only 13% of all employed mechanical engineers, 11.1% of electrical engineers (Zippia Careers Statistics, 2020) and represent approximately a quarter of workers in computer-related jobs (26%) (US Census Bureau, 2021).

Many female students lack experience with hands-on technical applications that would serve to develop confidence and interest, two relevant factors that contribute to the formation of engineering identity. The purpose of this study was to acquire information regarding undergraduate student experience on single-sex project teams and to compare differences among team members and non-team members. The impetus for the research was an observation that with minimal external support and a basic framework, the teams were successful. Ultimately, this intervention provides insight into engineering retention and participation in non-traditional engineering majors for underrepresented populations.

3.2 Overview of Competitive Engineering Project Teams

The three competitive engineering project teams were comprised of undergraduate students (first-year through fifth-year) and included graduate student mentors for the first three years to assist the teams. It is important to mention that graduate students played an auxiliary role to mentor project teams over the course of the research study and provided only limited guidance, when necessary. The teams were purposefully constructed as student-driven and student-led. For maximum impact, the bulk of the learning and discovery was undertaken by the undergraduates themselves. Though difficult, this intervention technique ensured that the team members were responsible for every aspect of the project and “succeeded” or “failed” through their own actions. The ideas of success and failure are further discussed in Chapter VI (Section 6.5 Ideas of Success and Failure).

Teams were developed by students, with support from the program. Over the course of five years, each team gained momentum from year-to-year. The program provided support each fall semester through four recruitment events targeted to women engineering students. An open invitation was sent through the listserv of all female undergraduate students to these events. Teams also became known by student word-of-mouth through their own networks. Members were considered volunteers, who engaged in meetings, design reviews, build sessions, and testing on their own time. From the pool of more than 3,500 undergraduate women students, it was up to the students themselves to self-select team participation and their level of engagement. Though internal discussions over the years have discussed “incentivizing activities”, students did not receive monetary support or course credit for engaging in the teams.

As interest grew and dynamics unfolded for each team, the teams began to provide a safe space for learning and development. The focus of the teams became students encouraging other students to learn through making “mistakes” and not to “win competitions”. The byproduct of this culture and environment were that teams consistently had interest and engagement and provided an open door for underrepresented populations to participate. Students were able to informally come and go and participate when they had time. It was observed that the welcoming and supportive environment provided by peers was a primary factor to the overall success of the teams.

Financially, team activities were supported through the program budget as well as various industry sponsors. All monetary support was acquired, and stewardship maintained, through the program. However, contact with industry mentors was highly encouraged to provide technical expertise and recommendations during annual design reviews. As a necessary element, three design reviews were required in the fall semester (October or November) to ensure teams were reporting out and making progress. Design review expertise included graduate students, industrial area staff, faculty, industry mentors and supporters. Although most teams competing do not start from scratch each year, it was important that these students started from scratch and went through the entire design and team building process each year. Again, the focus was to provide an opportunity in a real-world setting, without instructions, to foster student identity and development as engineers, <u>not</u> to win the competition.

As a standard practice, a leadership retreat was held in September for team leaders and active members. There, teams were able to gain information from the program and submit timelines including Gantt charts, to manage their projects. Teams were also able to meet each other and share information on best practices. After recruitment events to showcase teams were conducted, team rosters and budget estimates were required in early October from team leaders. Another important characteristic of the project teams was that they were not designated as traditional student organizations, rather they were considered a program offering under the program umbrella. Teams were open to all students within the college of engineering and fit largely into program and college-wide retention strategies to support first- and second-year students.

Due to funding constraints, a limited number of the most dedicated students were taken to compete in annual national and international technical competitions. Depending upon the team, they traveled to in-state and out-of-state events at various times during the year and in the summer. The following section provides a brief description of each project team and a general description of the number of students that participate each year on that particular team. It is important to mention that the structure of each team was up to the students themselves. A finding of this study was that if given an opportunity, students self-organize and determine their own pathway to meet goals they set for themselves and requirements for the season. More often than not, the teams were successful delivering written reports and meeting requirements, such as the design, manufacture, and completion of vehicles or robots prior to competition deadlines. Each season, most teams were able to qualify to compete or score enough to compete in semi-final events. Over the course of five (5) years and twelve (12) competitions attended, only two (2) teams were unable to meet technical requirements to compete or had technical failures with equipment that prevented them from making semi-final rounds. More information regarding each competition can be found in the reference section and on the competition websites provided.

3.2.1 VEX U Team

The VEX U team is typically comprised of an average of 28 active students annually and up to 25 students attend a regional qualifier for collegiate teams at the end of February in Houston, TX. During the competition season, students design, build and program robots using VEX parts and follow VEX U challenge rules to customize their designs, according to that year's mission challenge (VEX U, 2022). Currently, the team is comprised of two sub teams, mechanical and programming. Depending upon the year's mission challenge, team members navigate through props and have certain tasks to complete, while challenging another team in the arena. This competition usually contains a limited autonomous portion, usually 45 seconds, at the beginning of the match to gain points. Therefore, students learn C/C++ programming languages to showcase autonomous features. A team notebook is submitted prior to competition and an oral presentation, with demonstration, is required during the competition for overall team scores.

The VEX U team has been successful during annual regional competitions within the state. In their first year competing (FY16), the team placed 4th in the collegiate division for the regional qualifier event against 11 collegiate teams (Texas A&M News, 2016). Four years later (FY20), the team won the Excellence Award for collegiate participants and was invited to attend the VEX U Worlds in Louisville, KY. However, their participation in Worlds 2020 was thwarted by COVID. VEX U generally provides a bit more leniency in the use of 3D printed parts, rather than using only the prescribed VEX kit of parts, as required in high-school competitions. There are usually two robots required for the mission and collegiate teams may add to their designs to make their robots unique.

3.2.2 SAE Supermileage Team

The SAE Supermileage vehicle team members are tasked with the design and build of a lightweight, fuel-efficient vehicle to compete in an international challenge. The challenge is held on the Eaton proving grounds in Marshall, MI during early summer (SAE International, 2022). Team members learn chassis fabrication, design steering and braking systems, and customize a small engine for fuel efficiency. Subteams consist of mechanical (chassis), engine, and shell fabrication. Usually, there are an average of 32 active students on this team and up to 12 students have attended the competition. A technical written report is required prior to competition and an oral presentation is given during the competition. It is important to note that this team has been to competition twice in the past five years and fluctuates due to overall interest in the project and team leadership.

Anecdotally, the first year was a struggle to produce a working vehicle as the team was confused about where to start. They had difficulty with team dedication to the project as well as any prior knowledge about how to build a working vehicle. Advice was sought from the SAE Formula car team however, the vehicle function (slow-moving and lightweight) meant that the vehicle should have been designed to different specifications. The team traveled to competition, however, did not pass the technical inspection due to certain capabilities and safety aspects. Many of the students did not continue to the second year however, the leadership asked to continue.

During the second season, the team fabricated a new chassis, however, did not continue to complete the vehicle and compete. The third year, the team was taken over by a group of sophomores, who had participated the previous year as freshmen, and were able to fabricate a working vehicle and compete that summer. This team achieved over 400+ mi/gallon and were able to place in the competition above other teams from around the globe. Passing the technical inspection was a milestone in their development and allowed them to grow exponentially in their technical capabilities. Competing with other teams assisted in the development of engineering identity, as well as their interest in and excitement for engineering, in general. Many of the students involved in this team continued for the next season, though interest dwindled when the team leader became engaged in other activities. This team showed that strong leadership was important to the sustainability of the team and its continued success.

3.2.3 AUV Team

The Autonomous Underwater Vehicle (AUV) team usually boasts the most interest and commitment from students. Team members design, build, program, and test an autonomous underwater vehicle to compete in the AUVSI RoboSub international challenge in San Diego, CA in late summer (RoboSub, 2022). Team members program in Python and C++, while fabricating and learning to understand a complex, watertight, electrical underwater system. A team website is required and a written report, in IEEE format, are submitted prior to competition (Institute of Electrical and Electronics Engineers, 2022). On average, 49 students actively participate annually on this team. However, fall recruitment events have shown at least 120 – 150 students are interested at the start of the season. A total of 12 students are invited to attend the competition, based upon their active engagement in meetings and their ability to produce results. Oral presentations are given during the competition and judges provide support and feedback to teams throughout the competition week.

Another important element developed by the AUV team was a series of workshops delivered to incoming participants, especially to assist first-year students. These workshops explain elementary techniques and pass along technical knowledge gained in previous years. They also are a conduit to introduce more complex features of the AUV and offer a starting point at any level. The workshops have been helpful to new participants as they are developed and delivered by second-year or upper division students to explain concepts that first-year students may not see in their coursework for at least two years. With the success of the AUV workshops, other teams have adopted similar formats to initiate new participants and provide a foundation for individual learning and development. Though the program provided initial support to offer workshops in Fall 2018, team leaders have continued and expanded these peer-mentoring opportunities for current and past participants. Peer-mentoring is considered another emergent factor that has led to the overall success of the teams.

3.3 Research Questions

From chapter I, the purpose of this study is to evaluate if participation in competitive women in engineering project teams significantly leads to an increase in student identity to become an engineer as well as increased enrollment in non-traditional majors of interest. The main objectives of the research are to test whether participation in all-women competitive engineering project teams increases engineering identity among participants and to understand the relationship between engineering identity in project team participants and non-participants. Other research objectives are to understand if experience on competitive project teams is related to persistence in engineering for women and to determine differences in overall experience within the college of engineering environment for participants and non-participants. Therefore, research questions to be addressed by this study are:

- Are women who participate on project teams significantly different than other students in the college of engineering?
- Are project teams of interest to traditionally underrepresented ethnic populations and FGEn students?
- Are project team members more likely to choose non-traditional engineering majors, such as mechanical, electrical, or computer science?
- Is developing identity through hands-on learning a major indicator for women who persist in engineering, especially underrepresented ethnic groups or FGEn?
- Does participation on engineering project teams lead to a deeper sense of engineering identity than non-participating students?
- Are there other factors (covariates), that contribute to deepen engineering identity?

3.4 Methodology

To address specific research questions, the overall study methodology incorporated a quasi-experimental design (Reichardt, 2009) and employed a mixed-methods approach (Tashakkori & Creswell, 2007) to accumulate both qualitative and quantitative data from multiple sources. The research design was considered quasi-experimental as all cohorts were comprised of female engineering students only and excluded random assignment (Cook, 2015; Reichardt, 2009). The study consisted of two major parts, including a retrospective study of project teams in comparison to college populations, and partial analysis of a survey instrument, using ordinal data obtained from questions related to engineering identity. To answer the first four research questions, the retrospective study was used and will be discussed in this chapter (Chapter III). To answer the last two research questions, the survey was used and will be discussed in Chapter IV. The researcher determined that the use of multiple approaches, in combination, provided a greater understanding of the research problem to be addressed (Creswell, 2011; Tashakkori & Creswell, 2007).

3.4.1 Retrospective Study

Because the teams have existed since 2015, it was necessary to explore the overall success of each cohort by examining students that were actively engaged with each team. It was determined that a retrospective study of team participants was useful to provide information on the students engaged with the teams over time, the duration of time that they were engaged longitudinally, their chosen major, overall academic success within their major, and demographic data to compare intersectionality with other identity groups, such as ethnicity and first-generation.

3.4.1.1 Retrospective Study Design

To answer research questions concerning the active project team cohorts, a retrospective record review (RRR) was employed (Buxton, 2021). The method was used to investigate the information previously collected from project team leaders to answer one or more research questions. The advantages of conducting this type of review included the use of existing data, affordability, and an ability to provide longitudinal information on project team members that would indicate their success in engineering disciplines via active status, if they had changed their major, if they were still active in the university, or that they have graduated. Student identification numbers were used to link demographic data found on the university data system for each student. While student records are protected by The Family and Education and Rights Privacy Act (FERPA), approval was sought and obtained from the Institutional Review Board (#IRB2019-1106D) to compile this information.

To understand academic identity, one of the factors embedded in engineering identity, student data was linked to academic performance with semester and cumulative GPA, year and major classification, and retention in engineering or graduation. To obtain an understanding of student populations participating in project teams, ethnicity and first-generation status was also collected to provide a baseline for the number of historically underrepresented project team participants. Project team participants were then compared with non-project team participants by retrieving college-level data and information from the university data and research services academic enrollment student profiles. Though this information can be derived publicly, a query request was made to this office to ensure accuracy and continuity of data retrieved (Data and Research Services, 2021). Again, the data was retrieved to determine if there were similarities or differences between the project team cohorts and different engineering populations.

In addition to the retrospective study for project team participants, the study includes comparisons to college-wide data for women and comparison to all undergraduate students in engineering. To obtain information on numbers and percentages, some internal college-wide information was used however, it was determined that the college-wide information was not significantly different than certified data that is listed publicly.

To further the comparison, national data for the percentage of women in engineering from 2015 – 2020 (cohort years) was also obtained and included. Due to an inability to disaggregate national data, only the overall percentages for women were used from national annual reports.

3.4.1.2 Retrospective Study Sample Population

The sample population for the study comes from a large engineering college that ranks 11th in the nation overall (US News and World Report, 2021). The sample population of women targeted to participate on project teams comes from the current female college of engineering population. Typically, there are few women who actively seek and engage in competitive project teams. Therefore, a concerted effort is made to recruit new team members during the fall semester and provide 2 – 3 interactions with continuing team members, who serve as peer mentors, to start new participants. It is up to individual students to seek out these recruitment events or to self-select to become involved in team activities. Therefore, the teams encompass a variety of students from different backgrounds and various academic interests within engineering.

Team leaders keep track of participants from year to year and share team rosters with the program. For the retrospective study, individual teams tracked students and reported participation in their meetings and activities. Team rosters shared with the program were used to compile demographic data and categorize students as active participants over the academic year. To conduct an RRR, the researcher used unfiltered data provided by teams to determine the actual number of students that consistently participated on that team for at least one semester. The fall semester rosters were used by combining and condensing data into spreadsheets to categorize each student into teams and determine the fiscal year(s) that they were active. It is important to note that each team was responsible for their own data collection and reporting to the program therefore, the researcher is aware that inconsistencies between teams to track data exist.

For comparison, undergraduate student populations in engineering were retrieved and used, with women engineering student populations ranging between 2,575 (Fall 2015) and 3,515 (Fall 2019), during the timeframe covered by the research study (DARS Enrollment Profile, 2021).

3.4.2 Retrospective Study Data and Results

The following data was retrieved from the office of Data and Research Services (DARS) and compared to data reported and verified for active project team members. Data provided by the university contains unduplicated headcounts of students enrolled by the second day census and includes 20th day reporting for Fall semesters. Data includes distance education students, English Language Institute (ELI), and study abroad students.

Table 3.1 shows the ethnicity breakdown for project team members, all undergraduate women in the COE, and all undergraduate students in the COE. The total number of students in each category is reported on the bottom row of Table 3.1.

Table 3.1 Ethnicity and Gender of Undergraduate Students in the College of Engineering

Year	Fall 2015			Fall 2016			Fall 2017			Fall 2018			Fall 2019		
Cohorts	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**
Asian	14	248	1030	14	295	1242	14	382	1587	44	463	1914	43	498	2169
Black or Multiracial with Black	2	77	270	4	91	332	2	105	364	3	116	419	3	125	426
Hispanic or LatinX	9	573	2523	13	672	2946	35	772	3436	59	870	3745	48	929	3968
International	1	73	320	1	74	378	1	90	421	7	97	437	8	102	418
Multiracial Exclude Black	0	80	317	3	108	361	2	123	420	9	131	461	7	141	531
Native American	1	*	28	1	*	29	0	5	32	0	*	33	0	2	34
Native Hawaiian or Pacific Islander	0	*	11	0	*	13	0	*	15	0	*	16	0	5	14
Unknown/Not Reported	0	5	24	1	9	28	0	8	28	1	7	32	0	9	33
White	18	1514	7211	29	1626	7702	44	1660	8249	57	1678	8433	73	1704	8442
Total Number	**45**	**2575**	**11734**	**66**	**2882**	**13031**	**98**	**3148**	**14552**	**180**	**3371**	**15490**	**182**	**3515**	**16035**

*size <5

As shown in Table 3.1, the size of project teams increased 304.4% over the five-year period, with an average percent growth of 45.0% per year. In comparison, the size of female populations in the COE rose by 36.5% and the overall COE undergraduate population by 36.6%. The highest increase in project team active participation was seen between Fall 2017 and Fall 2018, with an overall increase of 83.7% from 98 to 180 students. Within that high-growth year, increases in participation on project teams are observed in Asian (214.3%), Black (50.0%), Hispanic/LatinX (68.6%), International (600%), Multi (350%), and White (29.5%) populations. In comparison, female COE underrepresented populations of interest and majority populations increased slightly between Fall 2017 and Fall 2018, including Black (10.5%), Hispanic/LatinX (12.7%) and White (1.1%). These populations also slightly increased in the COE overall with Black (15.1%), Hispanic/LatinX (9.0%) and White (2.2%).

