The Influences of First-Year Engineering Matriculation Structures on Electrical and Computer Engineering Students' Self-Efficacy

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ABSTRACT

While first-year engineering (FYE) programs have grown dramatically over the last 30 years, they take a variety of different structures. However, few if any, researchers and FYE program developers has considered how program structure, and specifically matriculation, impacts retention – an issue that continues to be of concern as we seek to grown the national engineering workforce. Low retention rates combined with lack of diversity becomes even more acute when considering the field of Electrical and Computer Engineering (ECE) which ranks as one of the least diverse engineering disciplines. One factor that has been shown to support retention is self-efficacy or individuals' beliefs in their ability to succeed. Therefore, to help address the retention issues in ECE, this dissertation explores the programmatic influence of first-year engineering matriculation structures on self-efficacy development in electrical and computer engineering students. In particular, it compares declared engineering (DE) programs, which admit students to a specific engineering field, to general engineering (GE) programs, in which students are admitted to engineering but do not select a specific engineering field until after their first year.

Using qualitative and quantitative methodologies, this dissertation presents three manuscripts: 1) a quantitative secondary analysis comparing competency beliefs in a GE program and a quasi- DE first-year engineering program for ECE students; 2) a qualitative secondary analysis of self-efficacy development in a DE first-year program; and 3) a qualitative analysis exploring similarities and differences in self-efficacy

development in EE students at two universities, one with a DE program and one with a GE program.

The exploratory studies resulted in findings that demonstrate strong similarities in self-efficacy development in students from the DE and GE programs. Those differences that did emerge are largely attributed to how self-efficacy is discussed by students: 1) self-efficacy is developed differently between the two programs because the tasks associated with each program are different; 2) GE students discuss self-efficacy more broadly regarding engineering in general, focusing on domains like professional skills; 3) DE students discuss self-efficacy development more narrowly, specifically related to being an electrical or computer engineer. Additionally, the findings from study 2 suggest that pedagogical structures may be more important regarding self-efficacy development than matriculation structures. These results broaden our understanding of how FYE programs impact self-efficacy development within the context of a specific major, but still lend themselves to further exploration regarding factors most related to persistence and the experiences of underrepresented minorities in engineering.

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GENERAL AUDIENCE ABSTRACT

While first-year engineering (FYE) programs have grown dramatically over the last 30 years, they take a variety of different structures. However, few if any, researchers and FYE program developers have considered how program structure impacts persistence – an issue that continues to be of concern as we seek to grown the national engineering workforce. Low retention rates combined with lack of diversity in the field becomes even more intense when considering the field of Electrical and Computer Engineering (ECE) which ranks as one of the least diverse engineering disciplines. One factor that has been shown to support retention is self-efficacy or individuals' beliefs in their ability to succeed. Therefore, to help address the retention issues in ECE, this dissertation explores the programmatic influence of first-year engineering matriculation structures on self-efficacy development in electrical and computer engineering students. In particular, it compares declared engineering (DE) programs, which admit students to a specific engineering field, to general engineering (GE) programs, in which students are admitted to engineering but do not select a specific engineering field until after their first year.

The dissertation includes three studies: 1) a quantitative comparison of expectancy (similar to self-efficacy) beliefs in a GE program and a quasi- DE first-year engineering program for ECE students; 2) a qualitative study of self-efficacy development in a DE first-year program using interviews with students; and 3) a qualitative study of similarities and differences in self-efficacy development in EE students at two universities, one with a DE program and one with a GE program.

The studies demonstrated similarities in self-efficacy development in students from the DE and GE programs, with differences largely attributed to how students described self-efficacy, as follows: 1) self-efficacy is developed differently between the two programs because the tasks associated with each program are different; 2) GE students discuss self-efficacy more broadly regarding engineering in general, focusing on issues like professional development skills; 3) DE students discuss self-efficacy development more narrowly, specifically related to being an electrical or computer engineer. Additionally, the findings from study 2 suggest that approaches to teaching may be more important for self-efficacy development than matriculation structures. These results broaden our understanding of how FYE programs impact self-efficacy development within the context of a specific major, but also point to the need for more research on factors most related to persistence and the experiences of underrepresented minorities in engineering.

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"I can do all things through Christ who strengthens me" – Philippians 4:13

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Chapter 1: Introduction of the Research

National reports consistently call for improvements in retention of engineering students. With the projection of an increasing engineering job market and a lack of domestic talent available to fill those positions (VanAntwerp & Wilson, 2015), universities are consistently doing research to understand why exactly students leave engineering and what can be done to retain them in the field (Geisinger, N., & Raman, 2013; Miller et al., 2015). Findings from such research indicate that attrition in engineering has been the highest for students transitioning from their first to their second year in college (Xianglei Chen, 2013; Daempfle, 2002). Although the likelihood of students leaving engineering decreases as students persist through the major (Xianglei Chen, 2013; Daempfle, 2002), the current number of students persisting does not resolve the workforce issue. Data also indicates that unlike other majors, few students transfer into engineering after their first year. In fact, Ohland et al. (2008) found that only 7% of students change their major from a non-engineering major to engineering, as opposed to other majors where 30%-65% of eighth semester students started in a different major. Thus, one way to address this gap is to focus on the first year to improve retention between the critical first and second years.

It is, in fact this concern for attrition amongst first-year engineering students that was a motivating factor for engineering institutions to revamp their undergraduate curricula at the end of the 20th century and pay more detailed attention to what students learn in their first year (Ambrose & Amon, 1997). Historically, subjects such as calculus, physics, chemistry, and other general education requirements dominated the first-year engineering (FYE) curriculum. However, this structure often leaves students with limited exposure to engineering and limits the opportunities for seeing engineering as a dynamic field (Prendergast & Etkina, 2014) and choosing among the wide range and disciplines available. Institutions with general first-year engineering programs, in contrast, support the idea that a common curriculum allows students to more effectively acclimate to the university and the field of engineering (Olds & Miller, 2004). Equally important, developing first-year experiences that actively engage students in learning has been shown to counteract attrition by improving the educational environment and addressing student-related issues such as race, gender, and class (Felder, Felder, Mauney, Hamrin, & Dietz, 1995, Felder, Forrest, Baker-Ward, Dietz, & Mohr, 1993). As a result, beginning in the 1990s, engineering programs began to offer more project-based courses in the first year in addition to the more traditional FYE content (Ambrose & Amon, 1997), and such changes have produced results. For example, Prendergast & Etkina (p. 2, 2014) found that when the traditional FYE course at Rutgers University was replaced with a new Engineering Exploration course, "three-year retention increased by 19% and students reported higher satisfaction with their experiences."

However, while specific teaching practices for FYE programs have been explored, very few studies have looked across programs to compare the impact of different types of program structures. What we do know about the first year preparation is that there are a variety of programs that are typically designed from scratch by instructors to cover what each institution considers important (Reid, Reeping, & Spingola, 2018). These first-year programs may cover general problem solving and professional skills or may cover a range of topics specific to different engineering discipline at the surface level. And while these programs may be prerequisites to second-year courses, there may be a lack of purposeful, if any, integration with the curricula of specific disciplines (Reid et al., 2018).

In addition to varying based on factors such as content and course size, programs also vary based on matriculation structure. That is, some engineering programs directly admit students into a specific sub-discipline of engineering and offer sub-discipline-specific first-year programs. Others admit students as general engineering majors and offer generalized first-year programs that include all engineering majors together (Chen 2014). These students will be referred to as declared engineering (DE) students and general engineering (GE) students respectively. While a number of researchers have explored the impact of pedagogical and content choices on first year students, the influence of DE versus GE matriculation structures on major choice and persistence has been underexplored. There is little evidence to guide universities in choosing the DE or GE model for first year students, despite the fact that attrition is highest at the end of the first year in engineering. Given that 93% of engineering graduates matriculate solely through engineering, the first year is the primary period of time to explore major choice for engineering students. In one of the few available studies on this issue, Orr et al., (2012) conducted a quantitative analysis of the impact different first-year program have on engineering students' persistence and reported that students' persistence rates were not impacted by their FYE major structure. That study examined quantitative data from the institutions in the Multiple-Institution Database for Investigating Engineering Longitudinal Development (a growing database that currently includes information from nineteen institutions, commonly referred to as MIDFIELD) but did not take into account how FYE programs do or do not influence persistence or consider individual engineering disciplines. Recent research exploring motivation in engineering suggest that self-efficacy may be one key mechanism of influence; therefore, this dissertation aims to add to this discussion by exploring how the different FYE matriculation structures impact self-efficacy in engineering students, specifically those majoring in electrical and computer engineering.

1.1 First Year Content and Pedagogical Choices

To begin to address first-year retention, in the 1990's engineering programs began to redevelop their first-year courses based on anecdotal feedback requesting more opportunities for hands-on learning. Examples of these changes include the declared first-year Mechanical Engineering program at Carnegie Mellon (Ambrose & Amon 1997), the University of Wisconsin-Madison's Engineering Professional Development general first-year engineering course (Courter, Millar, & Lyons, 1998), and even a more integrated approach by the University of Massachusetts Dartmouth that included a strategic scheduling placement of the calculus, physics, and engineering courses (Pendergrass et al., 1999).

The approach to curricula changes from the 1990's continued into the 2000's as Rutgers University designed a general first-year Engineering Exploration course (Prendergast & Etkina, 2014) and the University of Utah creating a 0.5 credit engineering exploration course to their declared engineering program (Bates, 2014).The development of these courses parallels with the rise of engineering education research and increased emphasis on active learning and project based pedagogies discussed by Prince & Felder (2006). As these examples suggest, in the 1990's, programs were redesigned to increase retention through hands-on activities across declared, general, and integrated matriculation structures in first-year engineering programs. In the 2000's courses were still designed around active learning activities, but also included an emphasis on helping students choose an engineering major.

In looking broadly across these types of program, Reid, Reeping, & Spingola (2018) found a variety of pieces that play into the success of student in these course. Reid, Reeping, & Spingola (2018) evaluated 28 syllabi of first-year engineering courses at different types of institutions and held a workshop at a national conference with interested parties, with the goal to "categorize and define a classification scheme for first-year courses, including expected outcomes and assessment methods and identify the assessment gaps" (p. 1). Objectives extracted were grouped into four categories: engineering skills, professional skills, orientation to the university and related items, and orientation to the profession of engineering. Regarding professional skills, teaming skills and communication were overwhelmingly mentioned in majority of the syllabi evaluated. In terms of orientation, objectives mentioned mostly in the syllabi were related to orienting students to the engineering program whereas discussions during the workshops distinctly discussed orienting students to the university's engineering program and to the profession. Through syllabi evaluations and feedback obtained through iterations of a Delphi Study, Reid et al. identified a broad consensus regarding topics that have been included in first-year engineering programs, shown in Figure 1.1.

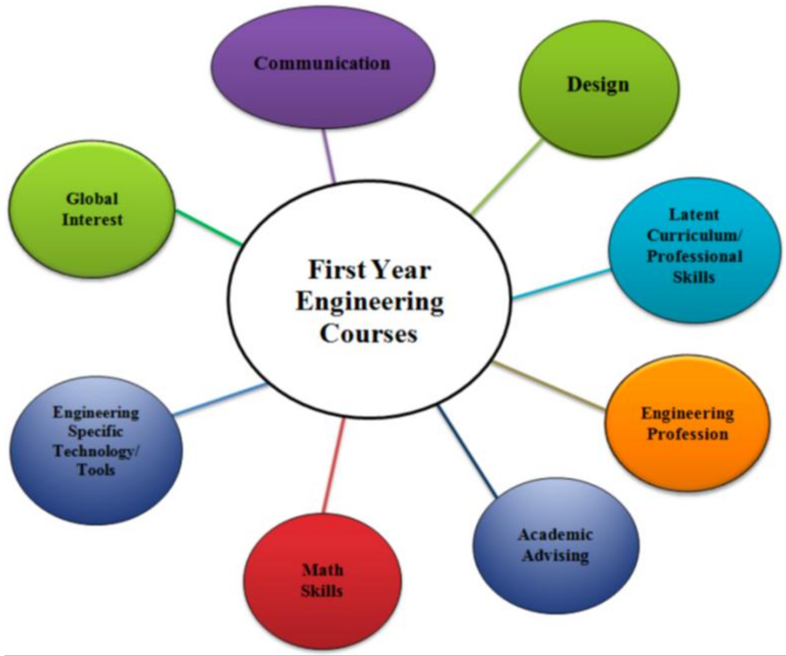

Figure 1.1 – Themes to be included in first-year engineering course (Reid et al., 2018)

However, what is interesting about Reid et al.'s study is that while there was a general consensus on what should be included in a first-year engineering course, there was no in-depth discussion about the role this course plays in the foundational development of students in of terms successfully navigating the subsequent engineering curriculum. There was mixed discussion about what the orientation theme oriented students to – i.e., orientation to the university, course, program, and/or profession – and this discussion may indicate that course designers and directors may be receptive to expanding that conversation to consider the matriculation structure of FYE programs. Despite this gap, some of the themes agreed upon in the Reid et al. study are also concepts other researchers (e.g., Ambrose & Amon (1997), Courter, Millar, & Lyons (1998), Pendergrass et al. (1999), Prendergast & Etkina (2014), and Bates (2014)) have incorporated in the development of their first-year engineering course to promote engagement and satisfaction amongst students and provide mastery and vicarious experiences, all of which support the retention of students in engineering.

In a related study regarding first-year engineering programs with a focus specifically on structure, Chen (2014, p. 28) conducted a “nationwide examination of the first-year engineering curricula and introductory engineering courses” of all ABET EAC-accredited programs, and investigated the degree to which these curricula and institutional characteristics varied by the matriculation policies of engineering programs. Based on this analysis, Chen defines engineering programs using three levels. The first level indicates whether students are admitted directly into their discipline, admitted to the college/school/department of engineering, or admitted to the university generally without admission to a specific college or department. The second level indicates the term when students are required to take their first engineering course and whether all engineering programs at the university require it simultaneously. The third level is similar to the second level but differs in terms that it indicates when students are required to take the first disciplinary engineering course and whether all engineering programs at the university require it simultaneously. Of the 1,873 engineering programs included in her study, Chen reports that 88% of programs required students to take an engineering course within the first two terms; 12% required students to take a course in the 3rd term, and two programs did not require an engineering course until the 4th term. Moreover, that 70% of ABET accredited institutions have declared first-year engineering matriculation structurers, while 18% have general first-year engineering matriculation structures in which students are admitted to the college but not to a specific engineering discipline (Chen, 2014). Notably, however, Chen also notes that GE programs are more common among large public institutions, suggesting that these programs may impact more than 30% of the student population. Given that both types of programs are widespread, this dissertation specifically aims to understand the difference in student development across those first-year engineering structures, and more importantly, how these differences in first-year engineering courses impact a student's decision to stay in engineering.

1.2 Self-Efficacy as a Guiding Framework

As discussed previously, engaging engineering courses that provide hands on experiences and various opportunities for practice and feedback are important to the development of the first-year engineering matriculation structure with a goal of better retaining engineering students. However, Chen (2013) reports that even with efforts of redevelopment, 56% of students who declared a STEM major in their first year left over the following six years. The desire to increase retention has been rooted primarily in active learning pedagogies, but not necessarily based on socio-cognitive models of student decision-making that supports positive attitudes in constructs such as motivation, self-efficacy and confidence, and expectancy value yield positive outcomes (in this case retention). Social cognitive theory was birthed from the idea that people are managers of their own development that enables them to be in control over their thoughts, feelings, and actions (Schunk & Pajares, 2005). There are a few researchers who have used social cognitive theories and motivation constructs to support the complete overhaul of course curricula or sections of a course curriculum to support the increased retention of students (Jones, Osborne, Paretti, & Matusovich, 2014; Jones, Tendhar, & Paretti, 2016; Tendhar, 2015; Virgüez, 2017). However, most of this research focuses on pedagogy rather than matriculation structure, and there is still a lack of coherence about what and how information should be taught (Reid & Reeping, 2014; Reid et al., 2018).

Understanding the role motivation plays in major choice is important to the design of FYE programs because several researchers have found that positive motivational experiences are linked to better academic performance and persistence including, but not limited to: Jones (2015), Jones, Paretti, Hein, & Knott (2010), Bernold, Spurlin, & Anson (2007), Schunk & Pajares (2007), Matusovich, Streveler, & Miller (2010). To explore the impact of program type (DE vs. GE), I turn to Bandura's theory of self-efficacy which has been used to explore retention in engineering.

As a subset of personal factors within social cognitive theory, perceived self-efficacy is defined as a person's belief about their capabilities to produce a certain level of performance on a given task, and it can have influence over events that affect their lives (Bandura, 1997). Self-efficacy influences the tasks and activities that a person may attempt and how much effort they will apply to those tasks and activities. Positive or an increased perception of self-efficacy yields greater effort, persistence, and resilience; the opposite is true for lower or decreased perception of self-efficacy (Bandura, 1997).