Standard formulas for calculating percent growth and average percent growth were used. These formulas are:

Equation 1 Percent Growth (PG)

*PG = (P2 – P1) / P1 * 100*

P = Population

Equation 2 Average Percent Growth (A)

$$A = \frac{1}{n}\sum_{i=1}^{n} \alpha_i$$

n = total number values
a_i = data set values

Table 3.2 shows first-generation status with ethnicity breakdown for project team members, all undergraduate women in the COE, and all undergraduate students in the COE. The total number of students in each category is reported on the bottom row of Table 3.2. Formulas for calculations are listed in the previous section.

Table 3.2 First-generation Undergraduate Students in the College of Engineering with Ethnicity and Gender

Year	Fall 2015			Fall 2016			Fall 2017			Fall 2018			Fall 2019		
Cohorts	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**
Asian	2	57	274	4	58	291	2	82	355	7	89	375	6	88	427
Black or Multiracial with Black	2	34	111	1	37	123	1	43	120	1	39	122	1	36	119
Hispanic or LatinX	2	264	1174	7	277	1310	18	315	1487	30	365	1600	23	396	1664
International			*			*			*		*	6		*	8
Multiracial Exclude Black		9	42		13	48	1	17	61	2	17	72	1	16	74
Native American			*			*			5			5			6
Native Hawaiian or Pacific Islander		*	*		*	*		*	*		*	*		*	6
Unknown/Not Reported			*		*	*		*	*		*	*		*	*
White	2	185	931	1	210	985	6	202	1035	5	189	1002	10	187	986
Total Number	**8**	**550**	**2538**	**13**	**597**	**2765**	**28**	**661**	**3072**	**45**	**703**	**3189**	**41**	**730**	**3294**

*size <5

Five-year growth on project teams of First-generation (FGEn) students showed 412.5%, with an average growth rate of 57.4%. Female COE FGEn populations showed an 32.7% increase overall, with an average growth rate of 7.4%. COE overall FGEn growth increased 29.8%, with an average growth rate of 6.8%. The highest increase FGEn populations in all three categories was seen in Hispanic/LatinX populations. Within this population, an increase of 1050.0% was seen in the participation of team members. Between Fall 2015 and Fall 2018, there was a 1400.0% increase. Female FGEn Hispanic/Latina populations within the college steadily increased with an overall percentage growth of 50.0% and COE overall increase of 41.7%. In comparison, as Hispanic/LatinX populations increased, White female FGEn populations remained roughly stagnant over the five-year period. However, an overall increase in White FGEn students participating on project teams was 400%.

Table 3.3 shows percentage breakdowns of project team members in comparison to women in the COE and COE female populations in comparison to overall COE undergraduate students disaggregated by ethnicity. The table also includes the percentage breakdown of first-generation students in similar comparisons without ethnicity disaggregation as well as the national percentage of women in undergraduate engineering programs for each year. Percentages for project team members were calculated from the total number of women in the college within that ethnic group. Similarly, the percentage of women in the college was calculated from the total number of overall students in the COE population within each category.

Table 3.3 Percentage of Undergraduate Students in the College of Engineering with Ethnicity and Gender

Year	**Fall 2015**			**Fall 2016**			**Fall 2017**			**Fall 2018**			**Fall 2019**		
Cohorts	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**
Asian	5.65	24.08	8.78	4.75	23.75	9.53	3.66	24.07	10.91	9.50	24.19	12.36	8.63	22.96	13.53
Black / Multi with Black	2.60	28.52	2.30	4.40	27.41	2.55	1.90	28.85	2.50	2.59	27.68	2.70	2.40	29.34	2.66
Hispanic / LatinX	1.57	22.71	21.50	1.93	22.81	22.61	4.53	22.47	23.61	6.78	23.23	24.18	5.17	23.41	24.75
International	1.37	22.81	2.73	1.35	19.58	2.90	1.11	21.38	2.89	7.22	22.20	2.82	7.84	24.40	2.61
Multi Exclude Black	0.00	25.24	2.70	2.78	29.92	2.77	1.63	29.29	2.89	6.87	28.42	2.98	4.96	26.55	3.31
Native Am	*25.0	*14.29	0.24	*25.0	*13.79	0.22	0.00	15.63	0.22	0.00	*12.12	0.21	0.00	5.88	0.21
Native Hawaiian / Pacific Islander	0.00	*36.36	0.09	0.00	*30.77	0.10	0.00	*26.67	0.10	0.00	*25.00	0.10	0.00	35.71	0.09
UK / No Report	0.00	20.83	0.20	11.11	32.14	0.21	0.00	28.57	0.19	14.29	21.88	0.21	0.00	27.27	0.21
White	1.19	21.00	61.45	1.78	21.11	59.11	2.65	20.12	56.69	3.40	19.90	54.44	4.28	20.18	52.65
Total Percent	**1.75**	**21.94**	**100.0**	**2.29**	**22.12**	**100.0**	**3.11**	**21.63**	**100.0**	**5.34**	**21.76**	**100.0**	**5.18**	**21.92**	**100.0**
% FGEn Status	1.5	21.67	100.0	2.18	21.59	100.0	4.24	21.52	100.0	6.40	22.04	100.0	5.62	22.16	100.0
% US Women Enrolled in UG Engineering**		21.4			22.3			22.9			23.4			23.8	

*% calc. w/ max 4

**ASEE, *Engineering by the Numbers* (2015 – 2020)

Table 3.3 is color coded to indicate differences in each of the categories, compared with the COE percentage. For example, green indicates the percentages in each respective category (PT and COE Female) that are higher than the overall college percentage in that category. In Fall 2015, significant differences in percentage were found in all ethnic categories, except White, for women in the COE. A significant percentage difference was found in PT in the category of Native American. However, percentages can be misleading as the Native American category in COE Females represents a numerical value of less than 4 students. One student on the PT was indicated and therefore, represented 25% of the overall female representation of Native students in the COE that year. Red indicates the COE percentage is lower than national percentages for women in undergraduate engineering programs that year. Blue indicates a percentage higher than national figures for the percentage of women in engineering undergraduate programs. Fall 2015 was the only year highlighted in the study that represented a percentage of women in the COE that was higher than the national average (ASEE, 2015-2021).

Table 3.4 shows classification distributions for project team members in comparison to women in the COE and COE female populations in comparison to overall COE undergraduate students. Classification data for COE female and COE overall populations was obtained from 12th Day Institutional Data and is considered unofficial. Institutionally, students are classified based on the number of credit hours earned. Definitions for each category (U1, U2, etc.) are in the "Nomenclature" section at the beginning of the work.

Table 3.4 Undergraduate Student Classification*

Year	Fall 2015			Fall 2016			Fall 2017			Fall 2018			Fall 2019		
Cohort	PT	COE Female	COE All	PT	COE Female	COE All	PT	COE Female	COE All	PT	COE Female	COE All	PT	COE Female	COE All
U1	19	811	3072	23	781	3389	40	808	3911	78	882	4066	88	809	3834
U2	16	565	2532	16	646	2540	27	616	2759	52	652	3158	53	742	3336
U3	7	472	2327	24	573	2690	17	610	2625	30	633	2827	25	669	3248
U4	3	777	3890	3	913	4386	14	1126	5048	20	1214	5191	16	1250	5219
U5	0	3	32	0	4	33	0	2	26	0	5	21	0	8	23
Total Number	**45**	**2628**	**11853**	**66**	**2917**	**13038**	**98**	**3162**	**14369**	**180**	**3386**	**15263**	**182**	**3478**	**15660**

*12th Day Institutional Data

Results show that the majority of project team members are skewed towards U1 and U2 students. Results also indicate that over the course of the five-year period, upper-division students, especially U4 students, became more interested. Since the average time on teams is approximately 2 years, the majority of team members are engaged during their U1 and U2 years. Differences in total number of students within COE data are attributed by how the data was mined from 12th day figures.

Table 3.5 shows major choice for of project team members in comparison to women in the COE and COE female populations in comparison to overall COE undergraduate students. Classification data for COE female and COE overall populations was obtained from 12th Day Institutional Data and is considered unofficial. Definitions for each major (AERO, AREN, etc.) are in the "Nomenclature" section at the beginning of the work.

Table 3.5 Undergraduate Student Major*

Year	Fall 2015				Fall 2016				Fall 2017			
Cohort	PT		COE	COE	PT		COE	COE	PT		COE	COE
	Start	Finish	Female	All	Start	Finish	Female	All	Start	Finish	Female	All
AERO	2	3	58	481	1	4	60	523	3	5	65	566
AREN	0	0	0	0	0	0	0	0	0	0	0	0
BAEN	1	1	65	169	1	2	68	160	2	2	67	150
BMEN	0	1	118	268	0	0	160	336	0	3	199	415
CHEN	1	5	216	607	1	6	268	714	1	4	305	795
CLEN (ENGE, TEAB)	24	0	928	3578	27	0	1001	4192	50	0	1021	4815
CSCE (CECN, CPSC)	3	6	118	951	9	13	137	973	11	20	150	1047
CVEN	1	2	219	727	0	0	226	725	1	2	245	766
ECEN (CEEN, ELEN)	5	7	124	904	9	15	137	953	10	12	157	1093
ETID (ESET, MMET, MXET, IDIS)	2	3	218	1354	4	8	266	1560	6	14	309	1703
EVEN	0	0	0	0	0	0	0	0	0	0	0	0
ISEN	3	7	189	776	3	3	185	726	1	6	188	662
ITDE	0	0	0	0	0	0	0	0	0	0	0	0
MEEN	2	5	170	1022	9	11	207	1144	10	16	255	1316
MSEN	0	0	0	0	0	0	0	0	0	0	0	0
NUEN	1	1	60	270	1	1	56	296	2	3	61	308
OCEN	0	0	33	110	1	2	36	110	1	2	40	137
PETE	0	0	112	636	0	0	110	626	0	0	100	596
Total Number	**45**	**41**	**2628**	**11853**	**66**	**65**	**2917**	**13038**	**98**	**89**	**3162**	**14369**

*12th Day Institutional Data

Table 3.5 (continued) Undergraduate Student Major*

Year	**Fall 2018**				**Fall 2019**			
Cohort	**PT**		**COE**	**COE**	**PT**		**COE**	**COE**
	Start	**Finish**	**Female**	**All**	**Start**	**Finish**	**Female**	**All**
AERO	4	7	64	611	5	8	79	634
AREN	0	0	0	0	0	2	2	3
BAEN	1	2	73	153	0	0	61	140
BMEN	3	8	221	457	2	11	227	475
CHEN	4	11	300	835	0	8	330	838
CLEN (ENGE, TEAB)	92	0	1100	5020	123	20	1121	5108
CSCE (CECN, CPSC)	18	29	168	1095	12	35	198	1228
CVEN	3	8	246	801	1	4	235	786
ECEN (CEEN, ELEN)	13	20	186	1290	9	18	186	1315
ETID (ESET, IDIS, MMET, MXET)	21	31	360	1935	9	16	354	2035
EVEN	0	0	0	0	0	1	9	14
ISEN	5	8	200	642	4	8	214	674
ITDE	0	2	7	24	0	0	14	37
MEEN	16	31	268	1417	17	40	266	1448
MSEN	0	4	19	44	0	2	30	97
NUEN	0	1	60	298	0	0	51	248
OCEN	0	0	35	144	0	1	34	156
PETE	0	1	79	497	0	0	67	424
Total Number	**180**	**163**	**3386**	**15263**	**182**	**174**	**3478**	**15660**

*12th Day Institutional Data

Table 3.6 shows the percentage of project team members in comparison to women in the COE and COE female populations in comparison to overall COE undergraduate students disaggregated by major choice. Percentages are calculated from formulas previously discussed and refer to data obtained and shown in Table 3.5. Percentages highlighted in red indicate steady growth can be seen in non-traditional engineering majors, including computing, mechanical and electrical, with larger numbers seen in computing and electrical. Growth can also be seen in areas of aerospace engineering and engineering technology, two departments of interest.

As seen in Table 3.6, aerospace engineering has the lowest percentage of women in that department compared with other departments. Computing and electrical engineering also show a low percentage of women compared with other department averages. It is important to note that the engineering technology and industrial distribution (ETID) major is comprised of both electrical and mechanical disciplines. These are electronic systems and engineering technology (ESET), manufacturing and mechanical engineering technology (MMET), and multidisciplinary engineering technology (MXET), with an emphasis in mechatronics. Though only a small number of students were designated as Industrial Distribution (ID), the majority of participating project team members represented the former three majors.

Table 3.6 Percentage of Undergraduate Students by Major Choice*

Year	Fall 2015			Fall 2016			Fall 2017			Fall 2018			Fall 2019		
Cohort	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**
AERO	5.17	12.06	4.06	6.67	11.47	4.01	7.69	11.48	3.94	10.94	10.47	4.00	10.13	12.46	4.05
AREN													100.00	66.67	0.02
BAEN	1.54	38.46	1.43	2.94	42.50	1.23	2.99	44.67	1.04	2.74	47.71	1.00		43.57	0.89
BMEN	0.85	44.03	2.26		47.62	2.58	1.51	47.95	2.89	3.62	48.36	2.99	4.85	47.79	3.03
CHEN	2.31	35.58	5.12	2.24	37.54	5.48	1.31	38.36	5.53	3.67	35.93	5.47	2.42	39.38	5.35
CLEN (ENGE, TEAB)		25.94	30.19		23.88	32.15		21.20	33.51		21.91	32.89	1.78	21.95	32.62
CSCE (CECN, CPSC)	5.08	12.41	8.02	9.49	14.08	7.46	13.33	14.33	7.29	17.26	15.34	7.17	17.68	16.12	7.84
CVEN	0.91	30.12	6.13		31.17	5.56	0.82	31.98	5.33	3.25	30.71	5.25	1.70	29.90	5.02
ECEN (CEEN, ELEN)	5.65	13.72	7.63	10.95	14.38	7.31	7.64	14.36	7.61	10.75	14.42	8.45	9.68	14.14	8.40
ETID (ESET, IDIS, MMET, MXET)	1.38	16.10	11.42	3.01	17.05	11.97	4.53	18.14	11.85	8.61	18.60	12.68	4.52	17.40	12.99
EVEN													11.11	64.29	0.09
ISEN	3.70	24.36	6.55	1.62	25.48	5.57	3.19	28.40	4.61	4.00	31.15	4.21	3.74	31.75	4.30
ITDE										28.57	29.17	0.16		37.84	0.24
MEEN	2.94	16.63	8.62	5.31	18.09	8.77	6.27	19.38	9.16	11.57	18.91	9.28	15.04	18.37	9.25
MSEN										21.05	43.18	0.29	6.67	30.93	0.62
NUEN	1.67	22.22	2.28	1.79	18.92	2.27	4.92	19.81	2.14	1.67	20.13	1.95		20.56	1.58
OCEN		30.00	0.93	5.56	32.73	0.84	5.00	29.20	0.95		24.31	0.94	2.94	21.79	1.00
PETE		17.61	5.37		17.57	4.80		16.78	4.15	1.27	15.90	3.26		15.80	2.71
Total %	**1.56**	**22.17**	**100.00**	**2.23**	**22.37**	**100.00**	**2.81**	**22.01**	**100.00**	**4.81**	**22.18**	**100.00**	**5.00**	**22.21**	**100.00**

*12th Day Institutional Data

Table 3.7 shows average semester and cumulative GPA of project team members in comparison to women in the COE and COE female populations in comparison to overall COE undergraduate students. Information for COE Female and COE All GPA was obtained from unofficial semester grade reporting for that semester and fiscal year from the institution. GPAs highlighted in red indicate project team member results that are higher than both the average GPA for female and all undergraduates. GPAs indicate COE Female results that are higher than the average GPA for all undergraduate COE students.

Table 3.7 Average Semester and Cumulative GPA Comparison*

Year	**Fall 2015**			**Fall 2016**			**Fall 2017**			**Fall 2018**			**Fall 2019**		
Cohort	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**
SEM GPA	3.08	3.05	2.99	3.20	3.14	3.06	3.14	3.15	3.05	3.14	3.15	3.04	3.37	3.19	3.11
CUM GPA	3.10	3.05	3.00	3.12	3.12	3.06	3.16	3.15	3.09	3.17	3.18	3.12	3.49	3.21	3.16
Total Number	**45**	**2635**	**11852**	**66**	**2914**	**13033**	**98**	**3163**	**14369**	**180**	**3387**	**15281**	**182**	**3479**	**15660**

*Semester Grade Institutional Data

Further analysis of Table 3.7 will be discussed in Chapter IV, to provide insight into significant differences between cohort GPA's and median values.

Table 3.8 shows graduation rates for of project team members in comparison to women in the COE and COE female populations in comparison to overall COE undergraduate students. Information was obtained from Data and Research Services for official six-, five-, four-year graduation rates for each cohort. COE cohorts were based upon first-time in college

(FTIC) data for first-year students of that cohort year.   Percentages indicate PT members graduate and are retained at a significantly higher rate than COE Female and COE All. Graduation rates for PT members are well above college rates and far exceed graduation goals set by the COE annually.

Table 3.8 Percent Graduation Comparison*

Year		**Fall 2015**			**Fall 2016**			**Fall 2017**			**Fall 2018**			**Fall 2019**	
Cohort	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**	**PT**	**COE Female**	**COE All**
Number Graduated / Active in Engineering	41	814	2967	65	796	2507	89	827	3060	163	908	4006	174	838	3781
Percent Graduated / Active in Engr.	91.11	61.55	65.96	98.50	67.09	67.21	90.82	70.37	69.22	90.56	71.59	71.34	95.60	75.89	74.24

*COE data obtained from https://accountability.tamu.edu/All-Metrics/Mixed-Metrics/Undergraduate-Student-Retention-Graduation

Figure 3.1 shows team distributions and growth over time with total number of active participants. Total number of all teams summed for that cohort year is shown in the farthest right column (light) in the figure.