Perceptions of self-efficacy are formed by four sources: mastery experience, vicarious experience, social persuasions, and somatic and emotional state (Bandura, 1997). The most influential of these sources is a person's *mastery experience*. The more successful one has been in mastering an event, the higher their self-efficacy is to attempt similar tasks at higher difficultly. Conversely, persistent failure to master an event can yield lower self-efficacy; however, an occasional failure along a path of success is deemed as an outlying event and has little negative effect on a person's self-efficacy (Schunk & Pajares, 2005). *Vicarious experiences* influence a person's self-efficacy when one has little to no experience in completing a desired task. In this source, a person's self-efficacy is influenced though observing and/or modeling someone they can relate to completing the task (Schunk & Pajares, 2005). A person's self-efficacy can also be undermined when observing someone fail at the desired task. *Social* *persuasions* influence a person's self-efficacy through thoughtful praise or judgment from others towards a person's ability to complete a task. False inflation of a person's self-efficacy can quickly be diminished by disappointing results (Bandura, 1997). Lastly, a person's self-efficacy is influenced by the *somatic and emotional state* they are in while completing a task. If a person experiences increased levels of stress, anxiety, or physical pain while completing a task, their self-efficacy is more likely to be lower than someone who feels energized by their performance.

Self-efficacy is a particularly useful construct to examine in the context of the relationship between matriculation structure and retention because of its key role in social cognitive career theory. Derived from Bandura's social cognitive theory, social cognitive career theory (SCCT) states that people develop a long-term interest in a task or action (such as majoring in engineering) when they consider themselves competent and expect positive outcomes that are important to them (Lent & Brown, 1996). SCCT explains that personal inputs such as gender, race, etc. and background influences impact learning experiences, which in turn influence self-efficacy development and outcome expectations. The levels of self-efficacy and outcome expectations a person has then influence their interests, goals, actions, and outcomes. The model of SCCT is shown below in Figure 1.2.

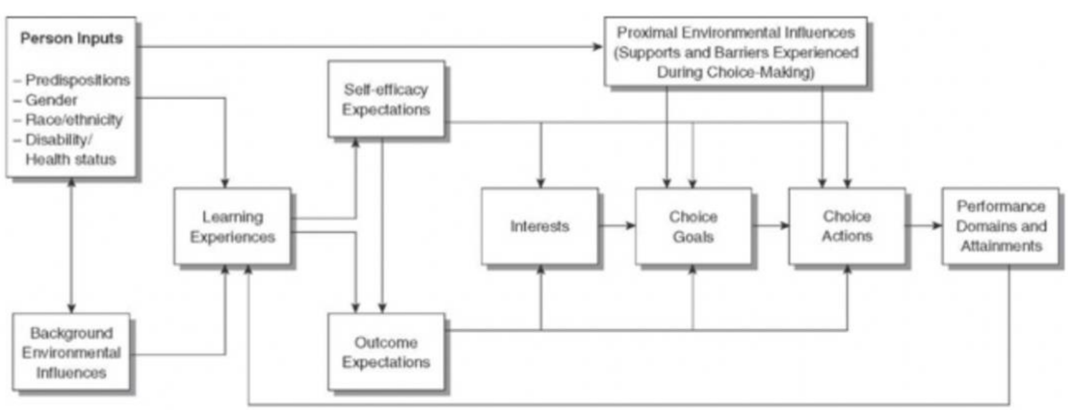

Figure 1.2 – SCCT reproduced with permission from authors: (Lent, Brown, & Hacket, 2002)

From the perspective of SCCT, first-year programs are a critical learning experience that can influence students' choices, goals, and actions – in this case, choosing and persisting in an engineering major. SCCT thus supports the idea that the nature of a first-year program will impact students' choices by impacting their self-efficacy. And while self-efficacy has been explored generally in FYE, it has not been used to compare matriculation structures (DE vs. GE) (Hutchison-Green, Follman, & Bodner, 2008; Hutchison, Follman, Sumpter, & Bodner, 2006; Jones et al., 2010). I expected this impact to vary because research shows that belonging, identification, and self-efficacy are all affected by learning experiences, and in turn affect choice of major and retention discussions (Fouad & Santana, 2017; Lent & Brown, 1996, 2013; Lent et al., 2002). These learning experiences likely differ based on matriculation structure due to the different foci of those structures; DE structures typically focus on a specific discipline whereas GE structures focus on engineering broadly (Xingyu Chen, Brawner, Ohland, & Orr, 2013). Exploring the relationship of differences in matriculation structures as an input to self-efficacy may provide insight regarding students' choices to major in engineering.

According to SCCT, the impact of learning experiences on students' choices, goals, and actions occurs through both self-efficacy and outcome expectations. Within engineering education research, self-efficacy has demonstrated particularly important to persistence. While an increased or high level of self-efficacy plays a role in students' decision to persist in engineering, little or no self-efficacy is one determining factor for students who leave engineering. There are several studies that have focused on self-efficacy and choosing/persisting in the field of engineering. Research results suggest that students who have low levels of self-efficacy (Lent et al., 2003; Schaefers, Epperson, & Nauta, 1997) are less likely to persist in science and engineering than students with higher levels of self-confidence and self-efficacy

(Ernst, Bowen, & Williams, 2016). There are studies that found women engineering students in particular, report lower levels of self-efficacy and self-confidence than that of their male peers (Vogt, Hocevar, & Hagedorn, 2016; Wee, Cordova-Wentling, Korte, Larson, & Loui, 2010). Lastly, a study conducted by Flores et al. (2014) suggests that all forms of self-efficacy development are not available to all demographics of engineering students as they found that students of Latin decent had few vicarious experiences at non-Hispanic Serving Institutions and stated that a benefit of a HSI is to provide those experiences to that population.

There are also studies that have used SCCT more broadly as the framework for exploring major choice. A study conducted by Lent et al. (2005, pg 90-91) on students at historically black colleges and universities (HBCUs) and predominantly white institutions (PWIs) found that SCCT variables such as “self-efficacy, outcome expectations, technical interests, social support, and educational goals” may aid in understanding the educational choices of engineering students and the results were independent of gender and university type. Patrick, Care, & Ainley (2011) conducted a study to explore whether Holland’s vocational interest model within the SCCT framework was a predictor of educational pathway and subject selection. Their claim was supported by the results reporting the major predictors were self-efficacy, academic achievement, and interest. However, Carrico et al. (2013) found that for some students in rural Appalachia, SCCT did not fully describe the pathway for their entry into engineering and that contextual factors played a stronger role in students’ decision to pursue engineering.

Although there is a plethora of research on self-efficacy and SCCT and the influences on whether students stay or leave engineering, most of that research focuses on belonging as a result of general institutional support or general first year experiences and doesn't take into account differences in first-year programs. However, the matriculation structure of first-year programs can differ significantly and thus studying those differences introduces a new viewpoint to the current conversation of retention (Xingyu Chen, 2014; Ohland, Brawner, Chen, & Orr, 2014; Orr et al., 2012). Given that self-efficacy is a construct that researchers have studied as a result of changes in course curriculum, the focus for this dissertation will be the exploration of how self-efficacy is developed in FYE students, recognizing that outcome expectations may be revealed through data results.

1.4 Summary and Research Focus

Research has demonstrated self-efficacy to be a good indicator for persistence in engineering. Over the years, FYE programs have undergone changes to better gauge students' interest with the goal of increasing retention of engineering students. However as discussed, changes to programs have been only minimally influenced by motivation constructs despite direct research linking self-efficacy and performance in engineering; in addition, the field generally lacks research exploring how self-efficacy has been developed in FYE students. Assessment of program changes have more often been evaluated using department created surveys and examinations rather than widely validated measures. Additionally, self-efficacy in engineering is usually measured quantitatively but rarely explored qualitatively. Lastly, self-efficacy has not been explored across types of FYE programs, specifically that of general versus declared first-year engineering programs thus leading to the purpose for my study.

To address these gaps, the purpose of this dissertation is to answer the overarching research question: In what ways do first-year engineering experiences shape the self-efficacy of engineering students and how do those patterns differ between DE and GE programs? To address this question, I approach this dissertation via three manuscripts:

1. The first manuscript is a secondary quantitative analysis of existing survey data collected by the college of engineering at a large land-grant university to compare expectancy and persistence among electrical engineering students in GE and quasi DE programs.
2. The second manuscript is a secondary analysis of interview data from a DE program to provide a comparison to existing self-efficacy research on GE programs.
3. The third manuscript is a multi-case study to investigate the qualitatively different ways that electrical and computer engineering students who matriculated through DE and GE programs develop self-efficacy and how that development impacts their persistence into their second year.

Although manuscript one uses expectancy and expectancy-value as the theoretical framework, it is important to note that in practice, expectancy and self-efficacy are both competency beliefs. While there are distinct differences in how expectancy and self-efficacy are defined (e.g. expectancy is broad or domain level competency and self-efficacy is task-specific competency), empirically, these motivation constructs are difficult to distinguish (Bong, 1999; Jones, 2010; Schunk & Pajares, 2005; Wigfield & Eccles, 2002). Both self-efficacy and outcome expectations influence a person's interests, choice goals, and choice actions as depicted in Figure 1.2, and both "stress the role of personal expectations as a cognitive motivator" (Schunk & Pajares, 2005, p. 90). The measurement of expectancy typically includes the individuals' beliefs about their own ability in addition to their comparative sense of competence (i.e. their competence beliefs compared to others), whereas self-efficacy focuses more on the individuals' beliefs of their ability with an emphasis placed on the ability to accomplish a task (Wigfield & Eccles, 2002).

Additionally, expectancy is the judgement of an outcome an individual expects to receive when completing a task whereas self-efficacy is the belief or confidence in one's ability to do a task. These subtle, yet important nuances are examples of motivational theorists' inability to agree on how to conceptualize perceived competence; thus, several similar constructs, such as self-efficacy and expectancy, exist in the literature (Schunk & Pajares, 2005). Thus while the primary focus of this dissertation is self-efficacy, existing data using expectancy still offers relevant insights to the overarching question.

Given the importance of self-efficacy within engineering education specifically and SCCT broadly relative to persistence, I focused this study on comparing the impact GE and DE matriculation structures have on self-efficacy. As stated previously, I expected this impact to vary given that prior research suggests that self-efficacy is impacted by learning experiences and is linked to persistence. Exploring those differences as an input to self-efficacy may influence one's actions regarding majoring in engineering.

Key findings of this dissertation are that there are no large differences in expectancy and persistence measures of GE and DE students and that students from both programs develop self-efficacy in very similar ways. DE students reported immediate applicability of the concepts learned in their FYE whereas GE students did not (though did note that they expect it to be applicable in project-based courses such as senior design). Common aspects of self-efficacy development discussed by both GE and DE students include: 1) foundation-building of engineering concepts; 2) teaching others as a form of self-assessed mastery; 3) performance-based mastery versus developing mastery for the purpose of understanding course content; 4) communication skills with regard to working in teams and public speaking; 5) social persuasions from peers to continue in engineering; 6) vicarious experiences through academic and professional examples; 7) familial examples of being an engineer; 8) and instructional environments created by professors that promoted positive or negative self-efficacy development. Each of the listed aspects fall into one of the four ways in which Bandura identifies self-efficacy development.

The findings of this dissertation contribute to existing literature in that they: 1) identify few differences in self-efficacy development quantitatively via the analysis of expectations regarding success in engineering, or qualitatively via analysis of interview data when exploring across FYE matriculation structures (even within the context of a single discipline); 2) reinforce mastery experiences as the most common ways in which self-efficacy is developed, following prior research (Hutchison-Green et al., 2006, 2008); 3) suggest that within engineering, skill, course, and major self-efficacy are often conflated, and4) suggest that somatic and emotional state experiences, particularly as it pertains to instructional environment, is just as important to students' success as learning content material. First, this dissertation suggests that quantitatively, matriculation structure does not affect self-efficacy but it does affect persistence. Therefore, there must be other factors to consider regarding how matriculation structures impact persistence. Secondly, qualitatively, regardless of matriculation structure, students develop self-efficacy in similar ways with mastery experiences being the most common form. However, this self-efficacy may develop relative to different tasks. Third, course self-efficacy and major self-efficacy may be inseparable for FYE students. The more aligned the course is with the major, more likely students related self-efficacy developed in the course to their self-efficacy development in their major. This alignment also ranged from developing self-efficacy broadly as it pertained to engineering to more narrowly as it pertained to being a specific type of engineer. Fourth, somatic and emotional state experiences emerged commonly amongst FYE students particularly as it pertained to the instructional environment. Students who had positive experiences in their FYE course demonstrated an increase in self-efficacy development as opposed to those who had negative experiences.

In closing, although matriculation structure has little impact on self-efficacy, it is still important to understand the nuanced ways in which self-efficacy is developed in students. This new understanding can provide researchers and practitioners with additional tools that can be used to support student success.

Chapter 2: Manuscript 1 – Persistence and Expectancy in First-Year GE and Quasi-DE Students

2.1 Introduction

National reports consistently call for improvements in the retention of engineering students. With the projection of an increasing engineering job market and a lack of domestic talent available to fill those positions (VanAntwerp & Wilson, 2015), universities are consistently doing research to understand why exactly students leave engineering and what can be done to retain them in the field (Geisinger, N., & Raman, 2013, Miller et al., 2015). Findings from such research indicate that attrition in engineering has been the highest for students transitioning from their first to their second year in college (Daempfle, 2002). Although the likelihood of students leaving engineering decreases as students persist through the major (Daempfle, 2002), the current number of students persisting does not resolve the workforce issue, and data also indicates that unlike other majors, few students transfer into engineering after their first year. An important reason for focusing on retention of first-year engineering students, then, is because the engineering curriculum does not lend itself to allow students to switch into the major to effectively "replace" those who leave. In fact, Ohland et al. (2008) found that only 7% of engineering students had changed their major from a non-engineering major to engineering, as opposed to other majors where 30%-65% of eighth semester students started in a different major. Thus, one way to address this workforce gap is to focus on the first year to improve retention between the critical first and second years.

It is, in fact, this concern for attrition amongst engineering students that was a motivating factor for engineering institutions to revamp their undergraduate curricula at the end of the 20th century and pay more detailed attention to what students learn in their first year (Ambrose & Amon, 1997). Historically, subjects such as calculus, physics, chemistry, and other general education requirements dominated the FYE curriculum. However, this structure often left students with limited exposure to engineering and limited their opportunities for seeing engineering as a dynamic field (Prendergast & Etkina, 2014). Institutions with a dedicated first-year engineering (FYE) matriculation structure, in contrast, support the idea that a common curriculum for all FYE students allows them to more effectively acclimate to the university and the field of engineering (Olds & Miller, 2004). Equally important, developing first-year experiences that actively engage students in learning has been shown to counteract attrition by improving the educational environment and addressing student-related issues such as race, gender, and class (Felder, Felder, Mauney, Hamrin, & Dietz, 1995, Felder, Forrest, Baker-Ward, Dietz, & Mohr, 1993). As a result, beginning in the 1990s, engineering programs began to offer more project-based courses in the first year in addition to the more traditional FYE content (Ambrose & Amon, 1997), and such changes have produced positive results. For example, Prendergast & Etkina (2014) found that when the traditional FYE course at Rutgers University was replaced with a new Engineering Exploration course, three-year retention increased by 19% and students reported higher satisfaction with their experiences.

However, while specific teaching practices for FYE programs have been explored, very few studies have looked across programs to compare the impact of different matriculation structures. What we do know about the first year preparation is that there are a variety of programs that are typically designed from scratch by instructors to cover what each institution considers important (Reid et al., 2018). These first-year programs may cover general problem solving and professional skills or may cover a range of topics specific to the individual engineering disciplines at the surface level. And while these programs may be prerequisites to second-year courses, there may be a lack of purposeful integration with the curricula of specific disciplines (Reid et al., 2018).

In a related study regarding first-year engineering programs with a focus specifically on structure, Chen (2014, p.28) conducted a “nationwide examination of the first-year engineering curricula and introductory engineering courses” of all ABET EAC-accredited programs, and investigated the degree to which these curricula and institutional characteristics varied by the matriculation policies of engineering programs. Of the 1,873 engineering programs included in her study, Chen reports that 88% of programs required students to take an engineering course within the first two terms; 12% required students to take a course in the 3rd term, and two programs don't require an engineering course until the 4th term. Moreover, that 70% of ABET accredited institutions have declared first-year engineering (DE) matriculation structures, while and 18% of ABET accredited institutions have general first-year engineering (GE) matriculation structures (Chen, 2014). Given that both types of matriculation structures are widespread, this dissertation specifically aims to understand the difference in self-efficacy development across those first-year engineering structures, and more importantly, how these differences in first-year engineering courses impact a student’s decision to stay in engineering.

In previous research, Orr et al. (2012) looked at persistence rates based on the type of matriculation structure but did so broadly in terms of engineering. They found that persistence rates are similar in GE and DE FYE matriculation structures reporting that students from GE matriculation structures (51%) and DE matriculation structures (50%) graduate in six years or less. Additionally, they found that GE matriculation structures lose a slightly larger percentage of students in the first four semesters than DE matriculation structures; however, they hypothesis a reasoning for this may be due to GE matriculation structures adding an additional gate to engineering (e.g. having to declare a major in the discipline after being undeclared/general engineering). These findings suggest that more work remains to better understand retention of engineering students, and I argue here that the disciplinary structure of students' first-year experience is a central unexplored dimension.

This structure becomes particularly important when considering the structure of electrical engineering degree granting departments. Electrical engineering (EE) is the studying and application of the physics and math of electricity, electromagnetism and electronics to process information and transmit energy (The University of New South Wales, n.d.). Most electrical engineering phenomena are invisible, such as electricity, light, and electromagnetic fields. However, they continuously serve as the foundations of many modern capabilities. Almost every piece of modern technology relies on electrical engineering. These technologies include, but are not limited to: viewing images from inside the body in medicine; the recording, production, storing, and playing of music; exploring space and the ocean through signal sensing; and smart technology such as phones, alarms, and robotic household appliances (Virginia Tech, n.d.-b). Thus, exploring this major helps make the case meaningful to a wide range of institutions and a high number of students and supports potential generalizations discovered from data analysis.

There are a few universities who grant electrical engineering degrees as a combination with another field such as computer science or biomedical engineering (ASEE, 2015). However, more than 10% of ABET accredited institutions combine electrical and computer engineering as the Electrical and Computer Engineering Department (Blandford & Hwang, 2007), which typically includes one department head and two program directors allowing for some degree of administrative efficiency. This combination is commonly due to the ability to provide students with a well-rounded education (a good electrical engineer should have knowledge of software and a good computer engineer should have knowledge of hardware), the similar foundational principles of the two fields, and provides the ability to change between the majors without losing time to degree completion (Blandford & Hwang, 2007).

Electrical and computer engineering are particularly useful as the focus for this study because these majors also pose key challenges with diversity because of the low number of women and people of color who are awarded degrees in these fields. According to *Engineering by the Numbers*, both electrical and computer engineering has consistently awarded less than 16% of degrees to women (Yoder, 2017) in contrast, to 50% in environmental, 44% in biomedical, and 21.3% overall. It is important to note that the number of degrees awarded to diverse populations are not solely due to attrition of those groups in EE but rather an effect of the low entrance rate of these groups into the field. The lack of diversity in this field suggest the need for more detailed research within the first year to learn how the matriculation structure in the first-year can better support underrepresented minorities who choose electrical engineering as a major and learn how to appeal to more students from diverse backgrounds with hopes to increase the likelihood of EE being a first-choice major for these students. To that end, the university used for analysis for this manuscript has consistently low numbers of diverse students in EE from Falls 2013 – 2017.

2.2 Theoretical Framework: Expectancy

To explore the impact of direct admit vs. general engineering matriculation structures on electrical engineering students, I draw on expectancy-value theory, focusing on expectancy because of its relationship to persistence.[1] Several researchers have studied and found that positive motivational experiences are linked to better academic performance and persistence including, but not limited to Jones (2015), Jones, Paretti, Hein, & Knott (2010), Bernold, Spurlin, & Anson (2007), Wigfield & Eccles (2002), Schunk & Pajares (2005), Matusovich, Streveler, & Miller (2010). The following discussion will provide a historical overview of the motivational construct of expectancy and examples of how expectancy has been measured within engineering.

2.2.1 History of Expectancy-Value

Eccles' expectancy-value theory (Eccles, 1987; Eccles et al., 1983; Wigfield & Eccles 1992, 2001) is derived from Atkinson's (1964) expectancy-value model by linking achievement performance, persistence, and choice to individuals' expectancy-related and task-value beliefs. However, Eccles' derivation of expectancy-value differs from Atkinson's in that "both the expectancy and the value components are more elaborate and are linked to a broader array of psychological and social-cultural determinants", and are approached from a positive viewpoint (Eccles & Wigfield, 2002, p. 108). Eccles et al.'s model assumes that choices one makes are influenced by both positive and negative task characteristics and that each of those choices have a cost associated with them, usually because this choice eliminated other options. Eccles et al. also assumes that "expectancies and values are influenced by task-specific beliefs such as perceptions of competence, difficulty of different tasks, and one's goals" (p. 108). These expectancy beliefs (J.S. Eccles, T.F. Adler, R. Futterman, S.B. Goff, C.M. Kaczala, J.L. Meece, 1983) are measured similarly to Bandura's definition of self-efficacy expectation (1997). While both expectancy beliefs and self-efficacy "stress the role of personal expectations as a cognitive

[1] While the dissertation overall uses self-efficacy, this manuscript uses a dataset that measured expectancy and the two are it is important to note that in practice, expectancy and self-efficacy are both competency beliefs and are similar enough to be indistinguishable empirically. (Bong, 1999; Jones, 2010; Schunk & Pajares, 2005; Wigfield & Eccles, 2002).

motivator" (Schunk & Pajares, 2005, p. 90), the measurement of expectancy typically includes the individuals' beliefs about their own ability in addition to their comparative sense of competence (i.e. their competence beliefs compared to others), whereas self-efficacy focuses more on the individuals' beliefs of their ability with an emphasis placed on the ability to accomplish a task (Wigfield & Eccles, 2002). Additionally, expectancy is the judgement of an outcome an individual expects to receive when completing a task whereas self-efficacy is the belief or confidence in one's ability to do a task. These subtle, yet important nuances is an example of motivational theorists' inability to agree on how to conceptualize perceived competence, thus several similar constructs, such as self-efficacy and expectancy, exist in the literature (Schunk & Pajares, 2005).

2.2.1.1 Expectancy Beliefs in Engineering

Within engineering education research, competence beliefs such as self-efficacy and expectancy-value has been demonstrated as particularly important to persistence, and as a result are the primary focus for this study. While an increased or high perception of competence play a role in students' decision to persist in engineering, "low competence beliefs" is one determining factor for students who leave engineering. Expectation for success combined with actual successes increases one's desire to perform a given activity, resulting in increased self-efficacy with the converse being similarly true (Carberry, Lee, & Ohland, 2010). Research results suggest that students who have low levels of self-confidence (Brainard & Carlin, 1998; Seymour, 1992) or self-efficacy (Lent et al., 2003; Schaefers et al., 1997) are less likely to persist in science and engineering than students with higher levels of self-confidence and self-efficacy. Some studies have shown that students whose self-efficacy is reduced with every perceived failure are less likely to persist in engineering. These students are more likely to attribute their failures to themselves as opposed to external factors (Deboer, 1984; Nauta, Epperson, & Waggoner, 1999). Wee et al. found that female engineering students in particular reported lower levels of self-efficacy and self-confidence than male engineering students (Wee et al., 2010).

Competency beliefs have been used in a number of different studies for example, Carberry, Lee, & Ohland's (2010) study focused on the relationship between competence beliefs and engineering design. The online survey they developed and administered was informed by the eight-step engineering design process proposed in the Massachusetts Department of Education (DoE) Science and Technology/Engineering Curriculum Framework. 202 participants were included in the final data analysis where the results showed significant differences in expectancy of task-specific concepts for participants with low, medium, and high engineering experiences, indicating that expectations to be successful in engineering are highly dependent upon these engineering experiences. Additionally, motivation, self-efficacy, and anxiety were significantly related to outcome expectancy in engineering design.

Expectancy has also been used to explore how first-year engineering students choose their major. Ortega-Alvarez, Atiq, Rodriguez-Simmonds, Eafit, & Lafayette (2016) examined interview and survey data to explore value beliefs that influenced GE students' decision-making process. Their results showed that students reported choosing a major that best aligned with their values, competence beliefs, and expectations. These expectancy beliefs reported by students include themes such as, but not limited to, breadth of field, professional interest, land the practicality of their future job.

Another study that support students in the decision-making process is one conducted by VanDeGrift & Liao (2017) who used social cognitive career theory (SCCT) to design resources, activities, and experiences to support DE students' self-efficacy belief regarding major choice.

Outcome expectations, a function in SCCT that is influenced by self-efficacy and by learning experiences (e.g. FYE matriculation structures), that influenced students' decisions the most were presentations about the engineering professions, videos by alumni, student panels, and student blogs. Overall, they found that students were 84% confident in their major choice by the conclusion of this course.

As noted previously, competency beliefs such as expectancy and self-efficacy are commonly used to explore choice and persistence in engineering. While existing literature states that the value placed on an outcome predicts an individual's persistence, competency beliefs predicts the choice an individual makes to engage in the task (e.g. the more likely they are to succeed, the more likely they are to engage and vice versa) (Eccles & Wigfield, 2002; Schunk & Pajares, 2005; Wigfield & Eccles, 2002). This demonstrates that the use of competency beliefs to explore persistence is common due to the role competency beliefs play in determining an individual's value and thus their persistence (Bandura, 1977, 1997; Eccles & Wigfield, 2002; Schunk & Pajares, 2005).

2.2.2 Engineering Curriculum and Persistence

Studies conducted by Orr et al., (2012; 2013) explored the impact of different first-year matriculation structures on student pathways into engineering. Of the universities included in their study, Orr et al. found that 42% offered DE matriculation structures and 58% offered GE matriculation structures. Their results showed that students from GE matriculation structures were more likely to persist and make informed major choices regarding engineering more broadly, in comparison to their DE counterparts. They also found that requiring students to participate in a GE matriculation structure negatively affect how students identify with a major due to their connection to their engineering discipline being delayed. Lastly, connectedness emerged from their results in which they found that DE students were more likely to stay in their first-choice engineering discipline (2013).

Another study relevant to the present work is the impact of enhancing course curriculum to support students with their major choice decisions by McNeil & Thompson (2016). Results of this study showed that the integration of department presentations into the GE FYE course early in the semester were particularly helpful in helping students decide their major. The integration of company panels also improved students' confidence in choice of major although not significantly so.

Despite these notable exceptions, most studies to date have either looked only at a single school or look at engineering as a whole across schools when considering expectancy and persistence. For example Jones et al., (2014, 2010), who conducted research with this same dataset used in this study, found that across majors and found "engineering program belonging was the strongest positive predictor of intentions to stay in the engineering major, followed by engineering program expectancy and engineering utility" (2014, p.13). But given the number of ABET accredited institutions that have general first-year engineering matriculation structures (18%) and the number of ABET accredited institutions have declared first-year engineering matriculation structures (70%) (Chen, 2014), this study specifically aims to understand the difference in self-efficacy development across those first-year engineering structures, and more importantly, how these differences in first-year engineering matriculation structures impact a student's decision to stay in engineering, using EE as a focus.

2.2.3 Summary

Research has demonstrated an undeniable link between competence beliefs such as expectancy and retention in engineering, but prior research has generally looked at engineering as a whole, without regard for differences in admission and curriculum structures. To address this gap, the purpose of this study is to answer the following research question: *How do GE and DE first-year matriculation structures affects expectancy and major-choice outcome variables for students who enter college intending to major in electrical engineering?* Given the importance of self-efficacy and expectancy within engineering education specifically and SCCT broadly relative to persistence, I am focusing this study on exploring expectancy in the contexts of a GE matriculation structure with students interested in electrical engineering. I expected this impact to vary because research shows that self-efficacy is affected by learning experiences, and in turn affects choice of major and retention discussions. Exploring those differences as an input to self-efficacy and expectancy may influence one's actions regarding persisting in engineering.

2.3 Methods

This manuscript is a secondary quantitative analysis of survey data collected by the College of Engineering at a large land-grant university over five years. To address the overarching question, manuscript #2 will answer the following question:

> RQ1: How do GE and DE first-year matriculation structures affect expectancy and major-choice outcome variables for students who enter college intending to major in electrical engineering?

2.3.1 Research Design

2.3.1.1 Research Site

For this study, data were collected at a large, public, land-grant university (nifa.usda.gov, 2018). As of Fall 2017, the university had approximately 30,000 students of which 27,000 are undergraduate and 8,000 of those undergraduate students are pursuing a degree in the college of engineering. At this institution the Electrical and Computer Engineering department is the second largest department in the College of Engineering with over 1000 undergraduate students in the department and about half of whom are in the electrical engineering program. The percentage of underrepresented minorities in the department is just greater than 9%.

A general demographic overview of the electrical engineering department as of the beginning of the fall semesters from 2013 – 2017 are outlined in Table 2.1. It is important to note that the demographics outlined of are all students in the EE department and not just the first-semester sophomores, to provide insight of the department's diversity. An average of 10% of students enrolled in electrical engineering are underrepresented minorities.

Table 2.1 – Demographic overview of all students in EE department

Major	Ethnicity	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017
EE	**URMs**	49	50	51	58	47
	Asian	70	80	81	78	75
	White	256	250	249	265	258
	Two or more races	8	18	22	30	26
	Not Reported	12	14	10	12	14
	Nonresident Alien	65	68	93	118	130
	Total	460	480	506	561	550

Students enter the university as General Engineering (GE) majors and take a two-semester introductory engineering sequence (fall and spring respectively) with course objectives such as teamwork, communication skills, and basic competency in common engineering software (Virginia Tech Department of Engineering Education, n.d.). The first course of the sequence is classified as a First Year Experience course designed to "equip students with problem solving skills, inquiry skills, and integration of learning skills necessary for navigating college level curricula" (Virginia Tech, n.d.-a). At the end of the spring semester, students must meet certain requirements in order to apply to an engineering degree granting program, including completion of selected courses with a C- or better and a minimum overall GPA of a 2.0 (Engineering & Management, 2019).

This site is particularly useful for considering DE vs GE because while this institution employs a 2-course GE FYE sequence, the second semester course differed based on students' intended major prior to 2014-2015. Students planning to major in ECE or CS were encouraged to take one course, while all others took a different course. Potential ECE students were also encouraged to take an introductory ECE course in programming. Beginning in the 2014-2015 academic year, the program shifted to a single common second semester course, though potential ECE students were still encouraged to take the ECE programming course (which is also available in the fall semester of the sophomore year). The site thus allows us to compare expectancy and major intention across two different first-year structures at the same institution. Data from the 2013-2014 academic year represents a quasi-DE structure since students choose their second semester FYE course based on intended major, while subsequent years represent a full GE matriculation structure with all engineering students in the same FYE courses. Figure 2.1 represents the pathways of participants in this study.

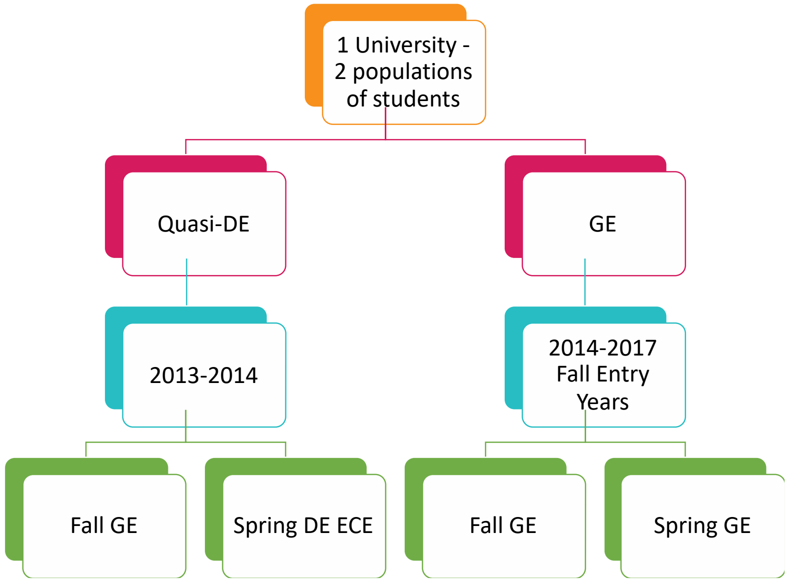

Figure 2.1 – Pathways of Electrical Engineering Students

2.3.1.2 Data Collection

Developed by (Jones et al., 2010), a survey was administered to first-year students at three points of their first year: at the beginning of fall semester; at the beginning of spring semester; and at the end of fall semester. This survey asks students about their choice of major, and their confidence development in relation to the first-year course, and measures expectancy amongst other constructs. All three surveys ask students about their intended engineering major; the surveys are administered as required homework assignments in the first-year courses, but students can choose whether to allow their responses to be included in research studies (Lewis & Knott, 2017). All survey questions have Likert-scale responses of Strongly Disagree, Disagree, Somewhat Disagree, Somewhat Agree, Agree, and Strongly Agree. The questions from the survey used in analysis are outlined in Table 2.2.

Table 2.2 – Survey Questions

Engineering Persistence Questions	Expectancy Questions
I am confident in my choice of a specific major	Compared to other engineering students, I expect to do well in my engineering-related courses this year
I have sufficient information to make an informed choice about a specific engineering major	I think that I will do well in my engineering-related courses this year
I am confident that I want to study engineering	I am good at math, science, and engineering
I plan to continue on in an engineering major	Compared to other engineering students, I have high engineering-related abilities
I don't intend to change my major from engineering to a non-engineering major	I have been doing well in my engineering-related courses this year

Data were cleaned in Microsoft Excel to identify consenting students who 1) took the survey at the beginning of the fall semester *and* at the end of the spring semester and 2) identified electrical engineering as their major of choice on at least one of these surveys. Because the goal of this study is to understand how the full FYE matriculation structure impacted students' expectancy, and because the number of students who took all three surveys created groups with populations too small for meaningful quantitative comparison, data from survey 2 (at the end of the fall semester) was excluded. Additionally, students who identified computer engineering as a major of interest on either survey were omitted for data analysis because switching between EE and CPE was deemed too small a change to be considered a shift in major choice, yet the majors are distinct enough to not consider students who changed to CPE persisters, either.