Figure 3.1 PT Distribution

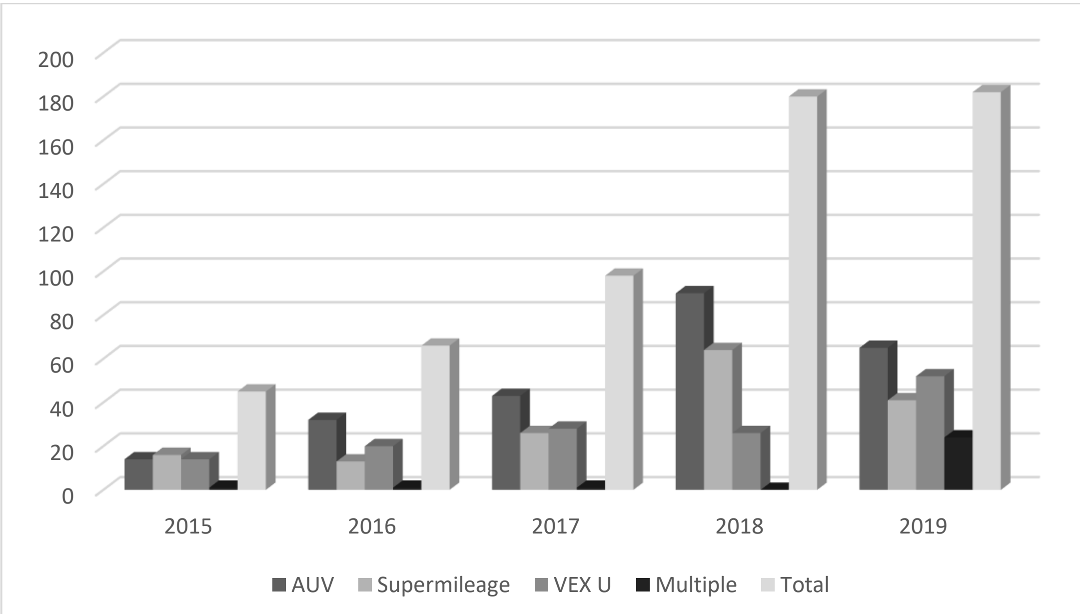


Table 3.9 shows average time of project team members spent on teams. For all cohorts, the average minimum time spent on project teams was >1.5 years.

Table 3.9 Average Time Students on Team (in years)

Year	2015	2016	2017	2018	2019
Original Team Members (Fall roster)	1.89	1.97	1.86	1.56	1.65
Team Members Retained in Engineering (Active or Graduated)	1.98	1.98	1.96	1.6	1.65

3.5 Summary

Findings from the retrospective study provided information on the participation of project team members and a baseline for comparison of team participants with the number and distribution of women in the college of engineering and the overall makeup of the COE itself. In addition, the retrospective study provided evidence for significant growth over cohorts for the participation of traditionally underrepresented students and FGEn. The data show there is evidence that project team members are participating in non-traditional engineering majors or seeking out these majors throughout their undergraduate academic pursuits. Further, the majority of project team members consisted of first- and second- year students. For all cohorts, the average minimum time spent on project teams was >1.5 years.

Data also indicated that project team members have slightly higher semester or cumulative GPA's than COE Females or COE All and that they are retained in engineering and graduate at a much higher percentage. Further analysis will be explored for GPA differences in the next chapter (Chapter IV). Analysis of survey data and further discussion of findings in relation to research questions are discussed in Chapter IV. Though the overall retrospective study provided reasonable results, limitations observed in data collection as well as comparison between cohorts will be further discussed in Chapter V.

CHAPTER IV

4.0 SURVEY METHODOLOGY

4.1 Introduction and Rationale

The previous chapter provided an overall description of engineering project teams and demographics that describe active members. In addition, project team member demographics were compared to COE Females and COE students overall. Though some of the information may assist in answering specific research questions related to academic identity, it does not provide information on developing a professional identity, the second factor important to develop engineering identity. Therefore, it was determined that a survey administered to undergraduate women would be useful to provide information about students and their reasons for participating, or not participating, on engineering project teams. Another valuable contribution could be to determine if there are differences among students participating on project teams and non-participating students. Because of the research questions, it was necessary to determine if there are aspects of engineering identity that are more strongly developed in project team members or not. Finally, the survey was used to determine if there are multiple factors, both internal and external, that relate to or influence the development of engineering identity in project team participants and non-participants.

4.1.1 Survey Design

To answer research questions concerning the development of engineering identity in each cohort, a survey was used that had previously been developed and administered to discern the success of project teams only. Approval was sought and obtained from the

Institutional Review Board (#IRB2019-1106D) to use this survey for both project team participants and non-participants. The survey contained demographic information as well as 18 questions designed as four-point forced Likert to exclude neutral responses. The research community has often debated the reliability and efficacy of forced Likert scale questionnaires (Albaum, 2006; Chang, 1994; Dolnicar, 2007; Grassi, 2007; Hancock, 1991) however, a forced Likert design was chosen for three reasons: ease for survey-takers to answer questions, time required to take the survey, and an ability to discern between positive and negative responses. Though the survey was designed to contain questions on confidence, interest, self-efficacy, and engineering environment, the questions utilized for this study were related to the development of engineering identity only.

Within this category, questions used closely resemble those tested and validated in the development of other identity instruments, especially those used to discern the construct of "recognition" in engineering identity (Godwin, 2016). The survey also contains several open-ended questions to provide qualitative data to further discern differences between the cohorts. Qualitative data is useful to determine students' overall understanding of project teams and why project teams may be of benefit to their development as professional engineers. Results from qualitative questions are briefly discussed at the end of this chapter to provide more insight on differences between students that participate and non-participants in project teams.

Finally, the survey requested identifying information for survey takers that could be used to provide demographic information for comparison to project team members as well as determine the overall makeup of survey takers. This information included major and classification, ethnicity, and first-generation status. The survey used in this study was administered on three occasions. The first was to project team members in Fall 2018, the second was during a retreat in Fall 2019, and the third was via an email request to all undergraduate women in the COE in Spring 2020.

4.1.2 Survey Administration

4.1.2.1 Subjects

As previously discussed, the survey was distributed on three occasions. First, the survey was administered in Fall 2018, to students actively engaged in project teams or those who attended a project team retreat held in early September. However, as project team members are recruited, all women undergraduate students were invited to attend recruitment events and become involved in project teams. In Fall 2018, there were 3371 female students in the COE and 180 were participating on project teams. The invitation was sent through a listserv obtained by the program to ensure communication with undergraduate women.

The second occasion was in Fall 2019 however, this was only administered to a small number of leaders who attended the fall leadership retreat that year. The third occasion was in Spring 2020 and the survey was sent to 3515 students from the current listserv of COE women and 182 students were engaged in project teams the semester before. The survey was sent out twice over email in Spring 2020 to obtain an adequate number of responses from non-participating students for comparison. From a combination of all three request, a total number of survey responses received was 264 (n=264), including project team participants and non-participants. Response rates varied from the cohorts, however, Fall 2018 contained a response rate of 27.7% of all project team participants.

4.1.2.2 Condensed Data

Because the survey was administered on three separate occasions, responses contained duplicates from individuals who participated in the survey more than once. It was decided that survey answers should be considered only once from participating respondents and that duplicates should be removed. In addition, it was decided that the first survey received in Fall 2018 would be used instead of those received later during the students' academic career (ie: those duplicated in Fall 2019 and Spring 2020). Since all Fall 2019 surveys were from leaders who participated and answered questions in Fall 2018, and because the survey was not sent to project team members at large, those 17 surveys collected in Fall 2019 were eliminated.

Of the 111 surveys received in Fall 2018, 108 were used in the study after all duplicates were removed (n=108). Of those surveys received in Spring 2020, 61 students did not complete the survey and were eliminated; 127 were found to contain complete information and consisted of unduplicated project team participants and non-participants. Data used in the research represented project team participants (n = 148) and non-participants (n=87) with a total number of subjects equal to 235 (n=235). As explained in section 4.2.2.3 the sample size was adequate for this study and comparison.

4.1.2.3 Demographic Information

Due to the nature of the study, similar demographic information was retrieved for non-participants, including their academic performance, major, year, ethnicity, and first-generation status. This information was sought for comparison to project team members and approved under #IRB2019-1106D.

4.2 Survey Analysis

4.2.1 JMP Software

The following sections contain results obtained from using a statistical software package called JMP. JMP is a suite of programs developed for the specific purpose of statistical analysis with a graphical user interface (JMP, 2022). The package has been used for design of experiments and application in engineering, science, and social science. This software was selected over other statistical packages due to availability through a user license, familiarity by the researcher, and faculty support to ensure reasonable output.

4.2.2 Academic Identity

4.2.2.1 Objective

The primary objective in this portion of the study is to examine if students who participated in the survey are academically different based on their participation on project teams or non-participation. Further, this section will examine project teams in comparison to COE Female and COE overall populations. Because literature on engineering identity argues both academic identity and professional identity are underlying factors, GPA is a metric used to determine if students have developed a stronger sense of academic identity through higher academic performance (Mamaril et al, 2016; Yoon & Sorby, 2020). The hypothesis is that students with higher GPA's are more likely to have a more pronounced sense of engineering identity. Further, those who participate on engineering project teams are representative of the engineering population overall and do not contain academic differences from the COE female population, in general.

4.2.2.2 Examination of Survey Response GPA

In this portion of the study, cumulative GPA at the time of the survey response was used as a numeric continuous variable. Cumulative GPA is calculated by multiplying each credit hour by total grade points received (i.e.: A = 4 points, B = 3 points, etc.) and dividing by the total number of cumulative credit hours acquired over time. When a distribution analysis was run in JMP, an initial review of GPA for n=235 survey respondents indicated values were heavily skewed. Values were skewed towards GPA above 3.0 with a median value of 3.33 and a range from 1.9474 to 4.0. Further inspection of raw data indicated that 16 surveys (6.8%) were returned from students with a cumulative GPA of 4.0. A Q-Q plot was used as a non-parametric test to visually inspect the probability of the distributions and normality. The Q-Q plot revealed the GPA data contained several outliers and did not fit the normal distribution.

4.2.2.3 Sample Size and Power

Though data was skewed, it was important to ensure sample size was adequate. JMP was used to calculate sample size from the DOE menu. The power explorer for two independent sample means was used for a one-sided test. With alpha set at .05 and power at .90 (90%), the difference to detect (delta) was initially set at .5. This revealed a sample size for group 1 = 69 and group 2 = 70, for a total of n=139. If the delta is lowered to .4, this increases the sample size to 108 for both groups, with n=216. Though collected surveys included project team participants (n = 148) and non-participants (n=87) with a total number of subjects equal to 235 (n=235), delta = .4 results in a power of 90.45%. If delta is lowered to .3, power becomes 71.54%. Therefore, it is determined that the sample size for this study was acceptable.

4.2.2.4 Assumptions

Assumptions are that samples are independent, exhibit homogeneous variance, and represent a normal distribution. A Levene's test to determine if GPA data was highly skewed by mean comparison between groups revealed p=.0108. Because the p-value is below p<.05, the data is not thought to be accurate. The more robust Brown-Forsythe was used to test if the samples were homogeneous. The p-value [p=.0110<.05] indicated that the homogeneous variance assumption was not satisfied. Finally, normality was checked using two methods. First, the QQ plot was examined to check for outliers as well as the ends of the tails. Further evidence was obtained by conducting a Shapiro-Wilk Test with p<.0001. This confirmed that the data was not from a normal distribution and the null hypothesis (H_0) was rejected with a confidence level of 95% and a level of significance $\alpha = .05$. Checking residuals with Shapiro-Wilk yielded the same result therefore, transformations were not necessary and did not offer any further information. Therefore, because assumptions are not satisfied, GPA cannot be used as an indicator to estimate PT vs. NOT participation. Table 4.1 includes data obtained from the distribution analysis and summary statistics.

Table 4.1 GPA Distribution and Summary for Survey Respondents

n = 235	**Numeric Value**
Mean X	3.3203872
Median	3.3333
Std Dev	.4709594
Std Error X	.030722
Lower 95% X	3.3809143
Upper 95% X	3.2598602

4.2.2.5 GPA Examination: Project Teams vs COE

Because GPA data from survey respondents was found to be heavily skewed, not normal or homogeneous, a one-way Analysis of Variance (ANOVA) test was used to determine levels of variance of GPA means between project teams, COE Females, and all COE students (Ott & Longnecker, 2016). This data was compiled and discussed in Chapter III, specifically Table 3.7. When data from each year was compared in JMP, a one-way ANOVA was used to determine if there were any statistically significant differences between the means of the three cohorts for both Semester GPA and Cumulative GPA.

4.2.2.5.1 Semester GPA

As seen in Table 4.2 for Semester GPA, probability of the F Ratio in all five years was significant $p<.05$. This indicated that the mean GPA in the populations were significantly different. It is interesting to note that as the years progress, the F Ratio appears larger, which indicates that the variation of group means is more than expected to see by chance. R squared values, that typically range from 0 to 1, are also included to show a low correlation between the independent variable (cohort) and dependent variables (GPA). Therefore, the cohorts do not explain much in the variation of GPA with confidence level of 95% and level of significance α = .05.

Table 4.2 Semester GPA Cohort Comparison (PT, COE Female, COE All) One-Way ANOVA in JMP

Year	**2015**	**2016**	**2017**	**2018**	**2019**
R^2	0.000785	0.001661	0.002176	0.002375	0.002213
F Ratio	5.69	13.2979	19.1869	22.3987	21.3981
Prob > F	0.0034*	<.0001*	<.0001*	<.0001*	<.0001*

Table 4.3 contains more detailed information on population means for each cohort in each year of the study. This table shows that PT participants had a wider range of GPA's and that lower and upper 95% GPA values confirm the range contains the true value of the population mean. For semester GPA, the 2019 PT cohort looks significantly different from the other cohort years and warrants further clarification.

Table 4.3 Semester GPA Cohort Comparison (PT, COE Female, COE All) Results of One-Way ANOVA in JMP

Year	**2015**			**2016**			**2017**			**2018**			**2019**		
Category	**PT**	**COE Female**	**COE**	**PT**	**COE Female**	**COE**	**PT**	**COE Female**	**COE**	**PT**	**COE Female**	**COE**	**PT**	**COE Female**	**COE**
Mean $\bar{X}$	3.054	3.046	2.989	3.200	3.143	3.064	3.138	3.147	3.052	3.140	3.153	3.048	3.366	3.187	3.114
Std Error	0.119	0.016	0.007	0.094	0.014	0.007	0.079	0.014	0.007	0.063	0.014	0.007	0.057	0.013	0.006
Lower 95%	2.820	3.016	2.974	3.015	3.115	3.051	2.983	3.194	3.039	3.017	3.124	3.034	3.253	3.162	3.102
Upper 95%	3.288	3.077	3.003	3.385	3.171	3.077	3.294	3.174	3.065	3.262	3.181	3.061	3.478	3.213	3.126
N	**45**	**2621**	**11822**	**66**	**2910**	**13015**	**98**	**3153**	**14349**	**180**	**3380**	**15262**	**182**	**3474**	**15640**

For a closer examination of differences in mean values between each cohort, a Tukey-Kramer HSD test was run. Table 4.4 shows significant differences in mean values in semester GPA between COE Females and COE All students for all years ($p<.05$). Between 2018 – 2019 cohorts, there were significant differences shown between all of the cohorts, especially between PT vs. COE Female and PT vs. COE All students. Therefore, there are significant differences between the mean values for Semester GPA for all cohorts and H_0 was rejected; with confidence level of 95% and significance of $\alpha = .05$.

Table 4.4 Semester GPA Cohort Comparison (PT, COE Female, COE All) Results of Tukey-Kramer HSD in JMP

Year	2015	2016	2017	2018	2019
PT vs. COE Female	0.998	0.821	0.9937	0.9776	.0069*
PT vs. COE	0.8494	0.3236	0.5252	0.3082	<.0001*
COE Female vs. COE	.0024*	<.0001*	<.0001*	<.0001*	<.0001*

4.2.2.5.2 Cumulative GPA

Similar results as those obtained in the previous section were obtained when examining Cumulative GPA. As seen in Table 4.5, probability of the F Ratio in all years were significant ($p<.05$), also indicating that the mean GPA in all populations were significantly different. Again, as the years progress, the F Ratio appears larger, indicating that the variation of group means is more than expected to see by chance. R squared values also show a low correlation between the independent variable (cohort) and dependent variables (GPA). Again, the cohorts do not explain much in the variation of Cumulative GPA with a confidence level of 95% and level of significance $\alpha = .05$.

Table 4.5 Cumulative GPA Cohort Comparison (PT, COE Female, COE All) One-Way ANOVA in JMP

Year	2015	2016	2017	2018	2019
R^2	0.0008	0.00148	0.001831	0.002019	0.004097
F Ratio	5.8053	11.8312	16.1434	19.0119	39.6746
Prob > F	.0030*	<.0001*	<.0001*	<.0001*	<.0001*

Table 4.6 contains more detailed information on population means for each cohort in each year of the study. This table shows that PT participants had similar results, except for the 2019 cohort. Again, the mean value looks significantly different and warrants further investigation.