2.3.1.3 Sample

The sample population for this manuscript are students who listed electrical engineering as their first-choice major in the first survey administered either at the beginning of the fall semester or at the end of spring semester and who completed all three surveys administered over the course of the first year. Using data from students who completed all surveys enabled me to see changes in expectancy and intentions to persistence that may have occurred over the of course the first year. Additionally, selecting students who chose EE as their first-choice major in the first or last enabled me to look at both those who switched in and those who switched out, as well as those who persisted. It is important to note that students who switched their major between EE and Computer Engineering (CPE) were not considered for data analysis given the high similarities between the two majors. Group 1 and 2 are those in the quasi-DE matriculation structure. Groups used for analysis are outlined in Table 2.3:

Table 2.3 – EE sample population

Group	Entry Year	Major Criteria	Label
1 (quasi-DE)	Fall 2013	Started as EE, took DE, ended EE	DE Persisters
2 (quasi-DE)	Fall 2013	Started EE, took DE, switched out of ECE	DE Leavers
3	Falls 2014-17	Started EE, ended EE	GE Persisters
4	Falls 2014-17	Started EE, switched out of ECE	GE Leavers
5	Falls 2014-17	Started not ECE, switched into EE	GE Switchers

For the purpose of this study the variables are:

- Independent: Population Groups outlined in Table 2.3
- Dependent: Responses to Engineering Persistence & Engineering Expectancy Questions

Data were grouped as demonstrated in Table 2.3. The population was be students who meet the sampling criteria for years 2013 – 2017.

2.3.2 Data Analysis

The goal of this study is to compare engineering persistence and engineering expectancy among five different groups of participants. In this section, I discuss the statistical analyses conducted to test my hypotheses and identify potential relationships and correlations amongst variables.

To answer the research question, I conducted the Mann-Whitney test for mean comparison and an explanatory correlation analysis to determine the statistical strength between students' responses related to engineering expectancy abilities and students' responses related to major choice and persistence in engineering. To analyze persistence, the 5 items in column 1 of Table 2.2 were treated as a single construct. To analyze expectancy, the 5 items in column 2 were treated as a single construct. Table 2.4 lists the Cronbach's alpha for each construct across the full dataset. All are above 0.7, and thus the constructs are considered valued (Field, 2009).

Table 2.4 – Cronbach's alpha for survey instruments

Construct	Cronbach's alpha
Persistence	0.754
Expectancy	0.905

2.3.2.1 Hypotheses

To answer research question 1, a comparison of means was conducted with the data across groups, within semesters (i.e. Fall Group 1 vs Fall Group 2 and the Spring equivalent), and between semesters (i.e. Fall Group 1 vs Spring Group 1). In answering this question, I hypothesized the following outcomes:

- H_0: DE Persisters are not different from GE Persisters on both measures and; DE Leavers are not different from GE Leavers on both measures.
- H_1: DE Persisters will have a higher expectancy and persistence score than DE Leavers.
- H_2: GE Persisters will have a higher expectancy and persistence score than GE Leavers.
- H_3: GE Switchers will have a higher expectancy and persistence score than GE

Leavers

- H_4: GE and DE Leavers will have a lower persistence score than DE and GE Persisters and GE Switchers.

2.3.2.2 Non-Parametric Data

The data analyzed for this manuscript do not follow that of a normal distribution. Parametric or normally distributed data are data that are evenly distributed across the center, most notably recognized by the bell curve (Field, 2009). Given the nature of Likert-scale responses, data from these surveys are not typically evenly distributed across the center and are often skewed towards the higher or lower end of responses (Field, 2009). Quantitative analyses, such as t-tests assume normality of data distribution (Field, 2009; Field, Miles, & Field, 2012). In the event where data is not normally distributed, the non-parametric versions of the test (Mann-Whitney) are employed to assess results from data. “Non-parametric tests are sometimes known as assumption-free tests because they make fewer assumptions about the type of data on which they can be used” such as normality (Field, 2009 p. 540)

2.3.2.3 Mann-Whitney Test

The Mann-Whitney test is the non-parametric equivalent to the t-test. Like the t-test, Mann-Whitney is used to compare the means of two groups (Field, 2009; Field, Miles, & Field, 2012). For non-parametric data, Mann-Whitney works by converting the ordinal data into ranked data, and then the statistical analysis is performed on the ranked data (Gignac, 2019). In order to properly conduct the Mann-Whitney test, the average score for each participant’s responses to the engineering expectancy and persistence scores were created. Due to the fact that each construct is measured by a set of five questions, it is typical in mean comparison tests that an average is taken for each construct to create one score for the respective construct for each participant (Field, 2009; Field, Miles, & Field, 2012).

2.3.2.4 Cohen's d

When conducting statistical analyses, finding statistical significance is important in understanding whether the difference found is large enough to occur less than 5% of the time if the null were true (or less than whatever significant threshold value is set for the test) (Howell, 2013). However, statistical significance does not always translate into practical significance. With that said, when statistical tests return results that are statistically significant, it is best practice to calculate the effect size of those results. Cohen's d is used to the measure of the effect size of the significance. This effect size indicates how many standard deviations two groups differ from one another. The effect size is denoted in three ways: >= .2 is a small effect size; >= .5 is a medium effect size; and >= .8 is a large effect size (Field, 2009; Field, Miles, & Field, 2012). Theoretically, the larger the effect size, the more likely the differences between the groups are apparent to the human eye, hence the reason Cohen's d is used to measure practical differences beyond the statistical ones. Even if a result is statistically significant, if the effect size is less than .2, the significance is trivial regarding real-world application. Thus, in order to determine if there is practical meaning to the significant results from the Mann-Whitney test, Cohen's d was calculated for each statistically significant test. Cohen's d for Mann-Whitney results is calculated using the following formula:

$$d = Z \times \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}$$

where z is the z statistic calculated from the Mann-Whitney test and N_1 and N_2 are the sizes of two groups being analyzed (Gignac, 2019).

2.3.3 Validity and Reliability

With any research study, the validity and reliability of data collection and analysis methods are important in ensure the generalizability, trustworthiness, credibility, and authenticity of a study (Creswell & Miller, 2000). In quantitative studies, threats to validity refer to specific reasons for why incorrect inferences can be made due to “covariance, causation constructs, or whether the causal relationship holds over variations in persons, setting, treatments, and outcomes” (Creswell, 2012; Shadish, Cook, & Campbell, 2002, p. 20). In this section, I discuss the validity and reliability of this research study, as well as address my own biases regarding this study.

2.3.3.1 Validity

Threats to internal validity occur in the context of claims about the influence of one variable on the variations in another variable - that is, when the research attempts to move from correlation to causation (Creswell, 2012; Shadish et al., 2002). This threat is the most severe in quantitative studies because it can compromise an otherwise good experiment. General threats to internal validity include “history, maturation, regression, selection, mortality, and interactions with selection” (Creswell, 2012, p. 303). Threats to consider for this study specifically are those of maturation, selection, and mortality. First, to control for maturation, the data analyzed includes only students in their first year of post-secondary education ensuring that all students are generally at the same maturity level when they took the survey. Second, to control for selection, the data analyzed only included students who fell into one of the five groups outlined in Table 2.3. Lastly, to control for mortality, the data analyzed consisted only of students who took the first and last of the three surveys administered. This ensures that the number of participants are the same for a given year. The other threats are not of concern regarding this study due to the fact that typically, these threats are associated with an experiment in progress as opposed to a study using existing data.

Threats to external validity arise when "our ability to draw correct inferences from the sample data to other persons, settings, treatment variables, and measures is threatened" (Creswell, 2012, p. 306). General threats to external validity include "interaction of selection and treatment, interaction of setting and treatment, and interaction of history and treatment" (Creswell, 2012, p. 306). The threat to consider for this study specifically is the interaction of selection and treatment. This threat involves the "inability to generalize beyond the groups in the experiment, such as other racial, social, geographical, age, gender, or personality groups" (Creswell, 2012, p. 306). To control for this, the data analyzed comes from a survey that was disseminated to all first-year students regardless of demographic data resulting in an equal opportunity for the student population to be well represented and increases the likelihood of generalizability. The other threats are not of concern regarding this study due to the fact that typically, these threats are also associated with an experiment in progress as opposed to a study using existing data.

2.3.3.2 Reliability

In quantitative studies, the reliability of a study is indicative of how consistent the instrument is to measure constructs (Heale & Twycross, 2015). The survey administered for this study was created by (Jones et al., 2010) to measure constructs such as expectancy, persistence, and more, using validated measures. Additionally, Cronbach's alpha was calculated to verify the reliability of the questions independent of the survey from which they came.

2.3.4 Limitations

A limitation of quantitative research using existing data is that although the data is representative of the larger population, if the population is not a diverse group of participants, information from underrepresented minorities may not be accounted for in data analysis (Creswell, 2009c). To account for this limitation, participants from underrepresented backgrounds were oversampled during the recruitment for study 3 in order to include perspectives from a diverse population.

` Secondly, quantitative research provides answers pertaining to “what” and “to what extent”. Another limitation of this study is the fact that these data are captured only during participants’ first-year and any information regarding actual major choice declared with the university is not captured or included in analyses. Thus, this study is limited to providing suggestions regarding the FYE curriculum based solely on first-year students’ experiences and not on the long-term impact the curriculum had on those participants experiences within their major. Additionally, this study uses a single university; results of the analysis is not a true comparison of GE vs. DE but rather a proxy. These limitations will also be addressed in study 3, a qualitative study, which will provide answers to the “why” or “how” (Creswell, 2009c) by drawing on a true DE matriculation structure as a comparison point, thus providing an opportunity to understand how students perceive the FYE program to be impactful regarding their pursuit of an electrical engineering degree.

Third, data analyzed in this study was captured before students are actually accepted into their engineering discipline and thus Leavers are those who did not indicate their intended major as electrical or computer engineering on the last survey. Additionally, this dissertation does not incorporate data (if any is available) that tracks whether or not the Persisters actually matriculated into electrical engineering.

Lastly, this study was conducted with a sample of engineering students at one university and it focused on a GE FYE matriculation structure that served a wide range of engineering majors. Given an average response rate of ~54% for the years used in this study, it is possible that there could be a non-response bias for which non-respondents held different beliefs than the respondents.

2.3.5 Results

2.3.5.1 Summary of Results

A summary of the results of this study are presented Table 2.5. Cohen's d was only calculated for statically significant differences thus "n/a" is used for results in which the effect size was not calculated. The following section review the results for each hypothesis.

Table 2.5 – Summary of Results

Null Hypothesis Persisters Comparison (Persistence)							
	DE Persisters		GE Persisters		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	5.07	0.75	5.08	0.78	-0.01	0.957	n/a
Spring	4.86	0.82	5.22	0.66	-0.36	0.016*	0.44
Null Hypothesis Persisters Comparison (Expectancy)							
	DE Persisters		GE Persisters		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	4.97	0.81	5.01	0.70	-0.04	0.860	n/a
Spring	4.99	0.62	5.03	0.74	-0.04	0.536	n/a
Null Hypothesis Leavers Comparison (Persistence)							
	DE Leavers		GE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	5.04	0.73	4.88	0.97	0.16	0.384	n/a
Spring	5.32	0.69	5.03	0.77	0.29	0.002*	0.40
Null Hypothesis Leavers Comparison (Expectancy)							
	DE Leavers		GE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	4.93	0.76	4.90	0.84	0.03	0.795	n/a
Spring	4.90	0.79	4.91	0.77	-0.01	0.819	n/a
Hypothesis 1 (Persistence)							
	DE Persisters		DE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	5.07	0.75	5.04	0.73	0.03	0.710	n/a
Spring	4.86	0.82	5.32	0.69	-0.46	0.001*	0.59
Hypothesis 1 (Expectancy)							
	DE Persisters		DE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	4.97	0.81	4.93	0.76	0.04	0.535	n/a
Spring	4.99	0.62	4.90	0.79	0.09	0.593	n/a

Hypothesis 2 (Persistence)							
	GE Persisters		GE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	5.08	0.78	4.88	0.97	0.20	0.163	n/a
Spring	5.22	0.07	5.03	0.77	0.19	0.073	n/a
Hypothesis 2 (Expectancy)							
	GE Persisters		GE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	5.01	0.70	4.90	0.84	0.11	0.213	n/a
Spring	5.03	0.74	4.91	0.77	0.12	0.135	n/a
Hypothesis 3 (Persistence)							
	GE Switchers		GE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	4.88	0.97	4.95	0.68	-0.07	0.810	n/a
Spring	5.03	0.77	5.16	0.75	-0.13	0.186	n/a
Hypothesis 3 (Expectancy)							
	GE Switchers		GE Leavers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	4.9	0.84	4.84	0.73	0.06	0.459	n/a
Spring	4.91	0.77	4.89	0.78	0.02	0.954	n/a
Hypothesis 4 (Persistence)							
	All Leavers		All Persisters & GE Switchers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Fall	4.99	0.82	5.03	0.74	-0.04	0.766	n/a
Spring	5.23	0.73	5.15	0.72	0.07	0.167	n/a
Emergent Results (Fall)							
	GE Persisters		GE Switchers		Mean Difference	p < .05	Cohen's d
	M	SD	M	SD			
Persistence	5.08	0.78	4.95	0.68	0.13	0.043*	0.24
Expectancy	5.01	0.70	4.84	0.73	0.17	0.019*	0.28

2.3.5.2 Null Hypothesis

The null hypothesis predicted that there was no difference in persistence and expectancy scores between the DE and GE Persisters (Groups 1 and 3). There was no statistically significant difference between the fall semester mean persistence scores for DE Persisters (M = 5.07, SD =

.75, n = 36) and GE Persisters (M = 5.08, SD = .78, n = 166), p = .957. However, during the spring semester, there was a statistically significant difference between the spring semester persistence scores for DE Persisters (M = 4.86, SD = .82, n = 36) and GE Persisters (M = 5.22, SD = .66, n = 166), p = .016, d = .44. The GE Persisters reported a higher intent to persist with a small effect size.

In regards to expectancy, there was no statistically significant difference between the fall semester mean expectancy scores DE Persisters (M = 4.97, SD = .81, n = 36) and GE Persisters (M = 5.01, SD = .70, n = 166), p = .860. Additionally, there was no statistically significant difference between the spring semester mean expectancy scores DE Persisters (M = 4.99, SD = .62, n = 36) and GE Persisters (M = 5.03, SD = .74, n = 166), p = .536.

The null hypothesis also predicted that there was no difference in persistence and expectancy scores between the DE and GE Leavers (Groups 2 and 4). There was no statistically significant difference between the fall semester mean persistence scores for DE Leavers (M = 5.04, SD = .73, n = 189) and GE Leavers (M = 4.88, SD = .97, n = 90), p = .16. However, during the spring semester, there was a statistically significant difference between persistence scores for DE Leavers (M = 5.32, SD = .69, n = 189) and GE Leavers (M = 5.03, SD = .77, n = 90), p = .002, d = .40. DE Leavers reported a higher intent to persist with a small effect size.

In regards to expectancy, there was no statistically significant difference between the fall semester mean expectancy scores DE Leavers (M = 4.93, SD = .76, n = 189) and GE Leavers (M = 4.90, SD = .84, n = 90), p = .795. Additionally, there was no statistically significant difference between the spring semester mean expectancy scores DE Leavers (M = 4.90, SD = .79, n = 189) and GE Leavers (M = 4.91, SD = .77, n = 90), p = .819.

2.3.5.3 Hypothesis 1

The first hypothesis predicted that the DE Persisters (Group 1) would have higher persistence and expectancy scores than the DE Leavers (Group 2). There was no statistically significant difference between the fall semester mean persistence score for DE Persisters (M = 5.07, SD = 0.75, n = 36) and for DE Leavers (M = 5.04, SD = 0.73, n = 189), p = .71. However, during the spring semester, there was a statistically significant difference between persistence scores for DE Persisters (M = 4.86, SD = .82, n = 36) and DE Leavers (M = 5.32, SD = .69, n = 189), p = .002, d = .59. DE Leavers reported a higher intent to persist with a moderate effect size.

In regards to expectancy, there was no statistically significant difference between the fall semester mean expectancy scores DE Persisters (M = 4.97, SD = .81, n = 36) and DE Leavers (M = 4.93, SD = .76, n = 189), p = .54. Additionally, there was no statistically significant difference between the spring semester mean expectancy scores DE Leavers (M = 4.99, SD = .62, n = 36) and GE Leavers (M = 4.90, SD = .79, n = 189), p = .59.

2.3.5.4 Hypothesis 2

The second hypothesis predicted that the GE Persisters (Group 3) would have higher persistence and expectancy scores than the GE Leavers (Group 4). There was no statistically significant difference between the fall semester mean persistence score for GE Persisters (M = 5.08, SD = 0.78, n = 166) and for GE Leavers (M = 4.88, SD = 0.97, n = 90), p = .16. Additionally, there was no statistically significant difference between the spring semester mean persistence scores for GE Persisters (M = 5.22, SD = .073, n = 166) and GE Leavers (M = 5.03, SD = .77, n = 90), p = .07.

In regards to expectancy, there was no statistically significant difference between the fall semester mean expectancy scores DE Persisters (M = 5.01, SD = .70, n = 166) and DE Leavers

(M = 4.90, SD = .84, n = 90), p = .21. Additionally, there was no statistically significant difference between the spring semester mean expectancy scores DE Leavers (M = 5.03, SD = .74, n = 166) and GE Leavers (M = 4.91, SD = .77, n = 90), p = .14.

2.3.5.5 Hypothesis 3

The third hypothesis predicted that the GE Switchers (Group 5) would have higher persistence and expectancy scores than the GE Leavers (Group 4). There was no statistically significant difference between the fall semester mean persistence score for GE Switchers (M = 4.88, SD = 0.97, n = 126) and for GE Leavers (M = 4.95, SD = 0.68, n = 90), p = .81. Additionally, there was no statistically significant difference between the spring semester mean persistence scores for GE Switchers (M = 5.03, SD = .077, n = 126) and GE Leavers (M = 5.03, SD = .75, n = 90), p = .19.

In regards to expectancy, there was no statistically significant difference between the fall semester mean expectancy scores GE Switchers (M = 4.90, SD = .84, n = 126) and GE Leavers (M = 4.84, SD = .73, n = 90), p = .46. Additionally, there was no statistically significant difference between the spring semester mean expectancy scores GE Switchers (M = 4.91, SD = .77, n = 162) and GE Leavers (M = 4.89, SD = .78, n = 90), p = .95.

2.3.5.6 Hypothesis 4

The fourth hypothesis predicted that All Leavers (Groups 2 and 4) would have a lower persistence score than the All Persisters and GE Switchers (Groups 1, 3, and 5). During the fall semester, the overall mean persistence value for All Persisters was 5.08 (SD = .77), for Switchers was 4.95 (SD = .68), and for All Leavers was 4.99 (SD = .82) and there no statistically significant difference between the mean persistence score for All Persisters and Switchers (M =

5.03, SD = .74, n = 328) and for All Leavers (M = 4.99, SD = .82, n = 279), p = .77.

During the spring semester, the overall mean persistence value for All Persisters was 5.15 (SD = .70), for Switchers was 5.16 (SD = .75), and for All Leavers was 5.23 (SD = .73) and there no statistically significant difference between the mean persistence score for All Persisters and Switchers (M = 5.15, SD = .72, n = 328) and for All Leavers (M = 5.23, SD = .73, n = 27), p = .17.

2.3.5.7 Emergent Results

There was not a hypothesis that compared Group 3 (GE Persisters) & 5 (GE Switchers) due the fact that by the end of the spring semester, students in both groups chose electrical engineering as their preferred major. However, analysis showed that there was a statistically significant difference between the fall semester mean persistence score for GE Persisters (M = 5.08, SD = 0.78, n = 166) and for GE Switchers (M = 4.95, SD = 0.68, n = 126), p = .04, d = .24. Additionally, there was a statistically significant difference between the mean expectancy score for GE Persisters (M = 5.01, SD = .70, n = 166) and for GE Switchers (M = 4.84, SD = 0.73, n = 126), p = .02, d = .28. GE Persisters reported higher expectancy and intent to persist with a small effect size.

2.3.6 Discussion

Overall, there were few statistical differences amongst the groups as outlined in the results. Where differences did occur, GE students who persisted in electrical engineering had slightly higher levels of persistence and expectancy than their counterparts who left the field. This is comes as no surprise given that Kelly, Maczka, & Grohs (2018) found that students who start college with the intention of majoring in electrical engineering were 4.41 times more likely to change their major in their first year than those who intend to major in industrial and systems engineering who were least likely to change their major.

Orr et al.'s (2012) findings stated DE and GE students generally persist at the same rate. While the results from the fall semester are consistent with Orr et al.'s findings, when looking at the differences mean persistence rates between DE and GE students during the spring semester, the results showed that GE students' intention to persist was higher than DE students in the spring semester. On the other hand, DE Leavers' intention to persist was higher than GE Leavers in the spring semester. These results suggest that matriculation structure can have an impact on students. These differences, however, were small as noted by small effect size. For the GE Persisters, this may imply that the addition of a common spring semester FYE course positively impacted their intention to persist whereas the opposite is true for DE Leavers. One may infer that the DE Leavers having a higher intention to persist score in the spring semester may indicate that while students had intentions to persist in engineering, they were more confident that electrical and computer engineer was not the discipline they wanted to major in. However, as previously discussed in the limitation section, this inference cannot be confirmed with the current dataset. Additionally, there were no differences in expectancy across these groups which is interesting given the fact that prior work suggests that learning experiences should impact choice through expectancy (Brown & Lent, 2016; Carpi, Ronan, Falconer, & Lents, 2017; Carrico & Tendhar, 2012; Lent & Brown, 1996). However, the results of this study suggest other things might be important in exploring this impact and could be addressed in future work.

Another finding of this study was the result of GE Persisters having a higher expectancy score and a higher intention to persist than GE Switchers. While ultimately both of these groups selected electrical engineering as their intended major at the end of their first year, given that GE

Persisters chose to major in electrical engineering from the beginning is consistent with existing literature that states students are more likely to remain in their first-choice major and that enrollment in a GE FYE course strengthens this intention to persist (Orr et al., 2013).

The results of this study also presented an interesting finding that indicates DE Leavers having a higher intent to persist than GE Persisters and GE Switchers. I expected for this result to be the opposite with DE Leavers having a lower intention to persist compared to GE Persisters and GE Switchers given that students in GE FYE matriculation structures are more likely to persist in their first choice major (Orr et al., 2012). However, Orr et al. also mentions that an advantage of a DE FYE matriculation structure is the ability for students to identify with their discipline early in their academic career. Thus, the fact that DE Leavers have a higher intention to persist may indicate that they did not identify with electrical and computer engineering (which is why they left), but still identified with being an engineer, especially given that the persistence survey questions ask about intentions regarding engineering broadly and not with respect to any particular discipline[2].

2.3.7 Implications

There are several implications of this study in order to truly measure the impact FYE structure has on persistence. First, in order to explore persistence and not just the intention to persist, data beyond the first year needs to be collected and analyzed to explore the longitudinal impacts FYE structure has on persistence. Secondly, given that this study was conducted at a single institution comparing a one-year quasi-DE matriculation structure to a three-year GE

[2] Although there is a survey question included in the construct that asked whether students had sufficient information to make an informed choice about a specific engineering major, responses to this question may have been answered with respect to the engineering major DE Leavers eventually chose rather than ECE.

matriculation structure allows for future work to explore the FYE matriculation structure impact across two different universities with a DE or GE FYE matriculation structure in order to develop more meaningful conclusions regarding the findings presented in this study. Lastly, expectancy may not be a critical factor in understanding persistence. This study suggests that FYE matriculation structure has little impact on students' expectations for majoring in engineering. Given the lack of changes in expectancy, the results of this study indicate that additional research needs to be conducted to understand how learning experiences impact students' intention to persist.

2.4 Summary

The purpose of this manuscript was to conduct an exploratory quantitative data analysis in order to answer the research question: *How do GE and DE first-year matriculation structures affect expectancy and major-choice outcome variables for students who enter college intending to major in electrical engineering?* Data used in this analysis included responses to a survey administered to first-year engineering students enrolled in a GE matriculation structure between from Fall semester entry years 2013 – 2017 and listed their intended major as electrical engineering. Data were parsed into five different groups: 1) DE Persisters; 2) DE Leavers (first-year students enrolled in the 2013-2014 academic year); 3) GE Persisters; 4) GE Leavers; and 5) GE Switchers (first-year students enrolled in the 2014-2017 academic years). With the results, I partially rejected the null hypothesis by demonstrating statistical ($p < .05$) and practical differences (Cohen's d) for the persistence variable in the spring semester for GE vs DE Persisters and GE vs DE Leavers. Similar to the findings reported by Orr et al. (2012), there is no difference in persistence and expectancy scores of GE and quasi-DE students in the fall semester. The small differences in the persistence score in the spring semester indicated that the removal of the spring semester DE required FYE course positively impacted DE Leavers' persistence, as their score was higher than GE Leavers. From this, I hypothesize that by the end of the first year, DE Leavers knew they still wanted to pursue engineering but did not want to do so in electrical and computer engineering. However, the removal of the spring semester DE required FYE course did positively impact GE Persisters' persistence score in comparison to the DE Persisters.

A limitation to this study includes the fact that this data is captured before students are accepted into their engineering discipline and thus Leavers (Groups 2 and 4) are simply those who "left" electrical and computer engineering but possibly not left the college of engineering entirely. Additionally, due to the period in which this data is captured, there is no way to determine if students who "stayed" in electrical engineering actually matriculated into the major. With that said, data from the 2017-2018 academic year were used to recruit participants for study 3 which qualitatively explored how self-efficacy is developed in electrical and computer engineering students across FYE matriculation structures (GE vs. DE).

Chapter 3: Manuscript 2 – Self-Efficacy in a Declared Engineering Matriculation Structure

3.1 Introduction

Prior research has shown that students' self-efficacy is key in retention, particularly as it pertains to engineering. These previous works have explored self-efficacy in engineering students at various stages in the engineering curriculum, including the first year. However, since much of the previous work on competence beliefs broadly and specifically self-efficacy in first-year engineering has been conducted with students in general engineering (GE) matriculation structures (e.g., Hutchinson-Green, Jones et al., etc.), this manuscript is an exploratory qualitative study of how students in a declared engineering (DE) matriculation structure describe their self-efficacy development. Some engineering programs directly admit students into a specific sub-discipline of engineering. Others admit students as general engineering majors and offer generalized first-year programs that include all engineering majors together (Chen 2014). These students will be referred to as declared engineering (DE) students and general engineering (GE) students respectively.

While not a direct comparison to previous work with GE students, this exploratory study provided initial insights regarding the extent to which the experiences of DE students correspond to findings from previous work with GE students. Using data collected from the NSF funded project "A Mixed-Methods Study of the Effects of First-Year Project Pedagogies on the Retention and Career Plans of Women in Engineering," (Jones, Ruff, & Paretti, 2013; Matusovich, Jones, Paretti, Moore, & Hunter, 2011) this secondary analysis of data addresses the overarching research question, *How do engineering students from a declared first-year* *matriculation structure develop engineering self-efficacy,* through first-level and pattern coding methods (Miles, Huberman, & Saldana, 2013).[3]

3.2 Review of Literature

3.2.1 Self-Efficacy

Perceptions of self-efficacy are formed by four sources: mastery experience, vicarious experience, social persuasions, and somatic and emotional state (Bandura, 1997). The most influential of these sources is a person's *mastery experience*. The more successful one has been in mastering an event, the higher their self-efficacy is to attempt similar tasks at higher difficultly. Conversely, persistent failure to master an event can yield lower self-efficacy; however, an occasional failure along a path of success is deemed as an outlying event and has little negative effect on a person's self-efficacy (Schunk & Pajares, 2005). *Vicarious experiences* influence a person's self-efficacy when one has little to no experience in completing a desired task. In this source, a person's self-efficacy is influenced though observing and/or modeling someone they can relate to completing the task (Schunk & Pajares, 2005). A person's self-efficacy can also be undermined when observing someone fail at the desired task. *Social persuasions* influence a person's self-efficacy through thoughtful praise or judgment from others towards a person's ability to complete a task. False inflation of a person's self-efficacy can quickly be diminished by disappointing results (Bandura, 1997). Lastly, a person's self-efficacy is influenced by the *somatic and emotional state* they are in while completing a task. If a person experiences increased levels of stress, anxiety, or physical pain while completing a task, their self-efficacy is more likely to be lower than someone who feels energized by their performance.

[3] It is important to note that this manuscript, an exploratory study, also served as a pilot test of the data analysis approach for manuscript 3 and provided the ability to test the coding process on an existing data set and identify new codes, challenges, and nuances associated specifically with the DE population.

Studies exploring self-efficacy in engineering have typically employed a quantitative methodology. For example Mamaril, Usher, Li, Economy, & Kennedy (2016) measured self-efficacy in undergraduate engineering students. Fantz, Siller, & Demiranda (2011) conducted a study exploring the relationship between pre-engineering experiences and self-efficacy. Carberry, Lee, & Ohland's (2010) study focused on the relationship between self-efficacy and engineering design. Finally Hutchison-Green, Follman, & Bodner (2008) conducted a qualitative follow-up study to their 2006 quantitative study, to explore more deeply how first-year engineering students perceive factors that influence their self-efficacy.

Mamaril, Usher, Li, Economy, & Kennedy (2016) measured self-efficacy in 728 undergraduate engineering students from two public, land grant institutions, 55% of who were sophomores and 23% were juniors. These students were in various engineering courses across multiple engineering disciplines. Mamaril, Usher, Li, Economy, & Kennedy created and distributed surveys to the participants using the General Engineering Self-Efficacy Scale, the Engineering Skills Self-Efficacy Scale, and several other validated measures. Results of the survey revealed that the General Engineering Self-Efficacy Scale, which assesses self-efficacy for content and course mastery in engineering, is one dimensional and “can be used to assess students’ general beliefs in their capabilities to perform in their engineering program” (Mamaril et al., 2016, p. 381). The Engineering Skills Self-Efficacy Scale, which assesses skill-specific self-efficacy, has a multidimensional factor structure that identified three key areas of competency beliefs: experimentation, tinkering, and design (Mamaril et al., 2016, p. 381). According to this study, students with high self-efficacy tend to develop new skills (Mamaril et al., 2016).

Another study that investigates self-efficacy quantitatively within engineering is one conducted by Fantz, Siller, & Demiranda (2011) exploring the relationship between pre-engineering experiences and self-efficacy. Participants of this study included 332 first-year engineering students at Colorado State University enrolled in various engineering departments. Data were collected through the Motivated Strategies of Learning Questionnaire, a close-ended questionnaire that inquired about pre-collegiate engineering experiences such as class, extra-curricular activities, work experiences, workshops or field trips, toys, and hobbies. Results showed a statistical difference in engineering self-efficacy with hobbies such as programming and robotics, and with formal courses such as technology and engineering classes, suggesting that more exposure to engineering content prior to college may yield higher self-efficacy in engineering. An important outcome from this research is that the rigor associated with formal technology and pre-engineering courses were associated with the highest perception of self-efficacy in engineering and that while outreach programs are important, the lack of formality may be the reason that there was no statistical significance in self-efficacy between students who participated in these programs versus those who did not.

Carberry, Lee, & Ohland's (2010) study focused on the relationship between self-efficacy and engineering design. The online survey that was developed and administered was informed by the eight-step engineering design process proposed in the Massachusetts Department of Education (DoE) Science and Technology/Engineering Curriculum Framework. 202 participants were included in the final data analysis. These participants had various engineering experiences ranging from undergraduate engineering students to engineering professors, engineers in industry, non-engineers with science backgrounds, and non-engineers without science backgrounds. Results of this research showed significant differences in self-efficacy of task-specific concepts for participants with low, medium, and high engineering experiences, indicating that engineering design self-efficacy is highly dependent upon these engineering experiences. Additionally, motivation, outcome expectancy, and anxiety were significantly related to self-efficacy in engineering design.

Most relevant to this study is the work of Hutchison, Follman, Sumpter, & Bodner (2006), who explored factors influencing self-efficacy within first year engineering students. Soliciting first-year engineering students at Purdue University for their study, Hutchison et al. used a phenomenological approach to explore how various students experience learning. Purdue has a GE first-year matriculation structure where students take math, chemistry, physics, English, and a two-semester engineering sequence course that focuses on teamwork, engineering design process, ethics, and other skills related to engineering (Purdue University, n.d.). The study included 1387 students, 80% of whom were men, and had representation from about eight ethnic backgrounds including international students and those who listed "other" as their ethnicity. While a survey was distributed to students, researchers used a stratified random sample of 436 participants to analyze the open-ended responses of the survey. In the open-ended portion of the survey, students were asked to list up to ten factors influential to their self-efficacy within the course. Analysis of the student responses yielded 9 factors: 1) understanding/learning; 2) drive and motivation; 3) teaming; 4) computing abilities; 5) help; 6) working assignments; 7) problem-solving abilities; 8) enjoyment, interest, and satisfaction; and 9) grades. Of these nine factors, motivation, understanding, and computing abilities were listed as the most influential to the students' self-efficacy. The key outcome of this study is that all the factors except drive and motivation could be categorized in one of Bandura's four sources of self-efficacy supporting previous findings relating to self-efficacy. Hutchison et al.'s study also reaffirmed that mastery experiences were the most influential for first-year engineering students' perception of self-efficacy through direct and/or indirect linking of the factors to this source. However, a limitation to this study is that the students' responses were very limited and did not examine how student perceived these factors as an influence, or whether students had similar first-year learning experiences.

A follow-up qualitative study was conducted by Hutchison-Green, Follman, & Bodner (2008) to explore more deeply how first-year engineering students perceive factors that influence their self-efficacy. This study was again conducted at Purdue University, a single institution with a single type of matriculation structure (GE), where twelve students volunteered for interviews. Hutchison-Green et al. conducted semi-structured, open-ended interviews with the student volunteers at the beginning of the semester and during the middle of the semester. The interviews were initially coded using first-level coding, following Miles and Huberman (1987) to summarize segments of data, informed by Bandura's four sources of self-efficacy. Pattern coding was then used to "identify themes that described various ways in which each self-efficacy sources was experienced" (Hutchison-Green et al., p 181, 2008). After interviews were coded and themes were formed, Hutchison-Green et al. found that conducting the interviews at two separate points in the semester painted a picture clear enough to understand how the first-year engineering course influenced student's self-efficacy. At the beginning of the semester during the first interview, all students who participated reported having increased levels of self-efficacy based on mastery experience. On the other hand, interviews conducted during the middle of the semester revealed that participants most frequently discussed performance comparisons, specifically to their peers.

Although Bandura's four sources of self-efficacy were not explicitly stated in any of the participants' responses regarding performance comparisons, researchers found it easy to make connections between the two. Key outcomes to note from this study are that participants consistently attributed their high sense of self-efficacy to their high school successes upon entering the engineering program (mastery experience). However, during the second interview, which was conducted three months after the first, participants began to attribute their self-efficacy to more vicarious experiences of performance comparisons in the course – that is, how they were doing in relation to their peers. Noting that not all students completed both interviews, Hutchison-Green et al. found that students who participated in both interviews had a longer period of time to reflect on experiences in relation to previous successes as opposed to those who were interviewed only during the middle of the semester and reflected only on their experiences in the engineering course. The researchers posited that the differences in self-efficacy shaping experiences may suggest that mastery experiences require time to mature before students may recognize them. Their research is consistent with Bandura's model in that students who lacked previous experiences with concepts taught in the engineering course heavily attributed their self-efficacy to vicarious experiences.