Table 4.6 Cumulative GPA Cohort Comparison (PT, COE Female, COE All) Results of One-Way ANOVA in JMP

Year	2015			2016			2017			2018			2019		
Category	PT	COE Female	COE	PT	COE Female	COE	PT	COE Female	COE	PT	COE Female	COE	PT	COE Female	COE
Mean $\bar{X}$	3.101	3.049	3.005	3.148	3.121	3.062	3.159	3.151	3.086	3.172	3.187	3.117	3.490	3.212	3.160
Std Error	0.093	0.012	0.006	0.074	0.011	0.005	0.060	0.011	0.005	0.045	0.010	0.005	0.043	0.010	0.005
Lower 95%	2.918	3.025	2.993	3.003	3.099	3.052	3.04	3.131	3.076	3.083	3.166	3.107	3.406	3.193	3.151
Upper 95%	3.284	3.073	3.016	3.292	3.142	3.072	3.277	3.172	3.095	3.260	3.207	3.126	3.574	3.231	3.169
N	**45**	**2622**	**11834**	**66**	**2905**	**13000**	**98**	**3161**	**14344**	**180**	**3378**	**15241**	**182**	**3474**	**15634**

For a closer examination of differences in mean values between each cohort, a Tukey-Kramer HSD test was also run. Table 4.7 shows significant differences in mean values in semester GPA between COE Females and COE All students for all years ($p<.05$). Again, the 2019 cohort showed significant differences in mean value for Cumulative GPA. Significance was seen in the 2019 cohort between PT vs. COE Female ($p<.05$) and PT vs. COE All ($p<.05$) mean GPA. Therefore, there are significant differences between the mean values for Cumulative GPA and H_0 was rejected, with a confidence level of 95% and significance of $\alpha = .05$.

Table 4.7 Cumulative GPA Cohort Comparison (PT, COE Female, COE All) Results of Tukey-Kramer HSD in JMP

Year	2015	2016	2017	2018	2019
PT vs. COE Female	0.844	0.9288	0.9925	0.9428	<.0001*
PT vs. COE	0.5569	0.4771	0.4517	0.4458	<.0001*
COE Female vs. COE	.0031*	<.0001*	<.0001*	<.0001*	<.0001*

4.2.3 Professional Identity

4.2.3.1 Objective

The second part of the survey analysis was used to determine if there are significant differences between PT participants and non-participants in the way they perceive themselves as engineers. The hypothesis is that students who participate in PT are more likely to develop a sense of engineering identity over their academic career. Further, because the concept of identity includes both external and internal elements, it is likely that PT participants show stronger statistical effects than non-participants. For the study, a confidence level of 95% with level of significance $\alpha = .05$ was assumed.

The data was transformed to represent forced Likert responses as categorical data with numeric values for 4=strongly agree, 3=agree, 2=disagree, and 1=strongly disagree. Though Likert data of this nature is usually treated as ordinal, numeric responses for these categories were used for ease of input into JMP and ability to interpret results.

4.2.3.2 Response Variable (Nominal)

In this study, “category” was designated as nominal and used as the response variable. Because the question of identity development formation difference is thought to be between PT participants and non-participants, only two categories were used, PT and NOT. Though further examination of each project team themselves could be warranted, this study asks only the difference in identity development between two cohorts, project team participants and non-participants.

4.2.3.3 Covariates (Categorical Data)

Because of the research questions, all covariates used in the study represented questions to discern the 1) depth of identity formation for each group and 2) internal/external factors rooted in the theoretical framework of the literature, as seen in Chapter II. Therefore, covariates represented three areas: overall identity, internal identity, and external identity factors. Table 4.8 lists the three questions from the survey instrument used in the analysis.

Table 4.8 Survey Questions to Define Covariates (Identity, Internal, External)

Covariate	Survey Question
Identity	"I am an engineer"
Internal Factor	"Sometimes, I have doubts about my ability as an engineer"
External Factor	"Engineering culture is sometimes difficult for me as a female"

- Identity (4 fixed/nominal levels: Strongly Agree, Agree, Disagree, Strongly Disagree)
- Internal Identity (4 fixed/nominal levels: Strongly Agree, Agree, Disagree, Strongly Disagree)
- External Identity (4 fixed/nominal levels: Strongly Agree, Agree, Disagree, Strongly Disagree)

Total Model = 4 x 4 x 4 factors = 64

Before further analysis is conducted it is important to understand the distribution of answers to each question. Table 4.9 shows raw data for each question and answer.

Table 4.9 Covariate Raw Data Distribution for Question Response

	Strongly Agree	Agree	Disagree	Strongly Disagree
Identity	121	88	25	1
Internal	55	146	26	8
External	54	139	32	10

4.2.3.4 Model Selection and Logistic Regression

To further understand the differences between project team participants and non-participants, a full factorial model was ultimately selected. Initially, a logistic regression was used on individual questions (Ott & Longnecker, 2016). However, because the data was similar, logistic regression did not reveal significant differences among cohorts. For example, a logistic regression (Fit Y by X) was run for the identity question. PT vs. NOT (nominal) was considered the dependent variable and results from "I am an engineer" (numerical continuous) was the independent variable. Chi Square analysis resulted in ChiSquare = 2.905629 and Prob>ChiSquare = .0883 ($p>.05$). Therefore, it was determined that a full factorial model would be better suited to analyze data results. In addition, the full factorial model was further analyzed by systematically reducing the model in steps to discern differences.

4.2.3.5 Full vs. Reduced Model (Internal vs. External Identity)

Raw data was imported into JMP statistical software and tests were run with a significance level of 0.05 ($\alpha = 0.05$). The full model represents PT or NOT as a predictor and a full factorial model with three factors (identity*internal*external). The full factorial design was used to investigate effects of these factors and all possible interactions to predict student participation or not.

To understand the model, JMP calculates results based upon traditional statistical formulas. The formula for full-model analysis is depicted by $Yijkl = \mu ijk + \epsilon ijkl$ and is a standard mathematical formula for this type of analysis (Ott & Longnecker, 2016). The formula is described below and contains further explanation of all factors.

Full Model (Ott & Longnecker, 2016)**:**

$Yijkl = \mu ijk + \epsilon ijkl$, where

$\mu ijk = \mu + \alpha i + \beta j + \gamma k + (\alpha\beta)ij + (\alpha\gamma)ik + (\beta\gamma)jk + (\alpha\beta\gamma)ijk$

In the full model above, Yijkl denotes the response (PT or NOT); μijk, and ϵijkl indicate overall mean and error (respectively) from the lth observation with factors (i, j, k). Further, μ denotes the overall intercept; αi denotes identity (i => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); βj denotes internal identity (j => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); γk indicates external identity effect (k => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); (αβ), (αγ), (βγ) parameters denote two-way interaction of Identity*Internal, Identity*External and Internal*External, respectively; (αβγ) denotes three-way interaction of Identity*Internal*External. The three-way interaction was run by using Fit Model in JMP, with personality Nominal Logistic and Y=PT as a target.

Because this model indicated bias in the estimates, lost degrees of freedom (DF's) and zeroed estimate values, interactions were sequentially removed one at a time to adjust the model. A reduced model was used to further evaluate results and is mathematically described as:

Reduced Model (Ott & Longnecker, 2016):

$Yijl = \mu + \alpha i + \beta j + (\alpha\beta)ij + \epsilon ijl$

In this model, μ denotes the overall intercept; αi denotes Identity (i => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); βj denotes Internal effect (j => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); (αβ) parameter indicates the two-way interaction of Identity*Internal; Yijl and ϵijl denote the response and error (respectively) from the lth observation with factors (i and j).

4.2.3.6 Model Analysis

Conducting a full factorial analysis in JMP using Fit Model, Chi Square analysis for individual questions resulted in p-values>.05 with Identity (p=.1207), Internal (p=.2726), and External (p=.8636). This may be interpreted that PT students answered individual questions similarly to non-participants and that sample values are not different than expected values. Three-way interaction (Identity*Internal*External) was also found to be insignificant p=.1455. Two-way interactions generated resulted in p-values between Identity*Internal (p-value = .0109), Identity*External (p = .3167), Internal*External (p=.3758). Because Identity*Internal was p<.05, H_0 was rejected. It is thought that a relationship exists between identity formation and internal identity and that internal identity may have a stronger effect than external identity among PT and non-participants.

Using Identity*Internal as the reduced model, the interaction was significant with Chi Square whole model p=.0321. However, individual effects from Likelihood Ratio Tests did not reveal significance. A confusion matrix was used to describe the performance of the model. Table 4.10 lists the confusion matrix and shows that the predicted rate of Type I error (false positive) was 67.8% and Type II error (false negative) was 13.8%. This indicates that it is more likely that relationship between identity and internal factors exist for project team participants than non-participants.

Table 4.10 Confusion Matrix Identity*Internal

n=235	Predicted	
Actual	**PT**	**NOT**
PT	125 (86.2%)	20 (13.8%)
NOT	61 (67.8%)	29 (32.2%)

4.2.3.7 Risk vs. Mistakes

In order to further understand difference between PT and NOT, a full-factorial model was also used to discern the effect of risk and mistakes on engineering identity. The questions from the survey used in the following analysis are listed in Table 4.11.

Table 4.11 Survey Questions to Define Covariates (Identity, Risk, Mistake)

Covariate	Survey Question
Identity	"I am an engineer"
Risk Factor	"Success in engineering means learning through risk-taking"
Mistake Factor	"Success in engineering means learning through making mistakes"

4.2.3.7.1 Full Model – Risk vs. Mistakes

In a similar fashion to section 4.2.3.5, tests were run with a significance level of 0.05 ($\alpha = 0.05$). The full model for risk vs. mistakes represents PT or NOT as a predictor and a full factorial model with three factors (identity*risk*mistakes). Again, a full factorial design was used to investigate effects of these factors and all possible interactions to predict student participation or not.

The formula for full-model analysis in JMP, depicted by $Yijkl = \mu ijk + \epsilon ijkl$ (Ott & Longnecker, 2016), is described below with further explanation of all factors in this model.

Full Model (Ott & Longnecker, 2016)**:**

$Yijkl = \mu ijk + \epsilon ijkl$, where

$\mu ijk = \mu + \alpha i + \beta j + \gamma k + (\alpha\beta)ij + (\alpha\gamma)ik + (\beta\gamma)jk + (\alpha\beta\gamma)ijk$

In this model, Yijkl denotes the response (PT or NOT); μijk, and ϵijkl indicate overall mean and error (respectively) from the lth observation with factors (i, j, k). Further, μ denotes the overall intercept; αi denotes identity (i => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); βj denotes risks (j => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); γk indicates mistakes effect (k => 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree); (αβ), (αγ), (βγ) parameters denote two-way interaction of Identity*Risk, Identity*Mistakes and Risk*Mistakes, respectively; (αβγ) denotes three-way interaction of Identity*Risk*Mistakes. The three-way interaction was run by using Fit Model in JMP, with personality Nominal Logistic and Y=PT as a target.

This model also indicated bias in the estimates, lost degrees of freedom (DF's) and zeroed estimate values however, the researcher believes the reduced model is not necessary in this case to further evaluate results.

4.2.3.7.2 Model Analysis – Risk vs. Mistakes

Conducting a full factorial analysis in JMP using Fit Model, Chi Square analysis for individual questions resulted in p-values>.05 with Identity (p=.77313), Risk (p=.17363), and Mistakes (p=.72271). This may be interpreted that PT students are similar to non-participants in these factors and that sample values are not significantly different than expected values. However, significance found in the whole model test with prob>Chi Square, p<.05 (p=.0005). The three-way interaction (Identity*Risk*Mistakes) was found to be significant p=.0054 and the two-way interaction Identity*Risk (p-value = .0232) was also significant (p<.05). Because these interactions (Identity*Risk*Mistakes and Identity*Risk) were $p<.05$, H_0 was rejected. Therefore, a relationship exists between identity formation and risk-taking with mistakes for PT participants and that risk-taking may have a stronger effect than making mistakes among PT vs. non-participants.

Using Identity*Risk as the reduced model, the interaction was significant with Chi Square whole model p=.0240. However, individual effects from Likelihood Ratio Tests did not reveal significance. A confusion matrix was again used to describe the performance of the model. Table 4.12 lists the confusion matrix for this interaction and shows that the predicted rate of Type I error (false positive) was high at 83.3% and Type II error (false negative) was low at 3.4%. This indicates that it is more likely that a relationship between identity and risk-taking exist for project team participants than non-participants however, more in-depth analysis may be required.

Table 4.12 Confusion Matrix Identity*Risk

n=235	**Predicted**	
Actual	**PT**	**NOT**
PT	140 (96.6%)	5 (3.4%)
NOT	75 (83.3%)	15 (16.7%)

4.2.3.8 Identity Analysis with Ethnicity

As discussed in Chapter II, the intersectionality of identity with may play a part in overall engineering identity. Therefore, multiple tests were run in JMP using Contingency Plots to determine the intersection of ethnicity with PT vs. NOT and the question, “I am an engineer”. Only one student answered, “strongly disagree” (n=1). This was a white female non-participant (NOT). For those students who “disagreed” (n=25), 12 PT students and 13 NOT students answered the question. Though the

Likelihood Ratio indicated this wasn't significant (p=.0760), there were 5 PT students from underrepresented populations who answered this way (1 black, 4 Hispanic, 0 multi) vs. 4 NOT students (0 black, 1 Hispanic, 3 multi). For those who "agreed" (n=88), the majority were Hispanic or white students, with similar responses from PT (17 H, 16 W) and NOT (11 H, 12 W). One black student answered this way from PT. The majority of students responded that they "strongly agree" (n=121) that they are an engineer. Though the Likelihood Ratio was p=.0875, Table 4.13 shows the majority of respondents were White and Hispanic.

Table 4.13 Contingency Analysis Table of Ethnicity by PT vs. NOT "Strongly Agree" "I am an Engineer"

Count Total % Col % Row %	B	H	M	O	T	U	W	Total
NOT	2 1.65 66.67 4.44	10 8.26 23.81 22.22	1 .83 100.00 2.22	3 2.48 27.27 6.67	1 .83 25.00 2.22	1 .83 100.00 2.22	27 22.31 45.76 60.00	45 37.19
PT	1 .83 33.33 1.32	32 26.45 76.19 42.11	0 0.00 0.00 0.00	8 6.61 72.73 10.53	3 2.48 75.00 3.95	0 0.00 0.00 0.00	32 26.45 54.24 42.11	76 62.81
Total	3 2.48	42 34.71	1 .83	11 9.09	4 3.31	1 .83	59 48.76	121

4.3 Qualitative Data

It is important to mention that in addition to questions that could be quantified, the survey contained several open-ended questions that required survey-takers to input individual responses. These responses were compiled into a rubric to look for common terms. The first question that was compiled asked survey-takers to, “list 2-3 important attributes that competitive project teams offer, or you believe they may offer”. Of the original survey-takers, 140 PT participants and 62 non-participants answered the question. Table 4.14 includes common terms in responses from PT and non-participants.

Table 4.14 Rubric of Common Terms PT and non-PT for “List 2-3 important attributes competitive project teams offer, or you believe they offer”

PT		Non-participants	
Experience	66	Experience	28
Skill	54	Skills	28
Team	47	Work	18
Work	41	Teamwork	16
Hands-on	35	Team	13
Learn	35	Build	12
Teamwork	28	Hands-on	10
Project	26	Community	9
Community	21	Learn	9
Engineers	20	Engineers	9
Technical	19	Ability	9
Opportunity	18	Opportunity	9
Leadership	16	Knowledge	7
Build	15	Creative	7
Competitive	15	Practice	7
People	15	Network	6
Applicable	14	Technical	6
Knowledge	13	Real	5
Network	12	World	5
# Answered	140	# Answered	62

In general, PT participants understood the importance of their experience on a project team for the experience, skill-building, working on a team, and hands-on learning. Though non-participants appeared to answer questions from a deficit approach, they understood the value of participating on project teams and skills they may offer. PT and non-participants answered this question very similarly however, PT participants were more likely to mention the value of specific technical aspects they were learning outside of the classroom. For instance, one PT participant mentioned, “outside classroom learning - experience with CAD software, fabrication tools”. In addition, though the question asked for “2-3 important attributes”, PT participants mentioned more than three detailed examples, on average. For example, one AUV team member mentioned, “technical experience – collaborative environment similar to internships - utilizes software commonly used in industry – critical thinking mindset – time management – fiscal responsibility”. Though the rubric for this question was useful, qualitative data collected could warrant more investigation through the use of individual interviews and other qualitative data techniques.

The second qualitative question that may provide insight was, “what challenges do you recognize you face by participating, or not participating, on competitive project teams”? The researcher acknowledges that this question may have been interpreted as asking about all competitive teams and not PT, specifically. However, 136 PT participants answered this question, as well as 81 non-participants. Table 4.15 includes common terms and the number of responses received for each population.