3.2.2 DE vs GE Matriculation Structures

What Hutchinson-Green et al. did was useful for understanding self-efficacy development in the first year broadly in the context of the general engineering matriculation structure; however, they did not take into account the specifics of the matriculation structure or, more importantly, how these learning experiences might be different if students were in a declared rather than general matriculation structure. I expected this impact to vary because research shows that belonging, identification, and self-efficacy are all affected by learning experiences, and in turn affect choice of major and retention discussions (Fouad & Santana, 2017; Lent & Brown, 1996, 2013; Lent et al., 2002). These learning experiences may also differ based on matriculation structure due to the different foci of those structures; DE structures typically focus on a specific discipline whereas GE structures focus on engineering broadly (Xingyu Chen et al., 2013). This could also impact types of vicarious experiences students are exposed to (e.g. engineers from various disciplines versus engineers in a specific discipline). Program specifics and differences across different types of FYE matriculation structures are important in understanding exactly how students' self-efficacy perceptions have been shaped. The learning experiences that students gain from their FYE matriculation structure impacts how students perceive engineering at their university.

Given that 70% of ABET accredited institutions have declared first-year engineering matriculation structures and 18% of ABET accredited institutions have general first-year engineering matriculation structures (Chen, 2014), this study specifically aims to understand the difference in self-efficacy development across those first-year engineering structures, and more importantly, how these differences in first-year engineering matriculation structures impact a student's decision to persist in engineering.

Thus, the key difference between Hutchison-Green et al.'s study and this study is that Hutchison-Green et al.'s study explored broad influences to self-efficacy development in first-year students in a GE matriculation structure whereas this study is exploring the development of engineering self-efficacy within a single DE matriculation structure.

To explore this phenomenon, this study aims to answer the following research question: How do engineering students from a declared first-year matriculation structure develop engineering self-efficacy?

3.3 Methods

To answer this research question, this manuscript presents a secondary analysis of interview data from a DE matriculation structure; the data were originally collected to explore student motivation with respect to problem-based learning (PBL), using expectancy-value theory as a guiding framework. Although the original study used expectancy-value theory, it is important to note that in practice, expectancy and self-efficacy are similar enough to be empirically indistinguishable (Bong, 1999; Schunk & Pajares, 2005; Wigfield & Eccles, 2002). Both are broadly considered types of competence beliefs and Eccles classifies self-efficacy as an expectancy theory (2002).

Given that prior research has explored self-efficacy in a single GE matriculation structure, this pilot study provided an exploratory analysis of how students in a DE matriculation structure in biomedical engineering developed course self-efficacy in their first-year biomedical engineering course; as described in the results, however, engineering self-efficacy also emerged during the analysis as closely intertwined with course self-efficacy in this context.. This pilot study is limited because, while the interview questions explored students' beliefs about their first-year generally and included questions centered on expectancy beliefs, the protocol was not designed to measure self-efficacy development. Nonetheless, participants did provide sufficient detail about their program experiences and perceptions to enable me to create and apply a detailed codebook of nuanced self-efficacy development codes and to develop a stronger interview protocol for use in study 3.

3.3.1 Research Design

3.3.1.1 Research Site

For this study, data were collected at a large public university (nifa.usda.gov, 2018) with a DE matriculation structure. The program explored in this study included an introductory biomedical engineering course offered in the Spring semester of students' first year, with the three major content topics: 1) build research skills; 2) design and conduct an experiment and analyze the data; 3) mathematically model a phenomenon (Hunter, 2015). At the time of data collection, the undergraduate population at this university was about 10,000 with more than half enrolled in the College of Engineering. The first-year biomedical engineering program in this study included approximately 200 students. This university is located in an urban setting with a high racial diversity (Matusovich et al., 2011). The goal of the original study was to "understand how applying the Problem-Based Learning (PBL) principles of problem definition and team facilitation to "first-year design courses affect women's beliefs about engineering and their persistence in engineering" (Jones et al., 2013, p.1).

3.3.1.2 Data Collection

Data were collected via interviews at the end of the first-year biomedical engineering course, which was also the end of the first-year for participants, a year later at the end of the second year, and finally at the end of the third year for the same students. Both male and female students were interviewed for this study. Interviews from the first and second year were used for analysis in this manuscript. Year 3 interviews were not included in order to more narrowly focus on the immediate impact the first-year engineering matriculation structure had on participants' self-efficacy development. Individual, semi-structured interviews were designed to address a range of motivation constructs and lasted about 30-60 minutes. The interviews were guided by a list of questions but enabled the interviewers the freedom to follow-up on participants' responses as necessary (Matusovich et al., 2011). The questions from the interview protocol most relevant for this dissertation are as follows:

Beliefs about your first-year engineering course

Before taking your FYE course, how certain were you of your major? Did your participation in your FYE course change this in anyway?

Tell me about your experience in your FYE course. What do you like best? What do you like worst? (General Motivation as well as Values for course)

Do you find this course interesting? Why or Why not? (Interest)
Is this course or the content of the course important to you? Why or Why not? (Utility)
How does this course fit or fail to fit your perception of what an engineering does? (Affinity)

Do you feel in control of your learning in this class? Why or Why not? (Autonomy)

Do you feel supported in this course? In what ways? Do you have all the tools and resources that you need to succeed? (Expectancy, Belongingness, Autonomy)

Describe your interactions with the faculty/workshop/team leaders in this course. Are they available? Do they help you? If so, how? (Expectancy, Belongingness, Self-determination)

How would you define success in this course? How confident are you that you can succeed in this course? (Expectancy/ability)

Prompts as needed:

Did you feel like you knew what was expected to get a high grade in this class? Did you feel like you could do what was expected?

Describe your PBL (or design project for your school) team to me. How do the team members interact? How do you interact with your faculty leader/instructor? (Belongingness, Self-determination)

Do you feel like you belong or fit in your FYE course? Why or why not? (Belongingness)

What is it like being a man (or woman) in this class? How about in engineering in general?

Beliefs about Engineering

At the beginning of the interview, we talked about why you chose engineering as a major. Now that you are here, what keeps you majoring in engineering? (Engineering Values)

How confident are you that you can succeed in earning an engineering degree? (Engineering Expectancy/ability)

Interviews 2 (One Year After the Course)

Introductory/Warm-up Questions (also address some beliefs about engineering):

When we last spoke, we talked about the reasons you decided to pursue an engineering degree. Tell me about those reasons again? Now that you are farther into your engineering major, what keeps you in engineering? (Values for engineering)

Beliefs about your FYE course

Do you ever think about your FYE course? If so, what do you think about?

Think back on your FYE course. How are your current engineering classes the same or different than your FYE course? (Values)

Did your experience in your FYE course prepare you for classes you are taking now? Why or Why not?

Do you think your experience in your FYE course is preparing you for your career? Why or Why not?

Beliefs about Engineering

How confident are you that you can succeed in earning an engineering degree? (Engineering Expectancy/ability)

The full protocol used for the original study can be referenced in Appendix A. The questions omitted from the original interview protocol are questions relating to students' career choices because majoring and persisting in engineering does not necessarily mean that a student will pursue an engineering related career upon graduating (Cady & Reid, 2018; Dina Verdin & Godwin, 2017). While the full transcripts were read and coded for this study, all coded segments were in response to the questions noted above.

Because the goal of this study is to compare the experiences of DE students to prior studies of self-efficacy in a GE context, in particular to Hutchison-Green et al. (2008), Appendix B provides a comparison of the interview questions used by Hutchison-Green et al. (2008) and Matusovich et al., (2011).

Similarities between the protocols include asking participants about background information, their definition of success in their engineering course, and their beliefs about engineering. The first difference between the protocols is that Hutchison-Green et al. asks an increased and detailed number of questions about definition of success in courses whereas Matusovich et al. only asks one. Secondly, Hutchison-Green et al. asks about problem solving self-efficacy in particular, whereas Matusovich et al. only explores expectancy generally. Both protocols ask about beliefs about engineering but Hutchison-Green et al. asks in much more detail. Lastly, Matusovich et al. asks questions about utility value of the course, support and belongingness in the course, and interests related to the course whereas Hutchison-Green et al. does not ask any questions surrounding those topics.

3.3.1.3 Secondary Data Analysis

Secondary data analysis involves the re-use of data collected from a previous research study (Heaton, 2008). The data used has been obtained through informal sharing where a primary researcher on the original data has provided me access to the data and will not play a major role in the analysis of this data, though two of the members of the research team are members of my dissertation committee. The type of secondary data analysis I conducted is a supra analysis. Heaton describes this type of analysis as one in which the "aims and focus of the secondary study transcend those of the original research." (p. 39, 2008).

While conducting a secondary data analysis eliminates the time and resources required to conduct interviews, there have been some debates regarding whether using secondary data is consistent with the fundamental principles of qualitative research. The first issue includes problem of data fit, where there is concern of whether the secondary data can be re-used for a new purpose (Heaton, 2008). However, due to the flexible nature of research and the nature of semi-structured data collection methods, results of data can vary in depth and breadth of coverage allowing for additional research questions to be answered. In this case, the purpose of the original study was to explore the impact of project-based learning on the motivation of first-year students. The study considered several motivation constructs, including expectancy which is empirically indistinguishable from self-efficacy when measured with a validated survey instrument (Bong, 1999; Schunk & Pajares, 2005; Wigfield & Eccles, 2002). My analysis focuses on how students' first-year matriculation structure influenced the development of their self-efficacy, which aligns with the original study in that the study focused on the impact of first-year design courses on persistence and beliefs about engineering among female students (Jones et al., 2013).

The second issue is the problem of not having "been there," where analysts attempt to interpret data collected by other researchers (Heaton, 2008). This issue is addressed by working with the original researchers to provide context regarding the data and collection methods. In this case, as noted above two members of the original research team (including one interviewer) are members of my dissertation committee. Several conversations regarding interpretation of the results took place to verify that the results of the data analysis were aligned with the purpose of this study.

Lastly, there have been ethical concerns regarding the use of these data for purposes other than what they were collected for initially. However, this analysis is consistent with the original goals of the study given the focus on first-year engineering students and the impact their FYE matriculation structure have on competency beliefs.

3.3.2 Data Analysis

Modeling the deductive, qualitative data analysis done by (Hutchison-Green et al., 2008), data were analyzed using first-level and pattern coding methods developed by (Miles et al., 2013). Data used were from transcripts already cleaned. First-level coding was used for summarizing segments of data based on Bandura's four sources of self-efficacy (Bandura, 1997). Similar to Hutchison-Green, Follman, and Bodner, "other" was used as a fifth code for data that fell out of the scope of Bandura's theory. This round of coding was informed by a codebook developed specifically for coding self-efficacy. The preliminary codebook is presented in Table 3.1.

Table 3.1 – Preliminary Codebook for First-Year Student's Development of Self-Efficacy

Bandura's Theory of Self-Efficacy Development		
Code	Definition	Operational Definition
Mastery experience	The more successful one has been in mastering an event, the higher their self-efficacy is to attempt similar tasks at higher difficultly	Students describe experiences in which they succeeded or failed in an engineering context
Social persuasions	a person's self-efficacy through thoughtful praise or judgment from others towards a person's ability to complete a task	Students describe experiences in which feedback on their engineering related task was provided
Vicarious experience	a person's self-efficacy is influenced though observing and/or modeling someone they can relate to completing the task	Students describe experiences in which they modeled their actions after observing someone doing an engineering related task
Somatic and emotional state	If a person experiences increased levels of stress, anxiety, or physical pain while completing a task, their self-efficacy is more likely to be lower than someone who feels energized by their performance	Students describe experiences in which their mood was impacted while completing an engineering task
Other		Preliminary codes that fall out of the 4 methods of self-efficacy development

Once first-level coding was completed, pattern coding was conducted to identify themes to describe different ways each source of self-efficacy was experienced by the participants and how the first-year engineering matriculation structure impacted that development. Each code was expanded to encapsulate the nuanced ways participants developed self-efficacy within the major categories of mastery, vicarious, social persuasions, and somatic and emotional state. The evolved codebook is presented in Table 3.2.

Table 3.2 – Evolved Codebook for First-Year Student's Development of Self-Efficacy

Mastery Experiences		**Students describe experiences in which they succeeded or failed in an engineering context**
Sources	Guided Mastery	Students develop mastery with the assistance of a supervisor (teacher, facilitator, etc.)
	Team Development	Students developed mastery through working in teams in order to achieve a common goal
	Figuring It Out	Students who developed mastery through independent (without supervisor assisted) trial and error
	Negative or Failed Mastery Experiences	Students' mastery development was stalled/halted due to poor performance on task
Focus: Practical or Transferable Experiences	Communication Related	Students developed mastery in communication skills either via public speaking w/ projects or communicating with group members
	External Course Related	Students developed mastery in DE that was applicable in future courses (reflective)
	Research Related	Students developed mastery in the form of research skills development
	Technical or Industry Related	Students developed mastery in the form of technical skills development that will be useful in industry

Social Persuasion		**Students describe social interactions in which feedback on their engineering related task was provided**
Sources	Constructive Support and Criticism	Feedback from supervisors and/or peers supported students' SE development
	Familial Influence	Students were encouraged to pursue engineering due to familial encouragement or familial employment as an engineer.
	Instructors, Facilitators, Supervisors	Students were encouraged to pursue engineering by instructors, facilitators, or job supervisors
	Peers	Students were encouraged to pursue engineering by peers.
	Discouragement	Students received negative feedback in relation to their SE development. Students generally took this feedback as fuel to do better rather than as a sign to quit.

Vicarious Experiences		Students describe experiences in which they modeled their actions after observing someone doing an engineering related task
Sources	Peer Examples	Students exposed to/following in the footsteps/confirmation in choice of engineering via peers

Somatic and Emotional State Experiences		Students describe experiences in which their mood was impacted while completing an engineering task
Emotion	Comfort	Students described feeling comfortable in their learning environment positively affecting their SE in being successful.
	Fear or Uneasiness	Students express being scared or nervous in completing engineering tasks in DE course negatively impacting their SE.
	Enjoyment - Course Related	Based on the definition of somatic experiences, experiencing joy while completing a task is a positive SE development and students here express how they love and enjoy what they are doing. This joy has been expressed through the completion of tasks in the course, validation that they made the right major/career choice, and/or how the validation of picking correctly will bring personal satisfaction. Focus of enjoyment is on the course
	Enjoyment - Major or Career Related	Focus of enjoyment is on the student's major choice

The results describe these codes in detail using illustrative quotations from the interviews.

3.3.3 Qualitative Validity and Reliability

With any research study, the validity and reliability of data collection and analysis methods are important in ensure the generalizability, trustworthiness, credibility, and authenticity of a study (Creswell & Miller, 2000). In qualitative studies, validity and reliability are treated differently and more independently than in quantitative studies. In this section, I discuss the validity and reliability of this research study, as well as address my own biases regarding this study.

3.3.3.1 Validity

Validity is a strength of qualitative studies given the fact that findings are determined to be accurate either from the standpoint of the researcher, the participants, or the reader (Creswell & Miller, 2000). Measures taken to ensure the validity of this study include triangulation and peer review.

Triangulation is defined as the use of different data sources to establish themes that ultimately converge, adding to the validity of the study (Creswell, 2007b). Given that this manuscript is a secondary analysis of previously collected data, triangulation involved discussion of the analysis with the original researchers, reviewing documents about the courses involved in the study, and listening to various audio recordings to gain a clearer perspective regarding interpretation of data (i.e. voice inflexions that signal excitement or indecisiveness).

Peer review includes soliciting a peer to serve as a reviewer, inquiring about the study in order to aid the researcher to develop an understanding of the study from a different perspective. This method of validation ensures that the results of the study resonates with readers beyond the researcher (Creswell, 2007b). Once the data was analyzed, I petitioned a peer with a doctorate in Engineering Education to serve as a second reviewer for this study. This peer review took place twice during data analysis, once after the development of the initial codebook and again after the development of emergent themes. During these reviews, the reviewer reviewed codes, code definitions, and referenced quotes as they were developed in the study in order to provide additional feedback regarding whether the codes were appropriately defining the expressed experience.

3.3.3.2 Reliability

In qualitative studies, the reliability of a study is indicative of how consistent the researcher's approach is across different projects (Creswell, 2007b). Given that this manuscript includes secondary data analysis, once I developed my codebook I consulted on my findings with the initial researchers of the study. This was done to ensure that my approach to data analysis made sense regarding the data the existing data and to test the analysis as a basis for future studies design specifically to compare self-efficacy development in GE and DE matriculation structures. Furthermore, Creswell (2007) emphasizes that researchers should make sure that the definition of codes do not change drastically during the process of coding. During the coding process I made memos of my thoughts regarding my initial thoughts, especially ideas that arose that I wanted to discuss with the original researchers of the study. From this process, I ensured the consistency of code definitions through the consistent refining of codes and using intercoder reliability to review the codebook developed and discussed in the data analysis section.

3.3.3.3 Researcher's Bias

It is especially important in qualitative research studies that I, the researcher, self-reflect and address the biases I have in conducting this study (Creswell, 2007b). I approach this study as a first-generation, African-American, female college graduate, from a low socioeconomic background, with an undergraduate degree in electrical engineering. As a first-generation student with no exposure to engineering prior to college, I became curious about whether my choices would have remained the same had I experienced a general first-year engineering matriculation structure as opposed to my declared matriculation structure. While my overall experience at my undergraduate institution was a positive one, I perceive my engineering self-efficacy to not be as high as I would like it to be. In summary, I have biases as a former confused engineering student in a declared engineering matriculation structure with lower engineering self-efficacy. However, these biases have been mitigated through peer checking of the data. Because I was not a part of the initial data collection, my approach to analysis was purely exploratory. With that said, I did find myself more interested in how students describe somatic and emotional state experiences because of the high number of mentions relating to this experience, yet there is minimal research exploration of those experiences in self-efficacy development of engineering students. Learning about how unexplored this area is increased my motivation to ensure that future studies probed for those experiences and that subsequent interview protocols enables me to follow up on any responses relating to those experiences.

3.3.3.4 Limitations

The limitation to this study is the analysis of secondary data. Due to my not being the original researcher on the study, I was unable to conduct member checking. These limitations have been addressed in the discussion regarding the use of secondary data in the data analysis section of 2.3. Another limitation is that site used in this study was a single DE matriculation structure with a well-developed PBL program, thus the pedagogy differed sharply from many of the GE programs studied by other self-efficacy researchers.

3.3.4 Results

The following sections provide a detailed discussion of each code. The goal of this study is to compare prior studies of self-efficacy in a GE context, in particular to Hutchison-Green’s study. In the second round of coding, excepts from interviews were examined more thoroughly in order to determine emergent codes from the data. As identified in Table 3.2, each of the five original codes from Table 3.1 has been expanded to include emergent codes and their definitions from the data representative of the respective category. In the following sections, I discuss in detail each of the codes that emerged from analysis.

3.3.4.1 The Tasks of Self-Efficacy

While my initial goal was to study participants' self-efficacy with respect to their DE FYE course broadly, in the interviews, the task changed depending on the context participants were describing. These tasks have been reported as the foci of self-efficacy development, with the context being the dimension of self-efficacy development the participants were discussing. Students related various tasks to engineering because they took place within their FYE DE course. While data was initially coded for course self-efficacy, subsequent analysis of the coded segments revealed that course self-efficacy and engineering self-efficacy intersected as students reported a positive engineering self-efficacy due to their positive course self-efficacy (which in this context is an engineering course). An example of this intersection was reported by one participant who explained what qualities an engineer should have, how they developed those qualities in their DE FYE course, and how those qualities were applicable beyond their DE FYE course:

> *Well, according to what I've seen from, uh, biomedical engineering, a good practicing engineer is, uh, okay on a team. He can uh – he or she can, um, work well with a team and doesn't necessarily have to be by themselves at all times to get their work done. Um, there is […] research-gathering – uh, information-gathering, how 'bout that? Uh, where you know what to look for, what not to, and uh, all that good stuff. And I think, I think that's about it.*

> *Um, well, now that I've taken [DE course], I'm starting to refine some of the skills I mentioned for a good engineer – the research and the, um, uh, the effective team, I guess, working in teams – so, um, definitely not there completely yet, but hopefully with more of these types of classes I'll get to where the good engineer is supposed to be.*

> *Um, just the research skills, the teambuilding, all of that, uh, so important to be able to actually succeed in – not necessarily just further classes, like the 3000-4000 level classes – but just eventually when you're out in the career, or out in the, uh, business world or where ever you wanna go. So, just learning those skills, if the grade doesn't necessarily reflect what I put in, what I get out definitely reflects it, because I'm just getting out those skills that I'll eventually need and I didn't have before in the classes I was taking [135_Interview_Lam_M4_2010]*

All participants reported positive self-efficacy development regarding skills learned in their FYE DE course, but they also related this course self-efficacy to their positive engineering self-efficacy.

3.3.4.2 Mastery Experiences

In this section, I discuss how students describe their development of self-efficacy through mastery experiences. Students discussed their mastery experiences in terms of both the sources and the focus of the mastery experiences.

Sources

With respect to sources, participants described four different sources of mastery experiences: 1) Figuring It Out; 2) Guided Mastery; 3) Team Development, and 4) Negative or Failed Mastery Experiences.

1) For the code of "Figuring It Out," students experienced mastery development through independent trial and error without the assistance of a supervisor or superior. Participants' self-efficacy was developed the most through their mastery experiences. One student expressed this development as:

> *So I think it's really interesting that you go into this like almost completely blind and you get this project and you're like, 'oh, my gosh, I'm never gonna be able to figure this out, what am I gonna do,' and then at the end, you're like, 'wait, hey, like I did something.' [135_Interview_Lam_F3_2010]*

It was very common that participants reported self-efficacy development through "Figuring It Out." Several participants reported mastery development through this particular code.

2) For the code of "Guided Mastery," students experienced mastery development with the support of a supervisor which, in this context, was often referred to as a facilitator. The term "Guided Mastery" was used to describe these experiences because most participants attributed their ability to understand and master the material due to the guidance or scaffolding provided by their facilitator. Most participants responded positively to this type of instruction:

> *he would basically support us in everything that we did. He'd ask us questions to kind of tickle our brains, to kind of think about— to think outside of the box. So he challenged us as well as supported us as well [935_Interview_Kahn_F1_Deidra_2011]*

These facilitators were not teachers in the sense of "here's a task, this is how to do said task, now you, student, should copy what I do." Instead, consistent with the literature on problem-based learning (Hmelo-Silver & Barrows, 2006, 2008; Hunter, 2015), most participants reported facilitators as guides through their experiences by asking probing questions, instructing students on how to verify their assumptions, and providing students with alternative measures to consider as relevant to the assignment.

3) For the code of "Team Development," students experience mastery development by working in teams in order to achieve a common goal. From these experiences, students learned that by working in teams, each member brought a particular strength that supported the success of the team as a whole. This development is different from vicarious experiences and social persuasions in that students do not discuss their learning in comparison to their peers or discuss their competence being validated by their peers, but rather mastering the ability to work in a team through sorting out scheduling, communication, compromising ideas, etc. The students who participated in this study expressed gratitude for their team members:

> *Actually, it's good to make mistakes in your group because nobody's perfect. [I: Right.] Everyone needs to learn, so if you learn here, good maybe you will walk with them later, so that they will benefit from them. Yea, this is kind of something like if I speak loud I'll have my idea heard, maybe sometimes I no guarantee that everything I heard is good, maybe something ideas suck, but there's certain ideas that are good. So if they heard me, they say "wow this idea's good" maybe they can change, they can change the direction and walk the group way. So even though you make mistakes, but you're also bringing*

your ideas to the table, other people benefit. So it's not really a big deal to let everyone make mistakes. [1205_Interview_Sennett_M2_2010]

Many participants reported having positive teamwork interactions especially given that some students observed teams that faced challenges amongst team members and with their respective facilitators. Thus, while the participants for this study developed mastery through positive experiences, based on reports from these participants, a positive experience may not have been consistent in the course.

4) For the code of "Negative or Failed Mastery Experiences," students' mastery development was stalled due to poor performance on a task. These experiences were typically discussed in reference to receiving a poor mark on an assignment, particularly after having the belief that they would excel on the assignment before receiving a poor grade. One participant reported this negative experience as discouraging:

> *I would be very, uh, discouraged and unmotivated by seeing, uh, that with your ridiculous amount of time and effort that I've put into the class and into helping the group out, just having a sixty appear in front of me or a fifty or something that's not reflective of the effort, put in, that would just be discouraging and I think it would probably make me try less, because if I know a hundred percent effort is gonna give me fifty percent of the grade, then I can scale it down, right? I can do less and get about the same. [135_Interview_Lam_M4_2010]*

But, another found these negative experiences served as fuel to fire their desires to do better in the course:

> *And for someone to tell you, 'I feel like you didn't—you weren't really as—as on point with the situation as you should have been.' [A: Mm hmm.] So now that kind of helps me*

to sit back and think outside of the box and analyze every problem that I'm faced with. [935_Interview_Kahn_F1_Deidra_2011]

There were very few instances where participants reported negative or failed mastery experiences; in fact, given the positive spin on one of these experiences shows that in this particular case, students rarely had negative experiences in this course.

Practical or Transferable Experiences

For the code of "Practical or Transferable Experiences," students described their mastery development in relation to skills that can be used in other contexts, which effectively form the task around which students reported developing self-efficacy. These contexts are categorized into four major themes: 1) Communication Related; 2) Related to External Courses; 3) Research Related; and 4) Technical or Industry Related.

1) For communications related experiences, students developed mastery in their communication skills through public speaking and communicating with group members.

    So communication in general. So how it's— it's really a public speaking class if you think of it in a sense because, I mean, you have to be good at doing that if you want to deliver your message and convince your audience, especially, the faculty or the panel that your idea's worthwhile. And they will rip you apart if you seem just the slightest bit, um, not as passionate or not convinced your idea is good. So you have to really be convinced and deliver it well. Because I think it's all in the delivery. [935_Interview_Kahn_M1_Frank_2011]

   Participants reported communications skills most frequently regarding practicality, transferability, and self-efficacy development through mastery.

2) For external course related experiences, students developed mastery in their current first-year engineering course that they knew would be applicable to courses they would have to take in their future. For example, one participant described how the fact that one of their team members enrollment in differential equations evidenced to be fruitful in their completion of the assignment. Other participants reflected on the experiences gained in their first-year course has become useful in their current in-major course:

> *it all makes more sense that the way [DE course] kind of sets up students' minds to think this way. And then you have this pattern developed so when you go into your conservation principles classes, your biomechanics classes, it's kind of preset that you break down the problem this way. [935_Interview_Harper_M2_2011]*

Understanding how the DE course related to other courses outlined in the students' curriculum was a rare occurrence amongst participant. There were very few instances where students reported understanding how this course fits into the bigger picture of their degree program.

3) For research related experiences, students developed mastery in their ability to research relevant journal articles and patents that would support the decisions they were making in their design processes. Participants described this skill to be useful not only in their first-year [major] course but also in the following [major] course sequence:

> *I feel like I really just learned how to find um, about research articles through databases and um, it made it so much easier when I came to [next course] and had to find research to back up like our designs and things like that. When I had been doing research like crazy in [DE course]. [935_Interview_Kahn_F2_2011]*

Several participants reported mastery development through increased research skills and found this skillset useful.

4) For technical or industry related experiences, students described their mastery development through the learning of skills that may be applicable to future career options. Students described these skills specifically relating to engineering related software such as Solidworks:

> *I feel like it's less of a class and more like job training. It's more of, it's getting you into the real thing, showing you what the future of your job might be like, or will be like, and it just gives you more work-type experience more than just academic learning-type experience, just knowledge [1205_Interview_Kahn_M1_2010]*

Several participants reported mastery development through skills that were applicable beyond the immediate coursework.

3.3.4.3 Social Persuasions

In this section, I discuss how students describe their development of self-efficacy through social persuasions. Students discussed social persuasions in two ways: 1) Constructive Support and Criticism; and 2) Discouragement. Most of the instances reported took place outside of the DE course however; there were some instances where persuasions were directly tied to a participant's major.

Constructive Support and Criticism

For the code of "Constructive Support and Criticism," students described being socially persuaded to persist in their DE course by three groups of people: 1) Supervisors; 2) Peers and; 3) Family.

1) Students described from their DE instructors when they felt mixed emotions about continuing engineering. There were instances where participants expressed that facilitators were encouraging in their pursuit of a solution such as when one participant states:

um, he always congratulates us on our strengths and tells us how to improve in different areas. So he's, um, he's good at what he does, essentially, being, he's a good facilitator [1205_Interview_Kahn_M2_2010].

There were other instances where constructive criticism was provided that served as an impetus for the participant to reevaluate their approach to the problem:

the coaching thing, like if some person has weakness like what to do, it definitely has to use experience to say 'ok you have to do this and then you'll get better.' You have to make you feel confident, like maybe you feel like, oh maybe it will be ok, if you are really trying hard to do this, you really can do well [1205_Interview_Sennett_M2_2010].

This code is different from "Guided Mastery" in that students discussed facilitators being encouraging and providing verbal encouragement regarding their competency whereas with "Guided Mastery" students discussed facilitators providing concrete assistance in a manner that enabled students to come to a solution or achieve mastery on their own.

2) Students also described social persuasions through instances where they received affirmations in their performance by peers. These affirmations were received either in

peer reviews or in conversations. One participant described feedback they received from their peers:

> *I'm fairly confident because of, um, every so often we'll do, uh, peer reviews of our different classmates and I haven't, like I haven't, I haven't received many, like, negative comments. People are always like, I'm always on time, that I contribute significant enough, um, in meetings and out of meetings, so I kind of, um, judge by my peers and my instructors given me, um, similar comments. I think I am succeeding in this course. [1205_Interview_Kahn_M2_2010]*

Persuasions from peers were always positive and were received by participants within their DE course or in conversations with other students about the DE course. This code is different from "Team Development" in that students discussed their competency being reinforced due to feedback from peers whereas in "Team Development" students discussed mastering the ability to work in a team on a project.

3) Lastly, students described social persuasions through instances where they were encouraged to pursue engineering by family members. These persuasions were either through intentional conversations, *"oh you should go into engineering because your grandfather was an engineer" [1205_Interview_Kahn_M2_2011],* or being in the same space as close family members in engineering fields:

> *Both of my parents are engineers, and they both work for big companies like [Company 1] and [Company 2], and, like, I grew up – I used to always go in with my mom to lab, and I'd, like, play around with the solder and, just, like, melt things and I just thought it was so cool, so. [305_Interview_Tostig_F2_2010*].

These forms of social persuasions align more with constructive support given the desire of familial persons wanting the best for the participant. One participant expressed this sentiment as:

I think I'm passionate about it, I think, like I said, I think it's the end-goal that keeps me going, it's like, "this is horrible right now" – 'cause my dad went to [University], like I said, and he always is like, you know, "[Participant], I know it's hard now, but I promise you, it'll be worth it at the end.' [935_Interview_Harper_F1_2010]

While this form of social persuasion is not directly tied to the DE course, given that the interviews took place in students' first and second year of their engineering major does provide insight to how participants were supported in their engineering program outside of class.

Discouragement

For the code of "Discouragement," students described being socially dissuaded to pursue engineering due to the difficulty of the field. Some of the dissuasion occurred in broad contexts such as in a lecture where students were presented other majors as options to switch to should the decide to leave biomedical engineering. Other dissuasions came from direct conversations participants had with other people who would "bet you fifty bucks you'll drop" out of biomedical engineering, as expressed by one participant:

Um, people are like, "oh, you're definitely gonna switch by the end, blah blah blah." But people like saying stuff like that just makes me like wanna do it more. You know, like if someone like tells me I can't do something, that makes me wanna do it like ten times more. [135_Interview_Lam_F3_2010]

This participant also reported a conversation where someone mentioned their poor chances of getting hired due to their major:

> *a lot of people like criticize [major], they're like, "um, what, you know, what are you gonna do with that, like nobody's hiring that field," um, but I mean, I feel like it's definitely like a growing field, you know. [135_Interview_Lam_F3_2010]*

Several participants reported being discouraged by others to pursue engineering however, each participant that expressed having these negative conversations also expressed not being dissuaded from pursuing biomedical engineering.

3.3.4.4 Vicarious Experiences

In this section, I discuss how students describe their development of self-efficacy through vicarious experiences. Students discussed their vicarious experiences primarily through Peer Examples. While some of the instances reported took place outside of the FYE program, there were some instances, that were directly tied to the FYE program.

Peer Examples

For the code of "Peer Examples," students described having vicarious experiences through being exposed to opportunities and alumni of the program that confirmed their choice of biomedical engineering and inspired them to continue in the field. One participant described this experience in their DE course as: *"But with more, with each, and each passing day uh, seeing more alums, seeing what they're doing. It's, gotten me pretty confident [1: Mhm.] that I, if I put my mind to it I can do a lot" [135_Interview_Lam_M4_2011]*. Peer examples were the most common form of vicarious experiences regarding students' self-efficacy development. This development is different from "Team Development" and social persuasions in that students do not discuss their learning in comparison to their peers or discuss their competence being validated by their peers, but rather identified how seeing other people succeed supported their own self-efficacy.

3.3.4.5 Somatic and Emotional State Experiences

In this section, I discuss how students describe their development of self-efficacy through their somatic and emotional states. Students' somatic and emotional state were influenced by their DE program in three different ways: 1) Comfort; 2) Fear or Uneasiness; and 3) Enjoyment.

Comfort

For the code of "Comfort," students described their somatic and emotional state as feeling comfortable in their learning environment. This feeling of comfort positively affected participants' self-efficacy by providing support in learning course materials. One participant described this support as

> *Yes, really comfortable, lots of people there, they're really friendly. I really appreciate that. They could be just kind of, let me do certain things, they're not taking the whole thing otherwise I'd be left alone or some sort of that, they help me to speak up. This is the only, like speak out, speak loud about my idea, they really support me So, I really feel, I really enjoy this class. [1205_Interview_Sennett_M2_2010]*

This was the least common form of self-efficacy development through somatic and emotional state experiences as reported by participants.