Table 4.15 Rubric of Common Terms PT and non-PT for "What challenges do you recognize you face by participating (or not participating) on competitive PT"

PT		Non-participants	
Time	73	Work	17
Team	50	Experience	17
Work	43	Team	16
Learn	37	Time	16
Project	34	Technical	16
Technical	30	Participate	16
Manage	28	Know	10
Experience	27	Project	9
Challenge	20	Knowledge	8
Participate	19	Learn	7
Commitment	17	Challenge	7
Know	16	Problem	5
Knowledge	15	Communicating	5
Communicate	14		
Idea	13		
Make	13		
# Answered	136	# Answered	81

Though more PT participants answered this question, the majority of students were concerned with the time it took to participate in project teams in addition to their engineering coursework. The difference was that PT participants knew the difficulties to manage their time while non-participants were foreseeing that they would have difficulty balancing time spent for any extracurricular activity. Another interesting aspect from non-project team participants is that they thought they had to have technical knowledge before joining the teams. They seemed to be extremely concerned with their lack of knowledge of technical subjects and believed that this was their shortcoming. One student mentioned, "by not participating, I am not learning fundamental technical expertise. I will not be employable, I foresee". In addition, both PT participants and non-participants were concerned with teamwork and communication. One non-participating student mentioned, “The most challenging thing about working on a team is…manage communicating with every member…communication is key, but difficult”. Another non-participating student mentioned, “I struggle working with other students in my classes on projects [and] assignments. I tend to be independent out of fear for criticism”. Further, “…I will have to collaborate with other students [to] face a difficult challenge. I will have to learn from others on team or online in books, etc.”. It appears the non-participants faced some sort of difficulty with teaming in their courses. They may have assumed working on this type of project team would afford the same experience and therefore, they chose to avoid the experience.

Finally, qualitative answers provided some insight to how the experience was different than classroom learning, especially those additional factors that may be important. AUV team members mentioned that they would be “…pushed to make mistakes and learn from them”, while another admitted “…I have never done a true hands-on engineering project before, there will be a learning curve…this will require me to step outside my comfort zone [to] try [and] learn new skills”. Though many of the respondents shared that project teams are intimidating, for those that participated, they understood the benefits of building confidence, taking risks, and making mistakes.

4.4 Evidence Summary and Conclusions

Based on the evidence in this study, several conclusions may be drawn. Chapter IV provides insight into the first research question, 1) are women who participate on project teams significantly different than other students in the college of engineering?

Based on the in-depth look at GPA data used to determine academic identity, those women who participated on PT were not found to be significantly different than women in the college or the overall COE as a whole. It was only in the 2019 cohort that significant differences were found between PT participants and COE women, and PT participants with the overall COE students. Based on the information in this study, there is not enough evidence that PT students show consistency in being significantly different than there COE counterparts.

To answer the second research question, 2) are project teams of interest to traditionally underrepresented ethnic populations and FGEn students?, ethnicity and FGEn data were analyzed. Though a concerted effort to recruit underrepresented and FGEn students was not made, the year of highest growth was found between Fall 2017 and Fall 2018. As shown in Table 3.1, between Fall 2017 and Fall 2018, increases in participation on project teams are observed in Asian (214.3%), Black (50.0%), Hispanic/LatinX (68.6%), International (600%), Multi (350%), and White (29.5%) populations. The highest increase FGEn populations in all three categories was seen in Hispanic/LatinX populations. Within this population, an increase of 1050.0% was seen in the participation of team members. Between Fall 2015 and Fall 2018, there was a 1400.0% increase. Though White FGEn women in the COE remained stagnant, an overall increase in White FGEn students participating on project teams was 400%.

Research question three can be answered by evidence in Chapter III, 3) are project team members more likely to choose non-traditional engineering majors, such as mechanical, electrical, or computer science? Table 3.6 provides evidence that PT encourage women to pursue degrees in aerospace, computing, electrical and mechanical engineering, as well as electrical and mechanical fields in engineering technology majors. To reiterate, the Fall 2019 PT cohort included 10.13% of all COE women in aerospace engineering; 17.68% of all women in computer science; 9.68% of all women in electrical engineering; 15.04% of all women in mechanical engineering; and 4.52% of women in engineering technology majors. The highest year for percentage of women in engineering technology was in Fall 2018, when 8.61% of female students were involved in PT. Because the CLEN category was used and students were tracked over several years, there is strong evidence that students choose those majors after choosing to participate on PT.

Because of limited sample size from those who participated in the survey, research question number four, 4) is developing identity through hands-on learning a major indicator for women who persist in engineering, especially those from underrepresented ethnic groups or FGEn? was difficult to explore. Therefore, this could be an area for future research and a focused effort could be made to acquire data and information in this area.

Finally, both quantitative and qualitative evidence support the notion that, 5) … there [are] other factors (covariates) that contribute to deepen engineering identity. Qualitative evidence points towards multiple factors including, confidence, making “mistakes”, and risk-taking. As mentioned earlier, these factors warrant further exploration to determine the impact of covariates on PT participants compared to general COE populations. On further inspection, the quantitative data seemed to suggest that project team participants were less sure about their internal identity as engineers. For instance, more PT members answered that they "agreed" or "strongly agreed" that they had doubts about their ability as an engineer than non-participants. For this question, 130/148 (87.84%) PT participants answered this way. The wording of the question could have been a factor however, 141/148 (95.27%) PT participants "agreed" or "strongly agreed" when asked, "I am an engineer". The idea that PT participants have a strong sense overall of engineering identity but, have conflicting feelings of internal identity may be of interest. As evidence for graduation rates show, PT participants are more likely to overcome feelings of doubt and persist through until graduation. This provides evidence that engineering project team experience is beneficial to long-term retention goals.

CHAPTER V

5.0 MODEL FOR PROJECT TEAM IDENTITY

5.1 Introduction and Rationale

As previously mentioned, the underlying theory for engineering identity development is disjointed and requires further refinement. As discussed in Chapter II, literature surrounding the development of engineering identity theory has relied heavily on models of math and physics identity (Hazari et al, 2010; Patrick, Prybutok, & Borrego, 2018), with little exploration of intersecting identities that may be relevant (Carlone & Johnson, 2007). In several studies, the development of a strong physics identity was an indicator of the likelihood that students would pursue engineering in college (Patrick, Prybutok, & Borrego, 2018) however, these studies did not take into account the societal effects of gender and ethnicity on the four identity factors; interest, recognition, competence and performance (Hazari et al, 2010; Patrick, Prybutok, & Borrego, 2018). In addition, these models visually described engineering identity as a separate identity than personal or social identity. This depiction may be flawed in several ways, especially when developing a model for students who participate on engineering project teams.

The Curtis model from the E-SIS (Curtis, Anderson, & Pierrakos, 2016) may provide more insight within the 11 overarching themes for identity as an engineering student. However, the depiction of a "siloed" model of factors also does not fully explain an approach to operationalize identity on students who participate on engineering project teams. Further, it does not explain how individuals identify with their profession or their internal connection to being an engineer. As explained by Pierrakos, Curtis, and Anderson (2016), approaches to define identity previously explored in the psychosocial literature include participation, distinctiveness, visibility of affiliation, citizenship, unified self-concept, in-group cooperation, self-enhancement, sense of belonging, interest, attitudes, and social support. For engineering, these factors thought to make up the concept of identity as an engineering student were used as the 11 overarching themes with one exception, "attitudes" was changed to "attitudes towards engineering" (Curtis, 2017). Though the themes provide a greater complexity, and therefore a view of engineering identity, they do not fully explain the process to develop engineering identity or the necessary elements for individuals to identify as "engineer". Therefore, a model that encompasses dynamic elements in every-day practice is required to further understand the development of engineering identity, especially in underrepresented populations.

5.2 Theoretical Frameworks

5.2.1 Erikson's 8 Stages of Psychosocial Development

Erikson's theory of psychosocial development has long been regarded as the cornerstone of learning and development. However, it has been sparingly used to define career development or applied to vocational development theory (Munley, 1977). While Erikson suggests the human development cycle evolves over eight stages, this theory also considers a dynamic environment and mutual interaction between the individual and society in which the individual functions (Erikson,1963, 1968). As the individual matures, a sequence of "crises" appears and is resolved by the individual in order to proceed to the next stage of development. According to Erikson, a "crisis" is a decisive or critical turning point, followed by either increasing strength of the trait or weakening. Negotiation of any stage lends itself to resolution, however, should the crisis not adequately become resolved, the individual remains vulnerable and inherently has difficulty with the development of certain attitudes towards one's "self" and relationship of "self" to the world. Further, although many academicians have described each stage as occurring by a certain age, for the purpose of this dissertation, stages are considered ongoing and simultaneous.

In summary, Erikson's stages are trust vs. mistrust, autonomy vs. shame/doubt, initiative vs. guilt, industry vs. inferiority, identity vs. identity confusion, intimacy vs. isolation, generativity vs. stagnation, and ego integrity vs. despair (Erikson, 1963, 1968). Although Erikson theorizes universality of the stages within the life cycle, an advantage of applying this framework to understand engineering project teams is that the theory recognizes identity development exists within a context. That there are social and cultural norms that affect or influence crisis resolution within each underlying stage.

The model to describe engineering identity development through participation on engineering project teams will utilize Erikson's stages to understand the underlying process at hand. By Erikson's definition, and for the purpose of this dissertation, it is assumed that engineering identity in underrepresented populations occurs in perpetual "crisis". Rather than being resolved, identity is continuously being strengthened or weakened, at the present age of the individual, a college-aged student. According to Erikson, the resolution of crisis stages is interdependent and the solution of one crisis has ramifications for the solution of other crises. For example, failure to make occupational and ideological commitments at adolescence necessary to achieve a sense of ego identity may lead to difficulty in interpersonal commitments in young adulthood and, therefore, contribute to a sense of isolation. Though Erikson's theory supports the idea that identity is developed at stage five (5), the model will describe the usefulness of the entirety of all eight stages as a simultaneous experience, rather than stopping at stage five, for example, to fully explain engineering identity formation. This framework, combined with systems elements, will serve as the foundation for the model to further understand engineering identity development through participation on project teams

5.2.2 Systems Approach: Errors, Faults, and Failures

A second theoretical framework for the project team participation model requires an engineering perspective to describe environmental factors in which team members function. Based upon standards set forth by the Institute of Electrical and Electronics Engineers (IEEE), and for the purpose of this dissertation, definitions for terms are used to describe an individual's interaction within the environment and/or the external engineering environment with that individual. Table 5.1 describes systems elements and their definition, based on IEEE standards (2010) and definitions used in the field of Human Factors (Proctor, 2018) and their adaptation for the purpose of this dissertation.

Table 5.1 Systems Element Definitions in Model

Term	IEEE Definition (IEEE, 2010)	Human Factors Definition (Proctor, 2018)	Dissertation Relationship
Error	A human action that produces an incorrect result	Measure of the estimated difference between the observed or calculated value of a quantity and its true value; difference between actual and expected output; failure of a planned action to achieve a desired outcome	Error relates to internal factors that lead to gaps in participation of women, esp. on engineering project teams
Fault	A manifestation / symptom of an error in the software	Displacement or discontinuity resulting from fracture between components; condition that causes failure to perform a required function	Fault relates to the interaction of internal (individual) and external (engineering environment) system components that lead to gaps in participation of women
Failure	An event in which a system or system component does not perform a required function within specified limits	Lack of success, deficiency, or action or state of not functioning. Inability of a system or component to perform required function according to its specification	Failure relates to external deficiencies in the engineering environment, that leads to gaps in participation of women

5.3 Model Components - Descriptions

To create a model for project team participation, there are three main components necessary to build a foundation. Each of those components contain sub-components that can be described to further understand how extracurricular project teams are envisioned and work. In combination, these three components work together to create emergent properties that ultimately build engineering identity for participants. As described, some components are external, initiated and maintained by an external "program" partner, and therefore, do not require attention from the participants. If a program with resources does not exist, additional actions are required on the part of student participants to ensure team structure and success. The author acknowledges that not every project team functions in this manner however, purposeful design has resulted in creating a successful and engaging environment to support engineering identity development. The framework and components are briefly discussed in section 5.3.1 and are depicted in Figure 5.1.

5.3.1 Framework for Team Model

5.3.1.1 Structural Components

Structural components are required to form a basis for the experience. For many project teams that exist on other university campuses, some structural components are left up to the participants to facilitate. In this case, structural components are a necessity to ensure team success. Without a basic structure, teams are potentially at risk and may not function as successfully. These components include, but are not limited to:

- Competition – availability of national/international competitions and organizations to provide framework, volunteers, and support for actual events and competitions to occur.
- Space/Fabrication Area – technical teams require space to meet and a work area for fabrication that allows them to store materials and equipment. This area should also provide necessary tools and equipment to perform advanced fabrication, such as the use of 3D printing, mill, lathe, drill press and welding equipment.
- Funding – project teams require financial support. Depending upon the project, many teams can get started with little funding. However, to compete in collegiate competitions and support team materials, supplies, and travel costs, it is necessary to ensure team start-up and longevity through developing funding partnerships.

These partnerships usually come from external sources; therefore, it is important to build strong industry partnerships.

- Support Networks – external support networks of various stakeholders are critical to team success. Though the bulk of the work is done by student participants, staff, faculty, graduate students, and industry mentors can offer expertise and insight to guide participants along the way. However, as stated in Chapter III, these networks are not the primary decision makers, nor do they hold a leadership capacity for the team. Therefore, they are ancillary in function.
- Team Design – single-sex teams are designed to remove the impact of societal constraints on performance. Designing a collegiate team in this manner ensures the focus of the team is on participation alone and that team goals align with other factors discussed in this dissertation. For example, it is more important that freshmen engineering students interact with peer mentors in leadership roles to program in Python than it is to be exceptional in Python programming. Further, in this case, teams are required to start from scratch annually and participate in design reviews. Again, the focus is to be deliberate about how students experience the engineering design process and for women to experience a real-world setting that eliminates internal or external factors that affect their performance, including stereotype threat.

5.3.1.2 Individual Requirements

For the teams to exist, a reciprocal relationship exists between the available structure and the individuals who participate in the endeavor. For the endeavor (project team) to be a success, voluntary commitment is required from a minimum number of individuals to ensure the project is carried throughout its life cycle. Internal factors required from the individual include, but are not limited to:

- Student Interest – participants should have an underlying interest or desire that will motivate them to act. It is important to mention that "interest" is subjective. Participants could be interested in any number of areas including, the project itself, a desire to enhance their technical skills, a need to become involved with other students and like-minded individuals, involvement in a formidable project to lead them to other professional opportunities, such as internships, etc.
- Learning & Development – participants should also have a desire for learning and personal development. However, in project teams, learning and development may occur both internally and externally. As seen by the number of female students participating in any one team, learning and development is a social endeavor. For many teams, functioning with a large amount of team members is a detriment to their ability to manage the project. However, it has been observed that single-sex teams are able to support participants at different stages of their learning and development, especially through peer mentoring and delivering technical content via workshops.
- Autonomy – in addition to functioning within the structure and support system, teams and participants are required to exhibit autonomy and take ultimate responsibility for their results. As explained in earlier sections, the focus of the teams is to "participate", not to "win". Therefore, team autonomy does not require

a “pressure to win” to be successful. In turn, pressure on the teams for high performance is reduced. Teams have been successful as a byproduct of their autonomous involvement without pressured expectations. Above all, ensuring autonomy has made a difference as it is important for teams to remain student driven and student run. Though results may vary, this has ensured that project design, fabrication, testing, and completion is solely the work of team members, not experts or influenced by program staff.

- Time – with any extracurricular activity, time commitment is essential. Students who have been most involved in teams are able to balance their responsibilities in academic, social, family, work, and personal settings. It is suggested that participants who spend the most time in these endeavors are most benefitted however, students who minimally participate also benefit from the availability of activities to practice the engineering profession and the example of their peers.

5.3.1.3 Guidance or Process Elements

Teams require certain elements to be in place to guide them towards success. These may be considered part of the structural elements; however, they are necessary to start team activities once a commitment has been made by individuals to become involved. These elements include, but are not limited to:

- Annual Leadership/Team Member Retreat – each year, the program provides a one-day weekend retreat. Leadership/member retreats are structured and usually last ½ day. They are necessary to introduce teams to one another, welcome new leaders, share best practices, provide information on funding limitations or updated policies, such as facility use agreements and other instructions. Retreats are timed to occur after member recruiting and before team meetings begin. Team leaders are chosen the previous semester, usually in spring, to ensure leaders are experienced team members that have been on the team at least one year. The greatest benefit for an annual leadership retreat is for teams to discuss projects and leadership responsibilities in a professional, setting.

- Deliverables – several deliverables are required from each team by October 1st. These are discussed at length at the annual retreat. As a standard practice, team rosters and budgets are due. Some flexibility is used throughout the year to accommodate teams that experience off-nominal or unexpected events. Another deliverable is a proposed Gantt Chart or timeline for the overall project team progress. This also may be revised by teams throughout the season however, it is recommended that teams refrain from adjusting the timeline once submitted.
- Bi-weekly Leader Meetings – the program facilitates intermittent meetings throughout the season to ensure teams are making progress or are communicating their challenges. Team meetings are usually rotated, and each team is guaranteed one solo meeting and one all team meeting per month.
- Design Reviews – the program also facilitates design reviews during the fall semester to ensure design ideas are within budget limits and are workable. Different stakeholders are invited to the reviews including, FEDC staff members, graduate mentors, faculty, and industry partners. The design reviews give each team 1.5 hours to present and discuss. A total of three design reviews were

conducted for most seasons in the study however, the current setting is two reviews, a preliminary and follow-up with design changes. If teams request a design review in spring, the program assists to invite stakeholders.

- Industry Connections – industry relationships are sought and facilitated by both student team members and the program. Due to funding and account structures, monetary opportunities are funneled through the program to receive and disperse. Industry professionals are also involved through mentoring relationships developed and maintained by teams and their members.

5.3.1.4 Emergent Properties

As a result of the aforementioned elements, and their interaction within the "system", emergent properties appear. The principle of emergence refers to properties that appear or materialize when a system operates (Proctor & Van Zant, 2018). Emergent properties give the system added value and as a consequence, change of the system propagates in unpredictable ways. For example, change in one factor will influence emergent properties however, it becomes difficult to predict the result. System success occurs when anticipated properties (outcomes) are visible and emerge. System failure occurs when emergent properties fail to appear or consequently, when unanticipated or undesirable properties appear (Proctor & Van Zant, 2018). Emergent properties that have appeared from PT experience include, but are not limited to:

- Individual Growth and Development – as first or second-year students, many of the individuals that participate are learning and practicing technical skills they have never seen before or will not see for several years in the engineering curriculum.

Therefore, the rate participants learn becomes exponential and activities become meaningful and relevant to grow and develop as an engineer. Several factors are:

  - Active Learning and Engagement – individuals are motivated to learn. The environment supports learning through experience with hands-on projects and encourages making mistakes. Single-sex teams reduce some negative peer interactions and stereotype-threat conditions.
  - Academic Growth - through research, writing, understanding *why* course materials are relevant and *how* information can be applied. Participants report understanding advanced materials after their experience on project teams. Exposure to academic information in advance assists participants to recognize concepts when they are presented in the classroom and pay closer attention to further understand how the information may be applied in various settings.
  - Technical Skill Development – through hands-on projects and real-world application. Technical skills are developed through purposeful interaction with peers, mentors, and experts. Experience helps participants discern if design choices work or not. In addition to technical skills, workplace skills are also developed through a complex configuration of emergent properties that arise.

- Team Organization – teams are left to their own devices to self-organize and figure out how to ensure projects will follow-through to completion. Emergent properties that appeared in the first year were team spontaneous organization that has not changed significantly since the early years. Two areas that emerged were:

   - Leadership – participants saw need for overall team leadership and “administrative” leadership to complete certain project management tasks.
   - Subteams - leaders emerged with specialization in technical areas to divide work and ensure project tasks were divided into sizeable pieces.
- Team Infrastructure – with leadership and subteams, team infrastructure emerged over the years. Most teams had the following tools in place by year two:
   - Team handbooks – contain written instructions for leader positions and duties in detail to determine commitment level of participants who wanted to assume leader positions for at least one season.
   - Websites/social media – for visibility of teams and external communication purposes. Some teams required to create websites to gain competition points.
   - Communication tools, such as GroupME or Discord – to communicate with participants for meeting reminders, timelines, and extra information for involvement in COE or as a peer mentoring platform.
- Team Dynamics – teams are constantly shifting and changing. Dynamics for each team can be attributed in any given season to leader/participant interactions between peers. Positive interactions result in high-performing teams, other interactions may create a dysfunctional team environment resulting in low performance. Patterns or dynamics for each team emerge however, teams have enhanced their positive interactions by creating events or activities to enhance the following:

- Professional interactions – with industry or peer mentors to create awareness for career opportunities or professional development practices, including interviews, networking, and resume writing.
- Social events – informal interactions used to create environment of trust and for participants to bond in a group setting. Many of these events are conducted on the weekend, when students have more time.
- Team building activities – include technical workshops (welding) or volunteer opportunities to give back to community and improve group interaction.

- Environmental Factors – presence of underrepresented populations in technical workspace improves the visibility of women in engineering and increases professional understanding and respect for non-traditional populations. Due to visibility in the workspace, there has been an emergence of, awareness for, and normalization of practices that encourage women, especially underrepresented populations. An emerging environmental impact is:
    - Inclusion - byproduct of visible presence of underrepresented in technical areas.

Figure 5.1 Visual of Team Framework for Model

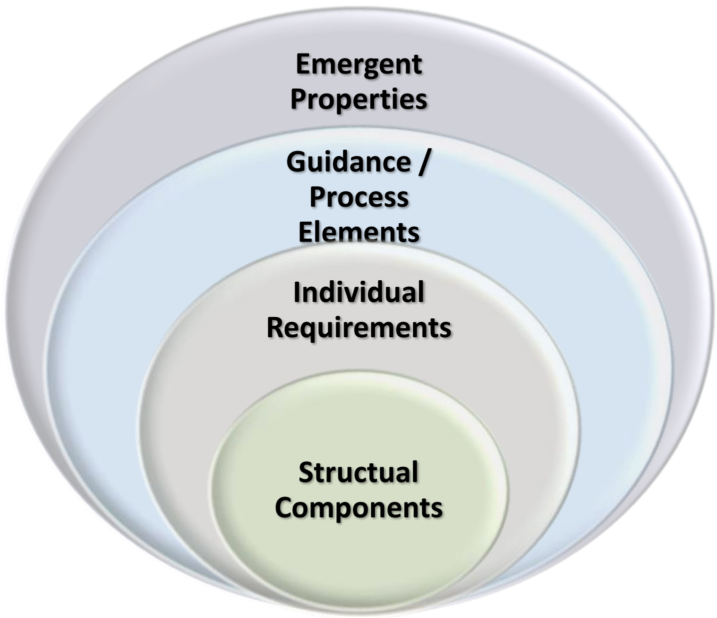
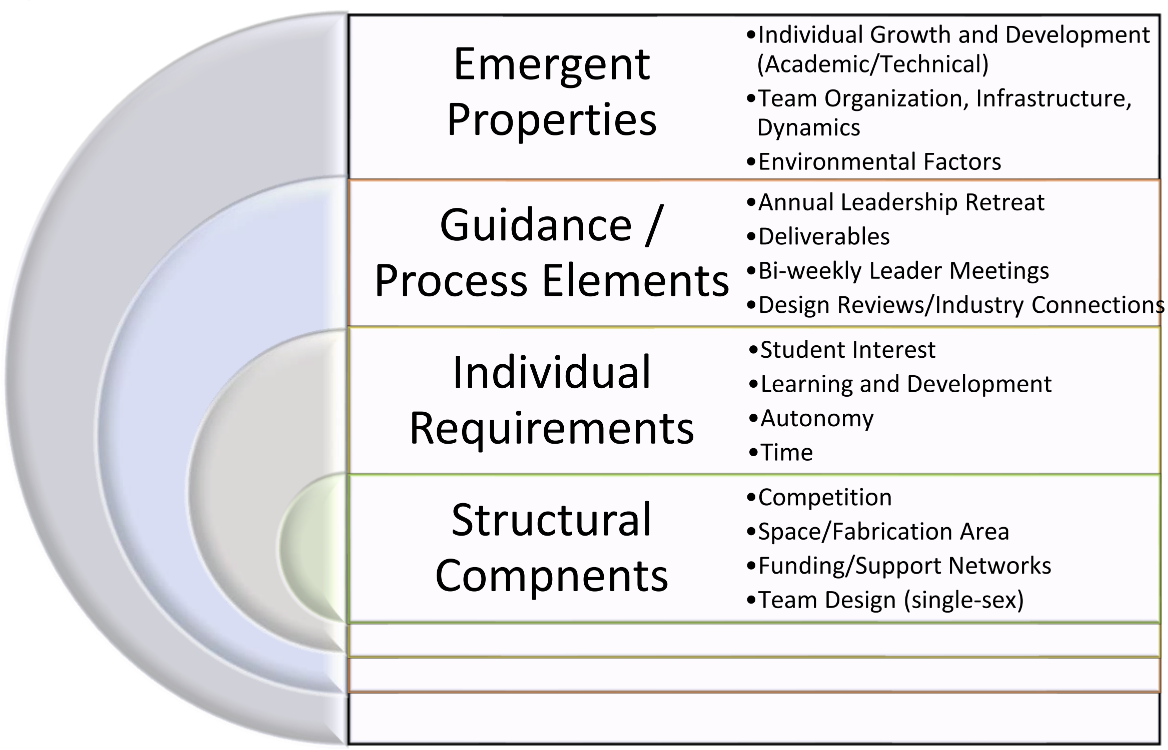


Figure 5.2 Detailed Visual of Team Framework for Model



5.4 Application of Theoretical Frameworks to Project Team Framework

To explain the project team framework and how teams promote identity development through each element, Erikson's Eight Stages of Psychosocial Development and Systems Elements may be applied. Each period in the following depiction provides insight to Erikson's classification of developmental stages and how an impending "crisis" is resolved. If crises are resolved with a positive outcome, the characteristic "virtue" is developed. If the crisis is resolved with a poor outcome, the characteristic "maldevelopment" is reinforced. Table 5.2 outlines Erikson, the project team framework, and examples of crises with traits for virtue and maldevelopment. An example within the Erikson context, extrapolated to explain project team development, is provided. Further, the model categorizes the maldeveloped trait in a systems context and explains how women may be impacted. For each stage, engineering identity is either reinforced or weakened. Again, it is theorized that engineering identity development through participation in project teams is not a *stepwise* process. Rather, the steps are simultaneous, ongoing, and occur in a dynamic setting.

The author acknowledges difficulty in describing ongoing, dynamic processes with two-dimensional depictions that do not fully describe the experience. However, the development of a preliminary model for women's participation on engineering project teams is explained in Table 5.2. Erickson's Eight Stages elements are provided by sources (Sokol, 2009; Vogel-Scibilia et al, 2009). Building off Table 5.2, a Causal Loop Model (CLM) is used to explain the individual experience and identity development through the project team experience in Section 5.5.

Table 5.2 Erikson's Eight Stages and Systems Elements Applied to Project Team Framework

Erikson's Development Period	Erikson Classification	PT Framework	Crisis Resolution	Virtue	Maldevelop-ment	Erikson Context Example	Maldevelopment Systems Classification	Maldevelopment Explanation / Impact
Childhood	Stage 1 – Infancy	Structural Components	Trust vs. Mistrust	Hope	Withdrawal	Secure environment provided by caregiver [other, program], with regular access to affection and food [resources]	Failure	External support structure doesn't exist, team weak/dysfunctional; women don't participate due to mistrust
	Stage 2 – Early Childhood	Individual Requirements	Autonomy vs. Shame, Doubt	Will	Compulsion (forced to do something)	Caregiver [program] promotes self-sufficiency while maintaining secure environment	Error	Women's academic experience personal; teaming seen as non-voluntary; may result in negative experience causing shame or doubt
	Stage 3 – Play Age	Guidance / Process Elements	Initiative vs. Guilt	Purpose	Inhibition	Caregiver [program] encourages, supports, and guides the child's [participant] own initiatives and interests	Fault	Academic setting inhibits women from seeking own interests to draw connection; feel guilt they aren't better or doing more
	Stage 4 – School Age	Guidance / Process Elements	Industry vs. Inferiority	Competence	Inertia (passivity)	Reasonable expectations set in school and at home, with praise for accomplishments	Fault	Academic experience largely passive, doesn't encourage active learning; environment reinforces inferiority and incompetence

Erikson's Development Period	Erikson Classification	PT Framework	Crisis Resolution	Virtue	Maldevelop-ment	Erikson Context Example	Maldevelopment Systems Classification	Maldevelopment Explanation / Impact
Adolescence	Stage 5 – Adolescence	Emergent Properties	Identity vs. Identity Confusion	Fidelity	Repudiation (denial)	Individual weighs out previous experiences, societal expectations, and aspirations in establishing values and 'finding themselves'	Error / Fault	Negative experience outweighs positive w/ individual; for women, environment is high-impact experience; engineering identity not strong or underdeveloped therefore, confusion
Adulthood	Stage 6 – Young Adulthood	Emergent Properties	Intimacy vs. Isolation	Love	Distantiation (lack of commitment)	Individual forms close bond and long-term partnership	Fault	Lack of synergy (reciprocity) felt between individual and environment; women isolated from engineering
	Stage 7 – Adulthood	Emergent Properties	Generativity vs. Stagnation / Self-absorption	Care	Rejectivity (stagnation; lack of meaning)	Engagement with next generation through parenting, coaching, or teaching	Error / Fault	Women only concerned with 'making it through degree'; stagnation and lack of involvement in activities or networks
	Stage 8 – Old Age	Emergent Properties	Integrity vs. Despair	Wisdom	Disdain (unworthy of consideration)	Contemplation acknowledges personal life accomplishments	Failure	33.33% women get engineering degrees and do not become engineers; do not identify with engineering profession

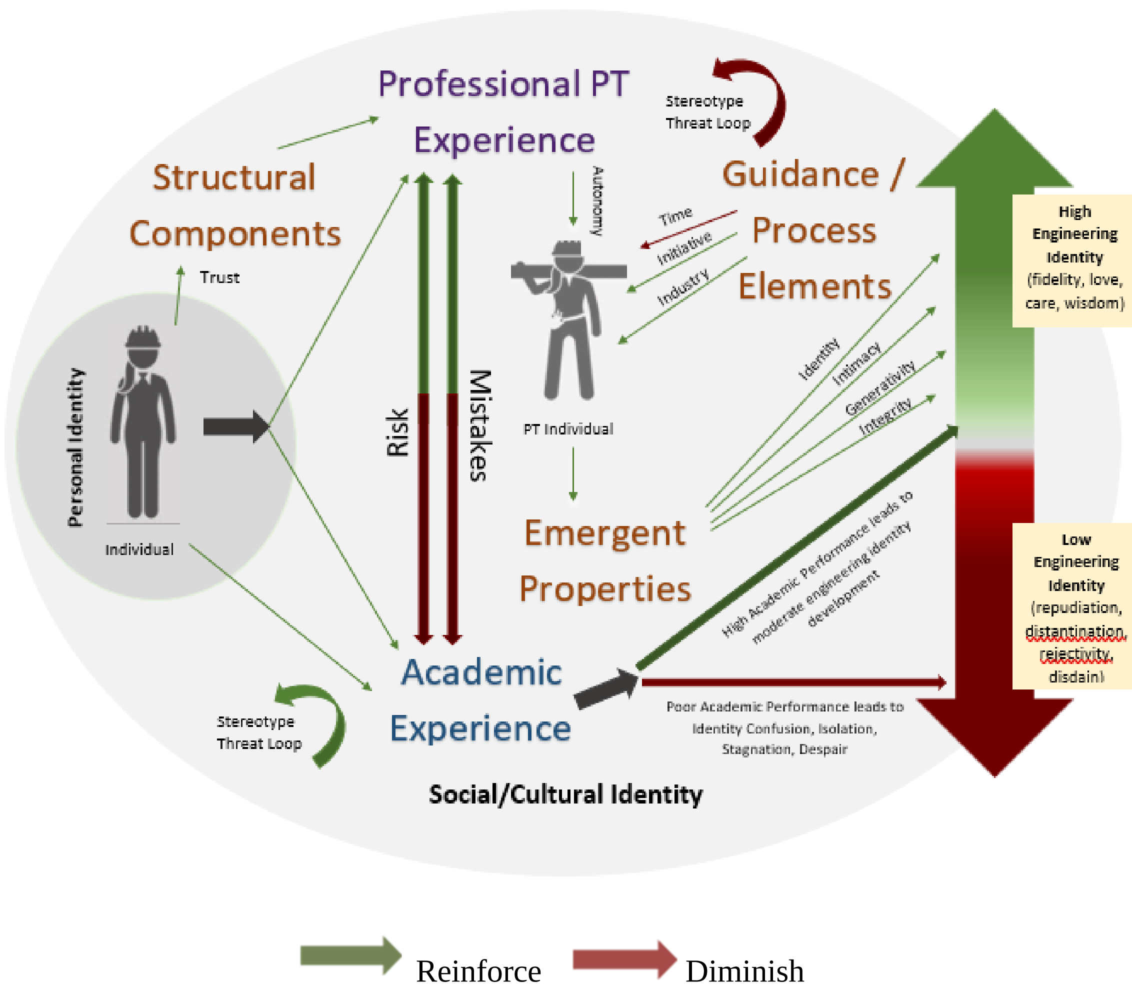
5.5 Causal Loop Model for Project Team Engineering Identity Development

5.5.1 Introduction and Rationale

In complex systems, a Causal Loop Model (CLM) can be used to conceptually model dynamic relationships of systems elements and their influence (Proctor & Van Zant, 2018). This type of model allows understanding for underlying feedback structures, as well as an ability to identify high- or low-leverage intervention points in the system. Simply, a CLM can be described as a "snapshot of relationships" and their interconnections. Within the diagram, text is used to describe variables of interest. Arrows are used to symbolize relationships and the direction of causality or nature of the relationships. These relationships can be proportional or inverse (Lannon, 2018). The importance of CLM's is that they provide a systems thinking view of each factor or process in tandem with each other, rather than in isolation. The relationships between the project team experience and an individual, in relation to the parts themselves, are what drive the outcome of developing engineering identity. Without understanding the relationships between components, it is difficult to discuss the true impact of the experience and why it is successful.

In complex systems, cause-effect relationships between multivariate elements can make connections obscure. In addition, real-world settings ensure the possibility for a large number of connections to occur, at various levels, and in infinite sequences. The challenge is to venture to understand basic connections between elements and how they may be depicted with an understanding of the relationships that have been created. A CLM is a first step to understand the development of engineering identity through participating on single-sex project teams. This model brings together elements and allows a broader perspective to accurately portray the "system" of the individual and the effect of the environment on the individual to develop themselves into an engineer. Figure 5.3 is a CLM that further explains the phenomena seen in Table 5.2 with the applied theoretical frameworks. A further explanation for the elements and relationships seen in Figure 5.3 is described in the next section. Green arrows signify reinforcing relationships while red arrows signify a diminishing effect.

Figure 5.3 Causal Loop Model for PT Identity Development



5.5.2 Explanation for CLM Elements

This model includes elements from several different theoretical contexts. To explain that individuals are perpetually interacting with the world at-large, the model shows that the development of engineering identity through participation on engineering project teams occurs within a societal and cultural context, first and foremost. The purple background defines the “system” individuals work within to establish their identity. Second, the CLM recognizes that personal identity exists within the context of social/cultural identity and the two are not separate. There may be beliefs from the outer social/cultural identity that the individual does not ascribe to however, personal identity exists within the context of the larger, social/cultural identity structures. This depiction differs from the physics identity models, as well as the engineering identity models that have been based on physics identity (Hazari et al, 2010; Patrick, Prybutok, & Borrego, 2018).

In the Hazari, et al (2010) and Patrick, Prybutok, & Borrego, (2018) models, three identities; social identity, personal identity, and physics/engineering identity, are depicted using Venn Diagram Models to describe that they exist separately yet overlap with one another. Though all three identities overlap and converge in the center, the Venn model does not consider that engineering identity may exist within one’s personal identity, and that one’s personal identity exists within a larger social identity, without separation. In both models, detail is shown to define physics/engineering identity with other factors of influence; performance, competence, recognition and interest. With the PT CLM, the concept of “interest” is assumed in their action of participating in the PT.

Also with PT participation, external “recognition” does not seem to hold as much weight. The stronger sense of recognition comes from individuals participating in hands-on projects that solidify their identity through professional practice. The ideas of “performance” and “competence” also do not hold as much weight as it is not essential for participants to “perform” at a high level or to be highly “competent”. The only requirement is that they spend time at their profession and that they participate. Therefore, Figure 5.3 can be used to explain the intersecting portion of the Venn relationship with all possible relationships, without the particular vocabulary.

Figure 5.3 shows that individuals may interact with three main drivers for engineering identity experience. For engineering students and non-students, they interact with structural components that maybe present in the system. These structural components exist for every student, and they interact with the programs and resources provided by the engineering college on an individual basis. As Table 5.2 explains, these structural components, if deemed “trustworthy”, provide a secure environment for the student to function in, thereby ensuring “hope” as a virtue that is developed by the individual. If these resources do not exist, or if students have a negative experience with structural components provided within the college, a feeling of “mistrust” is developed. As depicted in Table 5.2, the result is “withdrawal” instead of engagement and results in a failure on the part of the system to provide a foundation for the student to succeed.

As long as students are in engineering, they participate in their academic experience. For project team members, they participate in both an academic experience and the professional PT experience. As seen in Chapter IV, risk-taking and mistakes has a positive effect on developing engineering identity for project team members. For those who did not participate on project teams, risk-taking and mistakes may have negative consequences that influence a positive development of engineering identity. For the individual, engineering identity exists on a spectrum. Many student experiences reinforce or diminish a sense of engineering identity overall. With participation on engineering PT, the student develops a sense of autonomy and therefore, takes responsibility for their individual learning. Because “reward” is not built into the system, participants discover their own intrinsic value and reward for participating in the experience.

Guidance or process elements require participation from both the program/resource and the individual to be successful. These elements are in place to support the individual’s own interest, yet ensure they are engaging in the full experience. Though the program requests rosters, timelines, and budgets, there is not a high level of difficulty to perform these tasks. The low-level of difficulty but, high expectation that they complete the task, propels teams to take initiative and use their industry to submit their requested content. Recognition is given at this stage for completing requests or follow-up until tasks are complete. Submission of these elements ensure that individuals are making some level of commitment to participate and try to complete their projects so that they can travel and compete.

The emergent properties that result from participating in PT have a high impact on developing positive engineering identity. For engineering identity to develop, underrepresented individuals are often working against certain societal expectations.

They may even have previous experiences, in the classroom and elsewhere, that conflict with their own beliefs about being an engineer. Through the PT experience, individuals "find themselves" and draw their own connection from themselves to engineering. They form close bonds with both their peers and the project itself. They begin to create experiences and opportunities for others because of their feeling of belonging and accomplishment. With the spontaneous development of technical workshops, they begin to coach or teach others, thereby ensuring generativity and strengthen lasting effects necessary to carry the team beyond their tenure.

To extrapolate the emergent properties when they graduate, they are able to use their knowledge to be confident they can meet the challenges that lie ahead. They also look back upon their college experience and remember that PT provided them with a worth-while experience, that they accomplished something that was challenging, demanding, took time and effort, and yet showed them they could do engineering. And that they had a reliable experience to ensure they are prepared to enter the workforce as an engineer. Therefore, the positive effects experienced from PT may outweigh any negative effects from society, their individual outlooks, or the academic experience.

5.6 Event Tree

A qualitative event tree analysis was conducted to gain an understanding how certain circumstances led to pivotal events that contributed to project team recruitment and participation. Further, the event tree allows a clear depiction of identity development and the failure path that some students follow. In Figure 5.4, the upper bar represents an initiating event, with pivotal events, and plausible outcomes. From the initiating event, female students in the college of engineering, the path that leads to the development of engineering identity includes the project team experience. The path to engineering identity development is highlighted in orange. The event tree shows there are multiple paths to develop engineering identity through the experience and also shows how a slight deviation in the chain of events and decision-making process prevents engineering identity from being formed.

5.6.1 Event Tree and Relationship to Academics

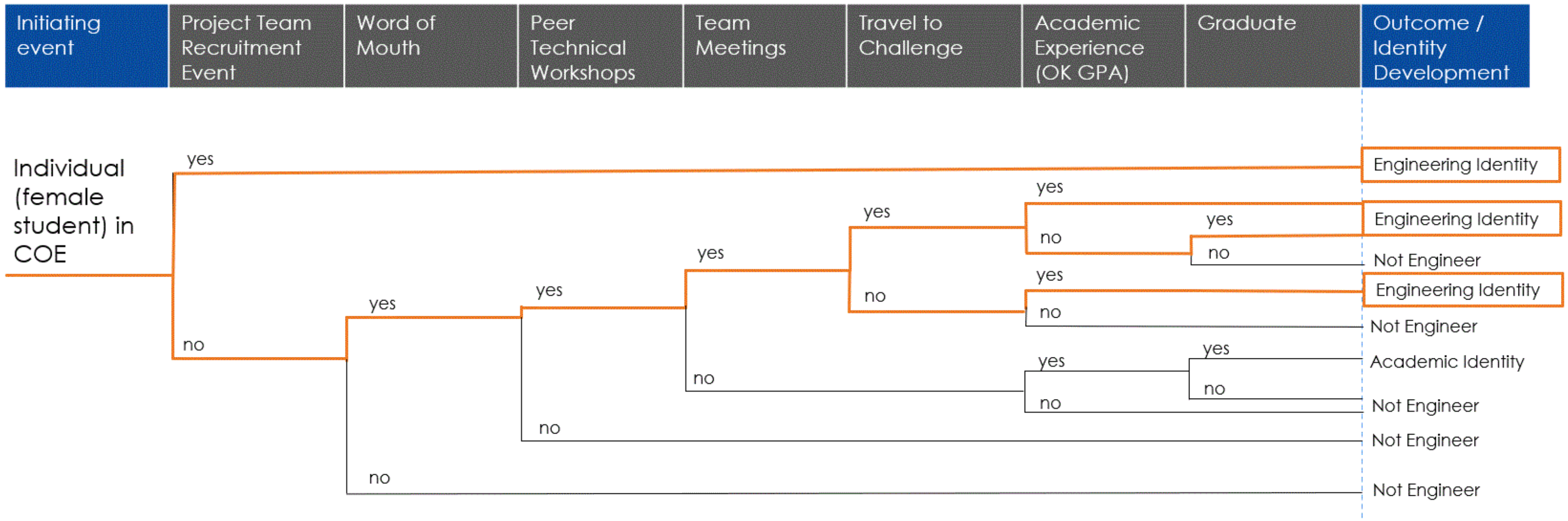
The failure path of a student who does not become an engineer rests largely upon their ability to perform academically and graduate. However, as shown in Figure 5.4, students who do not participate on competitive engineering PT are less likely to become an engineer after only participating in academics. Therefore, students who participate on engineering PT are more likely to become engineers and develop engineering identity as a result of their participation.

Also, as shown in the diagram, engineering identity does not necessarily depend upon a stellar academic performance. In this research study, it was apparent that some participants had "average" academic experience and yet continued through to graduation. The event tree allows us to view the chain of events, in succession, that lead to all possible outcomes. Though feasible, the path that shows PT participants as low academic performers and did not graduate, was not significant. Data from the retrospective study (Chapter III) suggests there were two students, fully dedicated to engineering project teams, that were put on probation or disqualified from the college. The majority of students not retained in engineering changed their majors to other colleges or disappeared from the university. Neither of these scenarios revealed a large number of students with low GPA overall. Therefore, the majority of students who participate in engineering project teams are able to maintain a balance between academics and their participation on PT. Since this is a voluntary activity, some of the challenges and shortcomings for participation are discussed in Chapter VI.

5.6.2 Event Tree Critical Points

The event tree also allows an ability to surmise critical points in the process. The first two events are critical in the recruitment of students. If students do not hear about the teams, either by attending an event or by word of mouth, they are likely not to become involved. The next two major events solidify the individual's participation on the team. There are many more students who only commit to attending one or two workshops but do not make a deeper commitment to attend team meetings. Students who regularly attend team meetings are more likely to become involved and contribute to team progress. The next critical point is traveling to the challenge. Because funding is limited, only a few students are invited to travel with the team. Many teams use a point system to determine the most involved students. Usually, team leaders and dedicated subteam members are the students chosen to attend team competitions. Therefore, this critical point represents the most dedicated and active participants are involved. The final two events represent the last critical area. Whether or not students succeed academically, the PT participants are likely to graduate and develop a strong engineering identity as a result. Again, if students do not perform well and do not participate in PT, they are less likely to graduate and consequently, less likely to become an engineer.

Figure 5.4: Event Tree Analysis to Develop Engineering Identity through PT



5.7 Summary

As shown in this study, project teams have proven to be an effective intervention to encourage overall participation in hands-on applications and to further develop engineering technical skills along with engineering identity. The purpose of Chapter V was to utilize data retrieved from the retrospective study in Chapter III and statistically significant results obtained from survey data in Chapter IV to develop a model to understand participation on engineering project teams and engineering identity development. The theoretical frameworks applied to the data, as well as theoretical information from Chapter II's Literature Review, was compiled to inform the basis for a Causal Loop Model and an Event Tree Analysis to be generated. The use of these "systems tools" provide an enhanced understanding for the process of engineering identity development in PT participants. Though the results were adequate, more research should be conducted on these student populations to further understand the value of this high-impact experience. Shortcomings of the research, as well as a summary of overall findings, is discussed in the next chapter.

CHAPTER VI

6.0 RESEARCH SUMMARY AND CONCLUSION

The purpose of this research was to evaluate the participation of women on engineering project teams and if participation significantly leads to an increase in engineering identity development, as compared to other females in engineering. In addition, the premise for the research was to further understand underrepresented students on project teams and if they were significantly impacted by their experience to develop engineering identity. Based on the evidence in this study, women who participate on engineering project teams are significantly different than other students in the college of engineering. The following sections explain these differences and give further evidence to the significance of this research.

6.1 Participation of Populations

Through analysis of retrospective study data, it was shown that project teams are of interest to a wide variety of students, including those from traditionally underrepresented ethnic populations and first-generation students. As mentioned in Chapter III, though there is not a concerted effort to recruit students, the number of traditionally underrepresented students and first-generation has been growing on the teams without dedicated targeted efforts. Over the five-year period for the study, the highest increase of underrepresented populations (Black 50.0%, Hispanic/LatinX 68.6%, Multi 350%) and FGEn populations (Hispanic/LatinX FGEn 1050.0%) was seen in the last two cohorts (Fall 2018, Fall 2019). Though White FGEn women in the COE remained stagnant, the overall increase of White FGEn students participating on project teams was 400%. Between Fall 2015 and Fall 2019, participation on the teams increased 1400.0%. Therefore, there is a need for activities that provide students with real-world settings in contexts that they are interested in participating. There is also a need for activities that inspire connections between engineering and academics. As the teams continue to grow, more research will be conducted to further understand population growth and the different demographics students represent. A final observation is that time was an important factor for the participation, or non-participation, of students. With future PT recruitment activities, this study showed that time demands can be explained by showcasing potential academic benefits, especially those that relate to graduation and success as an engineer. These benefits are explained in Section 6.2.

6.2 Academic Identity

6.2.1 GPA

Though women on PT are not significantly different from their peers in academic identity development, data suggested that women in the college are significantly different from the overall COE population. Using GPA to determine academic identity in the retrospective study (Chapter III) each of the cohort years showed that mean GPA's were different in COE women from the rest of the college. When analyzed further (Chapter IV), it was found that the mean GPA variance differed significantly in all cohort years. Therefore, women were found to be higher performing academically than average students within the COE. In addition, the 2019 PT cohort was found to be significantly different that COE females and COE students overall. However, based on the information in this study, there is not enough evidence that PT students show consistency in being significantly different than there COE counterparts. Because the Fall 2019 cohort was the largest within the study, data could be studied further to determine differences. For example, academic differences for the populations' performance in math or physics courses were not researched. Therefore, academic performance in these areas may provide greater insight to certain strengths or weaknesses of PT participants. In addition, further research to compare math and physics course results could support other research studies that correlate engineering identity to physics identity, or the importance of math identity with physics identity, and so forth.

6.2.2 Major Selection

Research question three was answered by evidence in Chapter III that showed participation on PT encourages women to pursue degrees in aerospace, computing, electrical and mechanical engineering, as well as electrical and mechanical fields in engineering technology majors. These are fields considered "non-traditional" due to the low participation of women in these majors nationally. To summarize, Fall 2018 and Fall 2019 cohorts were good examples of the diversity and number of women in non-traditional engineering majors, especially after participating on engineering PT. For example, the Fall 2019 PT cohort included 10.13% of all COE women in aerospace engineering; 17.68% of all women in computer science; 9.68% of all women in electrical engineering; 15.04% of all women in mechanical engineering; and 4.52% of women in engineering technology majors. The highest year for percentage of women in engineering technology was in Fall 2018, when 8.61% of female students were involved in PT. Because the CLEN category was used and students were tracked over several years, there is strong evidence that students choose those majors after participating on PT. This could also be another area for future research.

Because a limited number of survey participants, the research question about hands-on learning being a major indicator for women who persist in engineering, especially those from underrepresented ethnic groups or FGEn, was difficult to explore. Therefore, this could be an area for future research and a focused effort could be made to acquire data and information in this area.

6.3 Professional Identity

Finally, both quantitative and qualitative evidence support the notion that, there are other factors that contribute to deepen engineering identity. Qualitative evidence shows multiple factors including, confidence, making “mistakes”, and risk-taking. As mentioned earlier, these factors warrant further exploration to determine the impact of covariates on PT participants compared to general COE populations.

Chapter IV discusses that on further inspection of quantitative results, the data seemed to suggest that project team participants were less sure about their internal identity as engineers. For instance, more PT members answered that they “agreed” or “strongly agreed” that they had doubts about their ability as an engineer than non-participants. For this question, 130/148 (87.84%) PT participants answered this way. As discussed in the chapter, the wording of the question could have been a factor however, 141/148 (95.27%) PT participants “agreed” or “strongly agreed” when asked, “I am an engineer”. The idea that PT participants have a strong sense overall of engineering identity but, have conflicting feelings of internal identity may be of interest. As evidence for graduation rates show, PT participants are more likely to overcome feelings of doubt and persist through until graduation. This provides evidence that engineering project team experience is beneficial to long-term retention goals.

6.4 Intersecting Identities

As discussed in Chapter II and Chapter IV, the intersectionality of identity with ethnicity may play a part in developing engineering identity. Contingency Plots were used to determine the intersection of ethnicity with PT vs. NOT and the question, "I am an engineer". For students who "disagreed" (n=25), 12 PT students and 13 NOT students answered in this manner. However, 9 students (5 PT - 1 black, 4 Hispanic) (4 NOT - 1 Hispanic, 3 multi) answered that they disagreed they were an engineer. Though the sample size was small, this warrants further investigation. Further, for those students who "agreed" (n=88), the majority were Hispanic or white students, with similar responses from PT (17 H, 16 W) and NOT (11 H, 12 W). Only one black student answered this way from PT. The majority of students responded that they "strongly agree" (n=121) that they are an engineer. Results showed that the majority of respondents were white and Hispanic. This indicates that there may be differences in student experience for traditionally underrepresented populations and could be another area of interest. Again, as the number of first-generation students participating in the survey and project teams was low, it was difficult to determine if there were differences between FGEn populations and non-FGEn. This may also be another area for future research.

6.5 Survey Design Critique

There are a few points to be made about the survey design and sampling. For the sample population that answered the survey, because the GPA results were heavily skewed, it is thought that many of the students that were willing to take the survey were more involved in college activities. Further, students who take surveys are generally better performing students academically and therefore, results may be biased. Future research studies could be conducted by gathering more data from a larger sample pool or ensuring that students with various GPA's are randomly selected and invited to take the survey. It is also plausible that the data could be screened to remove outliers or mean GPA values that do not fit within predicted values. This technique was attempted in the course of the data analysis however, it was found that sample sizes were not adequate to predict values from PT in conjunction with non-participants. Therefore, the data from the survey questions were used but, any relationship between academic identity (i.e.: GPA) and overall engineering identity was not simulated in the full-factorial model.

Incomplete data from surveys was not included so that responses would not confound results. The sample size of n=235 was adequate however, a higher sample size, and more variance in response, could yield stronger results and greater power within the data to determine the model. Though some of the qualitative responses were paired down, the dataset for open-ended answers came from most survey-takers. Open-ended answers to questions were not required on the survey, and the majority of survey respondents chose to answer these questions. Therefore, they were thought to be unbiased and did not cause a confounding effect.

Based on self-reported responses for “I am an engineer”, Likert data showed similar results in the covariates (PT vs. non-PT) and may be a factor leading to bias. With rating values limited, the responses may not have been significantly variable. For example, individual questions for this study were chosen to answer different research questions. However, all PT showed similar responses for comfort with making mistakes on all-women teams. Therefore, fixed responses were limited to strongly agree and agree only. In addition, none of the subjects indicated that they strongly disagreed that success on project teams was due to learning through risk taking. Therefore, three fixed values for risk taking were limited to strongly agree, agree, and disagree only. However, if there was an alternative method for measuring risk taking, the researcher may have found a greater effect for the difference experienced from PT participants or non-participants.

Because of the limited number of responses, the researcher is aware that the study may reveal inconsistencies and not portray an accurate depiction of predictors that PT members are comfortable with making mistakes and risk-taking on all-women project teams. There was also no means of comparison for survey questions based on gender since male participants, on other co-ed competition project teams or otherwise, were not prompted to take the survey. Surveying co-ed teams may have produced unique results in terms of risk taking with the number of mistakes made as women tend to be more risk averse. Further analysis should be conducted in the future to compare survey data with mixed cohorts.

Finally, the use of the forced four-point Likert scale may not have provided enough variation to show significant results between cohorts. Future administration of the survey could require expansion of survey response choices to six points, with favorable, uncertain, and unfavorable groupings. The researcher believes that the use of "neutral" as a choice would give survey-takers an "opt out" option and therefore, should not be used. However, if responses were changed to strongly agree, somewhat agree, and agree, etc., survey participants would be forced to think more deeply about their thoughts, ideas, and feelings, and the question being asked.

6.6 Ideas of Success and Failure

Both ideas of "success" and "failure" were considered subjective throughout the course of the study. The single driving factor used to create the teams was to encourage participation of women in an industrial fabrication area. A partnership was first created with staff in the fabrication area to support the development of machining skills. It was up to individual team members to take advantage of learning opportunities within the space and expertise of the staff. As training was required for entry into the fabrication area, students were able to complete safety requirements and earn "badges" on equipment as first- or second-year students, opposed to traditional use of the area for senior capstone design projects. Early on, the students became acclimated to the area and held general meetings as well as build sessions in the space. Therefore, female students who are often absent from working in industrial spaces were comfortable to enter the space and were engaged in large numbers.

6.7 Research Significance

As previously stated, the significance of this study is that women's participation on competitive engineering project teams is rare. If women do participate, their contributions are assumed to be minimal. The large sample size of women participating in collegiate competition project teams at the university is unique. With support from a program within the engineering college, these teams are able to exist and thrive. The program provides the foundation for the opportunity for teams to become successful. As seen on many campuses, other competition teams live within a variety of environments, with and without resources. What makes this effort successful is that the students themselves drive the teams. The foundational elements are provided by the program. A mutually beneficial partnership between students and the program exists with "participation" is the focus, not "winning".

For many women, engineering is a social venture. This means that women thrive in environments that are supportive, meaningful, and contain peer-peer relationships. That they are not *competing against* each other but, *learning with* each other, in a social setting has made all the difference. Further, single-sex teams themselves provide a different environment that eliminates many of the social and cultural factors that limit the full engagement of women. Women understand these "implicit" factors, however, do not always recognize the social/cultural dynamics at play. They also may not attribute their learning or success to their own accomplishments, another theoretical framework not mentioned in this dissertation. One of the largest factors in this study is that the teams exist within a single-sex environment. Though single-sex teams provide a different dynamic, with a variety of outcomes for interactions, single-sex teams in technical settings provide an avenue for a safe environment that diminishes power structures. Learning from this model could be beneficial to create other engineering academic environments, with student-centric, growth-minded practices that foster active learning.

As explained earlier, the current body of research has theoretically equated engineering identity with academic success, rather than identity to the profession of engineering itself. Few researchers have explored a relational understanding of identity development or the impact of multiple factors on college-age students' engineering identity as a whole. Engineering identity is an area that requires further examination to understand how underrepresented populations, especially women of color or first-generation, can be successfully engaged and retained. To date, formidable studies in student success have yet to apply identity theory, especially studies to determine causal relationships between "factors" that increase participation in voluntary, extracurricular project teams.

This area of research is the first of its kind and has the potential for opening new avenues for understanding the development of technical skill sets that strengthen the sense of engineering identity for women. Because women earn engineering degrees and do not go into engineering, it is important to understand that building engineering identity is a process. That the educational environment plays a large part in student decision-making within their process. Providing opportunities to underrepresented populations, as a standard practice, could serve to benefit these students by building confidence and interest. For many students, ultimately, it is the setting that matters.

6.8 Conclusion

This venture has proven to be successful. The results are clear, engineering identity can be built through individual participation in high-impact, engaging learning environments, especially on extracurricular engineering project teams. In this case, the experience encourages risk-taking and making mistakes in a real-world setting, with built-in safety measures. The students take responsibility for their own learning and make a commitment to practice their profession. Many of the women participating on these project teams will go on to work in engineering, long-term. The question now is, how can academic environments learn from this research, listen to underrepresented students, and provide a setting that meets their wants and needs?

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APPENDIX A

CHAPTER II - LITERATURE REVIEW

Table 1 Research Study Methods

Qualitative	Quantitative	Mixed
Tate & Linn (2005) n = 5	Rubineau (2007) n = 75	Chachra, et al., (2008) n=970
Tonso (2006) n = 33	Meyers (2012) n = 701	Fleming (2013) n = 184
Capobianco (2006) n = 24	Godwin et al. (2013) n = 6772	Revelo (2015) n=22
Carlone (2007) n = 15	Knight (2013) n = 623	Verdin, Godwin (2018) n = 2916
Eliot, Turns, Xu (2008) n = 35	Jones (2013) n = 363	Kendall, Denton (2019) n= 902
Dukhan (2008) n = 35	Godwin, Potvin, et al. (2013) n = 6772	Rohde (2019) n = 2916
Beam (2009) n = 36	Godwin et al. (2015) n = 6772	
Pierrakos, Beam (2009) n = 8	Cech (2015) n = 312	
Foor & Walden (2009) n = 118	Prybutok (2016) n = 563	
Matusovich (2011) n = 20	Stoup (2016) n = 267	
Eliot & Turns (2011) n = 36	Tatar (2016) n = 423	
Cass (2011) n = 36	Godwin (2016) n = 3337	
Godwin & Potvin (2017) n = 1	Pierrakos (2016) n = 266	
Torralba (2019) n = 16	Curtis (2017) n = 562	
	Henderson (2017) n = 397	
	Patrick, et al. (2017) n = 1465	
	Kendall, et al. (2018) n = 765	

Qualitative	Quantitative	Mixed
	Borrego, et al. (2018) n = 1528	
	Patrick, et al. (2018) n = 474	
	Verdin, Godwin (March 2018) n = 2916	
	Sax, et al. (2018) n = 3814	
	Choe (2019) n = 1536	
	Kendall (2019) n = 184	
	Taheri (2019) n = 1640	

Table 2 Population Studied / Categories of Disaggregated Data

Author & Year	Subjects	FGEn	SES	Gender	Race / Ethnicity	Ability	Military	LGBTQ
Tate (2005)	5			X	X			
Tonso (2006)	33			X				
Capobianco (2006)	24			X				
Carlone (2007)	15			X	X			
Rubineau (2007)	75			X				
Eliot (2008)	35			X				
Chachra (2008)	970			X				
Dukhan (2008)	35							
Beam (2009)	36			X	X			
Pierrakos (2009)	8			X	X			
Foor (2009)	118			X	X			
Matusovich (2011)	20						X	
Eliot (2011)	36							
Cass (2011)	36			X	X			
Meyers (2012)	701		X	X				
Fleming (2013)	184			X	X			
Godwin (2013)	6772			X				
Knight (2013)	623	X	X	X	X			
Jones (2013)	363			X	X			
Godwin (2013)	6772			X				
Revelo (2015)	22			X	X			
Godwin (2015)	6772			X				
Chech (2015)	312			X	X			

Author & Year	Subjects	FGEn	SES	Gender	Race / Ethnicity	Ability	Military	LGBTQ
Prybutok (2016)	563			collect	collect			
Stoup (2016)	267			X				
Tatar (2016)	423			X				
Godwin (2016)	3337							
Pierrakos (2016)	266							
Curtis (2017)	562							
Henderson (2017)	397			X				
Patrick (2017)	1465							
Godwin (2017)	1			X	X			
Verdin (2018)	2916			X				
Kendall (2018)	765				X			
Borrego (2018)	1528							
Patrick (2018)	474			X				
Verdin (2018)	2916	X						
Sax (2018)	3814			X	X			
Choe (2019)	1536			?				
Kendall (2019, June)	184			collect	collect			
Taheri (2019)	1640			X				
Kendall (2019, August)	902			X	X			
Rohde (2019)	2916							
Torralba (2019)	16			X				

Table 3 Identity Type / Themes

Author & Year	N = subjects	Self-Perception	Academic	Professional	Social / Peer	Engineering Cultural "Fit" or "Belonging"	Multiple Identity	Themes / Findings
Tate (2005)	5	X	X		X			Three types identity (EI): academic, social, intellectual
Tonso (2006)	33		X		X	X		Three types identity (EI): nerds, academic-achievers, greeks
Capobianco (2006)	24		X	X		X		Professional identity (PI): academic, institutional, gendered, role-models
Carlone (2007)	15			X				Science identity (SI): competence, performance, recognition - research scientist identity, disrupted identity, altruistic scientist identity
Rubineau (2007)	75	X		X				Professional identity (PI): positive peer effects for men, not women
Eliot, et al. (2008)	35	X		X			X	Professional identity (PI): purposeful construction of professional identity / internal frame of references / external frame of reference / multiple identities (academic, personal interests, family)
Chachra, et al. (2008)	970	X		X			X	Engineering identity (EI): gender differences in engineering design activities / connect identity and commitment
Dukhan (2008)	35			X				Engineering identity (EI): identity with service learning
Beam (2009)	36	X		X	X			Professional identity (PI): identity with recruitment and retention

Author & Year	N = subjects	Self-Perception	Academic	Professional	Social / Peer	Engineering Cult "Fit" or "Belonging"	Multiple Identity	Themes / Findings
Pierrakos (2009)	8			X		X		Professional identity (PI): identity with interest and preparation / recruitment and retention
Foor (2009)	118		X					Gendered identity (GI): IE perception of field, feminizing disciplines "business" vs. "technical"
Matusovich (2011)	20			X		X	X	Engineering identity (EI): men and women but not disaggregated data
Eliot, et al. (2011)	36			X				Professional identity (PI): external and internal frames of reference
Cass (2011)	36			X				Academic identity (AI): external and internal frame sense-making activities
Meyers, et al. (2012)	701	X						Engineering identity (EI): self-identify due to belonging and organizational recognition. Factors to be engineer are making competent design decisions, working with others, accepting responsibility.
Fleming (2013)	184					X	X	Engineering identity (EI): identity shaped by minority serving institutions (MSI's)
Godwin, et al. (2013)	6772	X	X					Engineering identity (EI): significance for math, physics, science identities / personal and global agency
Knight (2013)	623	X	X	X				Engineering identity (EI): access, performance, retention / identity with programs

Author & Year	N = subjects	Self-Perception	Academic	Professional	Social / Peer	Engineering Cult "Fit" or "Belonging"	Multiple Identity	Themes / Findings
Jones (2013)	363		X		X			Engineering identity (EI): identity with stereotype threat / gender identity
Godwin, et al. (2013)	6772	X	X				X	Engineering identity (EI): identity coupled with interest, significance for math, physics, science identities
Revelo (2015)	22		X	X	X	X	X	Engineering identity (EI): identity with cultural belonging and "familia" / academic, social, professional identity through SHPE
Godwin, et al. (2015)	6772	X	X					Engineering identity (EI): identity variables are interest, recognition, performance/ competence (math) / agency / physics identity
Chech (2015)	312	X		X				Professional identity (PI) / gendered identity (GI): gendered professional identities
Prybutok (2016)	563		X	X				Engineering identity (EI): engineering identity with design efficacy, creativity, global agency as factors
Stoup (2016)	267	X	X					Engineering identity (EI): self-concept differentiation (SCD) identity with personality (agreeableness, conscientiousness, extroversion, neuroticism, openness to experience) and authenticity

Author & Year	N = subjects	Self-Perception	Academic	Professional	Social / Peer	Engineering Cult "Fit" or "Belonging"	Multiple Identity	Themes / Findings
Tatar (2016)	423	X		X	X			Engineering identity (EI): self-determination theory (SDT), Chickering's seven vectors (developing competence, interpersonal relationships, managing emotions, autonomy towards interdependence, develop purpose, establish identity, develop integrity)
Godwin (2016)	3337	X	X	X	X			Engineering identity (EI): student identity = personal identity (related to individual characteristics), social identity (group member), engineering identity (interest, performance/ competence, recognition) - engineering identity developed from Hazari et al. (physics identity K-12)
Pierrakos (2016)	266	X						Engineering identity (EI): composite unified self-concept, distinctiveness, participation, self-enhancement, visibility of affiliation / citizenship is best
Curtis (2017)	562	X		X	X	X		Engineering identity (EI): measurement instrument development = 38 items/11 factors
Henderson (2017)	397	X						Engineering identity (EI): identity with fixed or growth mindset

Author & Year	N = subjects	Self-Perception	Academic	Professional	Social / Peer	Engineering Cult "Fit" or "Belonging"	Multiple Identity	Themes / Findings
Patrick (2017)	1465			X				Professional identity (PI): identity measurement instrument align w/ ABET a-k. Constructs: framing and solving problems, design, project management, analysis, collaboration, tinkering
Godwin, et al. (2017)	1	X			X		X	Engineering identity (EI): subject-related identity / agency with critical engineering identity / social construction of identity / interest, recognition / communities of practice
Verdin, et al. (2018)	2916	X	X				X	Academic identity (AI): discipline identity with grit, personality, physics identity, math identity, performance/competence (engrg, physics, math)
Kendall (2018)	765			X	X			Engineering identity (EI): professional engineering identity found with HSI Hispanic students / social identity found in PWI Hispanic students
Borrego (2018)	1528			X				Engineering identity (EI): 2 item scale measures professional practice, engineering performance/competence, engineering recognition, engineering interest
Patrick (2018)	474	X		X		X		Engineering identity (EI): IPE survey constructed from APPLES, SaGE, Hazari et al. and Meyers

Author & Year	N = subjects	Self-Perception	Academic	Professional	Social / Peer	Engineering Cult "Fit" or "Belonging"	Multiple Identity	Themes / Findings
Verdin, et al. (2018)	2916			X				Engineering identity (EI): engineering identity with grit in FGEn students / no effect from performance/ competence to identity
Sax (2018)	3814					X		Cultural identity (CI): belonging and student climate, underrepresented women and men / yes control group
Choe (2019)	1536		?	X				Engineering identity (EI): identity factors: framing and problem solving, design, project management, analysis, collaboration, tinkering
Kendall (2019)	184		X	X				Engineering identity (EI): identity factors: performance/competence, interest, recognition, framing and solving problems, design, project management, analysis, collaboration, tinkering
Taheri (2019)	1640			X		X		engineering identity factors: performance/competence, recognition, interest, belonging
Kendall, et al. (2019)	902		X	X				Engineering identity (EI): identity factors: performance/competence, interest, recognition, framing and solving problems, design, project management, analysis, collaboration, tinkering

Author & Year	N = subjects	Self-Perception	Academic	Professional	Social / Peer	Engineering Cult "Fit" or "Belonging"	Multiple Identity	Themes / Findings
Rohde (2019)	2916		X	X		X		Engineering identity (EI): identity factors: performance/competence, interest, recognition, belonging, academic interest in EE and computing
Torralba (2019)	16			X				Engineering identity (EI): form engineering identity in makerspace