Fear or Uneasiness

For the code of "Fear or Uneasiness," students described their somatic and emotional state as feeling scared or nervous about completing engineering task which, subsequently had a negative impact on their self-efficacy development. It is important to note that these negative impacts were temporary for majority of participants as students described these experiences as getting a "slap in the face" before regrouping to move forward with the goal of being more successful on the next task. An example of this, as stated by one student:

> *And I mean, [DE course] was a sl— you know, a slap in the face for those who do think they're very talented. They don't have to do a lot of work to achieve things. Because for that class you had to work hard because otherwise you weren't going to succeed.*
>
> *[935_Interview_Kahn_M1_Frank_2011]*

Students reported having fear or uneasiness infrequently as a form of somatic and emotional state experiences.

Enjoyment

For the code of "Enjoyment," students described their somatic and emotional state as enjoying and loving what they are doing. This joy has been developed in two contexts: 1) Course Related; and 2) Major or Career Related.

1) Through the completion of tasks in the course, participants expressed enjoying learning new things, being academically challenged, and succeeding at tasks that once seemed difficult. One participant describes their enjoyment as:

> *before I wasn't very sure if I wanted to stay with [major]. Um, I was thinking about CS, maybe, too. But once I took this [DE] class, it showed me more of what the actual major is and what kind of job you would get afterwards, and it made me wanna, wanna stick with [major], actually, because I enjoyed working in groups and talking to people and working with people, so, uh, this class made me get an idea what [major] is. [1205_Interview_Kahn_M1_2010].*

Several participants attributed their emerging situational interest to their first- and second-year engineering course.

2) In addition to participants feeling enjoyment from tasks completed in the course, these feelings span beyond the course by providing validation that they made the right major/career choice. One participant specifically talks about how:

> *I see myself fitting in. Um, I feel like I do enjoy the work, I do enjoy the studying, certain aspects of the degree. I think I'll, I wanna do research in the end, and I think I'll definitely enjoy that, I think I'll fit in pretty well [1205_Interview_Kahn_M1_2010]*

Many participants discussed how they felt their enjoyment of the course material further reassured them that they were on the right path regarding their major and subsequent career.

3.3.5 Discussion

The purpose of this manuscript was to conduct an exploratory secondary data analysis in order to answer the research question: *How do engineering students from a declared first-year matriculation structure develop engineering self-efficacy?* Through first-level and pattern coding methods, this question was answered through the emergence of the codes outlined in Table 3.3:

Table 3.3 – Ways in which engineering students from a DE matriculation structure develop engineering self-efficacy

Bandura's Theory of Self-Efficacy Development	Emergent Aspects
Mastery experience	Figuring It Out
	Guided Mastery
	Negative or Failed Mastery Experiences
	Practical or Transferable Experiences
	Team Development
Social persuasions	Constructive Support and Criticism
	Discouragement
Vicarious experience	Peer Examples
Somatic and emotional state	Comfort
	Fear or Uneasiness
	Enjoyment

As outlined in Table 3.3, all four ways in which self-efficacy is developed were present in the data, but only some closely tied to the DE matriculation structure such as the mastery experiences, constructive support and criticism, and vicarious peer examples. The other sources, though they may have emerged during the first-year, were not linked directly to the DE FYE matriculation structure.

Hutchison-Green et al. conducted both a quantitative (2006) and qualitative (2008) study exploring self-efficacy development in GE FYE students. These studies served as a foundation to this study which explores how self-efficacy is developed in students in a DE FYE matriculation structure. The results of this present study show that aside from grades, students in a DE matriculation structure develop self-efficacy in much the same way that students in a GE matriculation structure as reported by Hutchison-Green et al.'s 2006 study. However, in comparison to Hutchison-Green et al.'s 2008 study, there is less alignment with their final results. A summary of how this study confirms or expands how Hutchison-Green et al.'s reported self-efficacy development in DE FYE students is outlined below in Table 3.4.

Table 3.4 – Comparison of Study 1 Codebook to Hutchison-Green et al.

		Hutchison-Green et al. (2006)	Hutchison-Green et al. (2008)	This Study
Mastery Experiences	Sources	Teaming Help		Guided Mastery Team Development Figuring It Out
	Evidence	Grades		Negative or Failed Mastery Experiences
	Focus	Computing Working assignments Problem-solving abilities	Technical Skills Professional Skills	Practical or Transferable Experiences Communication Related External Course Related Research Related Technical or Industry Related
Social Persuasions	Sources		Course Policies	Familial Influence Instructors, Facilitators, Supervisors Peers
	Type		Verbal Persuasions Non-Verbal	Constructive Support and Criticism Discouragement
	Focus		Frustration with policies	
Vicarious Experiences	Sources			Peer Examples
	Focus		Comparison by speed Comparison by contribution to team Comparison by amount of mastery relative to peers Comparison by grades of peers	
Somatic and Emotional State Experiences	Emotion	Enjoyment, interest, and satisfaction	Satisfaction from success	Comfort Fear or Uneasiness Enjoyment
	Focus		Frustration with policies	Course Related Enjoyment Major or Career Related Enjoyment

3.3.5.1 The Tasks of Self-Efficacy

Participants in this study described positive course self-efficacy regarding skills learned in their DE course and how this positive development influenced positive engineering self-efficacy. This relation of tasks as reported by participants demonstrates the intersection of course self-efficacy and engineering self-efficacy when the course is in engineering. While skills such as teamwork are commonly associated as an engineering skill, other skills such as communication and research skills are not; yet, these were the skills commonly reported by students when reporting their course and engineering self-efficacy development. This finding adds to the existing literature regarding 1) how do we actually define engineering and 2) the lines of course self-efficacy and field self-efficacy are blurred when the course is in the field.

In regard to how engineering is defined, due to the broad nature of the field, there is no set definition of what it means to be an engineer. In fact, Bunhaver, Carrico, Kajfez, Matusovich, & Sheppard (n.d.) states that previous studies typically invite participants to define what their engineering experience is in the workplace which has provided a number of self-defined definitions of what engineering is given that there is currently no concrete definition or consensus of what it means to be an engineer. While Bunhaver et al. attempts to create a definition of what it means to be an engineer, participants in their study reported teamwork and communication skills as non-engineering work which is a contrast to how participants in this study describe those exact skills, which is further indication of how variable the definition of engineering can be.

Secondly, the lines of course self-efficacy and engineering self-efficacy are blurred in this context given that the course in this study is an engineering course. Bandura (1997, 2006) states that there are instances where self-efficacy development can co-vary or can be interrelated when different spheres of activities are governed by similar sub-skills. According to Bandura, in this context, engineering self-efficacy and course self-efficacy can be distinct spheres of activities. However, because the sub-skills in each of these spheres are very similar and not distinguished independently by participants, the relationship between these two spheres change as depicted in Figure 3.1.

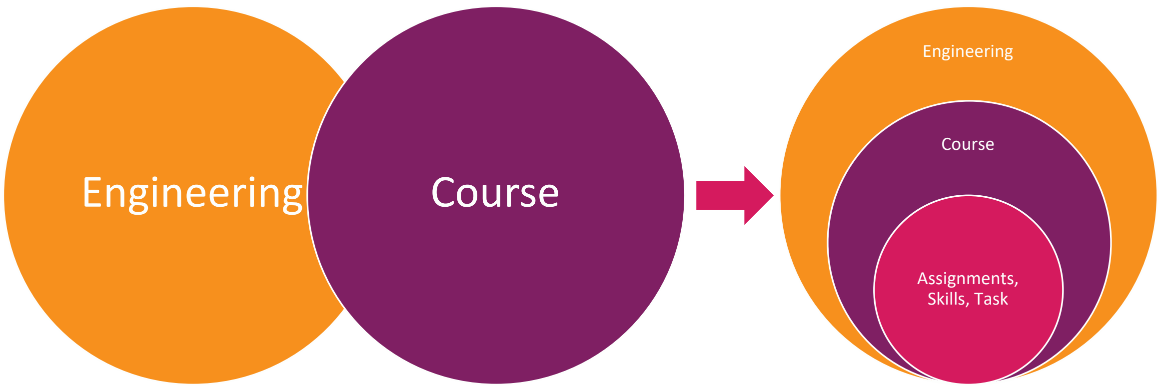

Figure 3.1 – The relationship between the tasks of self-efficacy

Given that this was a secondary data analysis, DE students in this study did relate their sub-tasks to being successful in the course and in engineering, but spoke to engineering broadly as opposed to their specific engineering discipline. This is another limitation of this study given that the original interview protocol asked about engineering generally, thus it is difficult to determine if responses to this particular question would be more specific if the interview protocol asked specifically about the major.

3.3.5.2 Mastery Experiences

Participants in this study described three different sources of mastery: guided, figuring it out on their own, and team development. Similarly, to the DE students in this study, GE students in Hutchison-Green et al.'s studies also described sources of mastery to be help and teaming. The difference between the DE and GE students is that the DE students also reported developing mastery through figuring things out without the assistance of an instructor.

Evidence of participants' mastery was described as negative or failed mastery experiences. The context in which DE students describe their evidence is similar to how the GE students described evidence of their mastery which was reported as grades. GE students described their evidence of mastery with regard to receiving a high mark on assignments. However, while DE students also aimed to get high marks, their evidence was described more so with regard to overcoming setbacks such as negative feedback during presentations and poor marks on group assignments. DE students described these experiences as an impactful to their effort, with some instances being a diminisher of effort (Bandura, 1977; Wilson, Bates, Scott, Painter, & Shaffer, 2015) and others being a motivator (Eccles & Wigfield, 2002).

The focus of the mastery described by DE students included practical and transferable skills. These skills were identified more specifically with regard to communication, transferability to courses other than their DE course, conducting research, and applicability to the industry of their major. Similarly, GE students described the focus of their mastery with regard to technical and professional skills and computing. The difference between the GE and DE students is that GE students reported working assignments and problem-solving skills as a focus of mastery development, whereas GE students do not. These foci support how mastery is typically developed: gaining of knowledge, practice using the knowledge, and learning when to apply the knowledge (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010).

Given the fact that the DE FYE matriculation structure in this study employs problem-based learning techniques, the communicated outcomes of this course (per the syllabus) are similar to the course goals of Hutchison-Green et al.'s GE matriculation structure. While there are some similarities in how Hutchison-Green et al.'s GE students and study's DE students develop and describe mastery experiences, as previously mentioned, there are also some differences in this development. However, due to the specific PBL pedagogical choice for the DE FYE matriculation structure, where students are typically put in groups to solve a complex, ill-structured problem (Matusovich et al., 2011), this difference pedagogical approach may be the reason for some of the differences found between the DE and GE students.

3.3.5.3 Social Persuasions

Participants in this study described three sources of social persuasions and that was from family, instructors, and peers. Although most instances occurred during the first year, most familial influences were encouraging DE students to persist in engineering broadly. Sources of persuasions from instructors and peers typically occurred within the DE course and were generally positive. These positive affirmations may have positively influenced DE students' self-efficacy by also positively developing their sense of belonging in their engineering major, a construct that has emerged in previous studies exploring engineering self-efficacy (Carrico & Tendhar, 2012; Jones et al., 2014; Marra, Rodgers, Shen, & Bogue, 2012; Virgüez, 2017). There were also some instances where negative persuasions arose from peers of the participant. Sources of persuasions described by GE students were from the FYE course policies and mainly reported as negative persuasions. These policies were described as harsh with a goal to weed-out students, particularly as it pertained to grading.

Participants in this study described two types of social persuasions and that was through constructive support and criticism and discouragement. This study's DE students reported these types of persuasions with regard to the sources noted previously. Most positive persuasions reported were directly related to the DE course. Negative persuasions reported took place in the first year, but independently of their DE course. These types of social persuasions are similar to how GE students describe social persuasions which they received verbally. The difference between the types of social persuasions in GE and DE students is that GE students also reported non-verbal persuasions and were mainly negative persuasions within their GE course.

The focus of the social persuasions described by GE students included frustrations with their GE course policies. As mentioned previously, GE students reported negative verbal and non-verbal persuasions with regard to their GE course indicating that course policies were "weed-out" in nature (Geisinger et al., 2013).

3.3.5.4 Vicarious Experiences

Participants in this study reported sources of vicarious experiences as peer examples. DE students reported instances where they were exposed to upperclassmen in their major or alumni of their degree program within their DE course. These instances were described positively impacting their self-efficacy and wanting to emulate those examples.

In contrast to the DE students, GE students reported vicarious experiences through performance comparisons with a focus on comparing themselves to their peers by speed, contribution to team, mastery developed relative to peers, and grades of peers. GE students reported their peers as a benchmark of their success, mainly in the first semester. Hutchison-Green et al. (2008) reported that using peers as a benchmark in the first semester may be due to the timing at which the study was conducted and projects taking place in the FYE course had not come to fruition and that interviews conducted after the first semester showed that students recognized and reported more of their mastery development than vicarious experiences through performance comparisons.

3.3.5.5 Somatic and Emotional State

Evidence of DE students somatic and emotional state were reported being comfortable in their learning environment or being afraid and uneasy. DE students described evidence of comfort in their FYE course as being in a space where they could learn from their mistakes and rely on their group to help bridge knowledge gaps. However, DE students also reported evidence as fear of performing poorly in their FYE course, particularly as it pertained to oral presentations. As a contrast, GE students reported evidence of somatic and emotional state through enjoyment, interest, and satisfaction and satisfaction from success. This evidence provided by GE students were typically focused on increased interest and satisfaction from learning the FYE course material.

The focus of the somatic and emotional state experiences described by DE students were with regard to their enjoyment of their FYE course and their major. The experiences from the DE FYE course were reported by students as validations that they made the right choice regarding their engineering major. However, the focus of somatic and emotional state experiences described by GE students were with regard to their frustration with their FYE course policies. These results indicate that DE students generally had a positive learning environment supported by their peers and their instructors, whereas GE students did not. Marra et al. (2012) states that difficult curricula combined with poor teaching are major factors influencing students to leave engineering. Conversely, an emphasis on demonstrating a level of care for students can have positive impacts on students persisting in engineering (Jones et. al, 2010).

3.3.6 Implications

From this study, we can conclude that there are some similarities in how the FYE matriculation structure impacts self-efficacy development in DE and GE students. This qualitative analysis of a DE FYE matriculation structure adds to existing literature of previous studies that have explored self-efficacy more broadly in engineering (e.g., Lent et al. (2005), Patrick, Care, & Ainley (2011), Salzman, Callahan, Hunt, Sevier, & Moll (2015), Tendhar (2015), Virgüez (2017), Mamaril, Usher, Li, Economy, & Kennedy (2016)), confirming that mastery experiences are still a common form of self-efficacy development in FYE students. Additionally, this study contributes to the current understanding of self-efficacy in DE students as a contrast to a GE matriculation structure (e.g., Hutchison-Green et al.).

The results of this study may have on the engineering education community includes broadening a conversation typically dominated by quantitative studies, potentially uncovering better practices for first-year engineering programs and understanding how impactful the matriculation structure of the first-year can be on a student's major choice. As discussed in Section 3.2, there are various studies that use quantitative methods to explore self-efficacy but very few that use qualitative methods. Through the use of qualitative methods to explore this phenomenon, the results of this manuscript have provided more insight into the development of self-efficacy of first-year engineering students. An example of this insight comes from mastery experiences, which are still the most common way in which students report self-efficacy development. But, in addition to knowing that mastery experience is a common form of self-efficacy development, the results of this study show that there are three sources of this development (they figure it out independently, they get assistance, and learn through teamwork), students recognize this development (through trial and error), and students communicate their understanding of content material when the content is practical immediately (other courses) or in the future (career focus). This addition to existing literature will hopefully encourage FYE program directors to consider curriculum development along the axes outlined in Table 3.4.

Lastly, given that the results have shown that there are little differences in how FYE matriculation structure impacts self-efficacy development may indicate that self-efficacy may not be the appropriate lens to research the impact FYE matriculation structures have on the persistence of engineering students. It may also indicate that pedagogical choice may influence self-efficacy more than matriculation structure given the PBL structure of the course in this study and the fact that PBL has a positive link to self-efficacy development (Maraj, Hale, Kogelbauer, & Hellgardt, 2019). Because of the positive relationship between PBL pedagogy and self-efficacy development, it is difficult to differentiate the big influencer in these participants' self-efficacy since in this study, I compared a PBL DE course to a non-PBL GE course. Additionally, given the nature of this study (secondary analysis, different construct used for analysis relative to initial protocol), there may be differences that could emerge from the data if the study was originally designed to measure self-efficacy. With that said, further exploration of how self-efficacy is developed in DE students in comparison to GE students both within the same major, will be explored in study 3.

3.4 Summary

As previously discussed this manuscript is a qualitative secondary data analysis to explore how self-efficacy is developed in students from a declared first-year engineering matriculation structure. This study was conducted to add to the results of the study conducted by Hutchison-Green et al. (2006, 2008) who explored the same phenomenon but in the context of a general first-year engineering matriculation structure. Data were coded initially using Bandura's theory of self-efficacy and pattern level coding was conducted to report themes that emerged from responses. Results of this study demonstrate that students in a DE matriculation structure develop self-efficacy in the same manner as GE students do as reported by Hutchison-Green et al. (2006, 2008). Some aspects of this study had slightly different findings than Hutchison-Green et al.'s. Reasons for this may be due to the fact that the interview protocol used for the original study was designed using expectancy-value as the theoretical framework as opposed to self-efficacy which is a limitation of this study. While this study was fruitful in exploring self-efficacy development in DE students, additional work to explore self-efficacy development across types of FYE matriculation structures (DE vs. GE) and within the same engineering major, may provide an understanding of engineering self-efficacy within the context of a discipline and add to the discussion around the relationship between motivation and retention. With that said, this study served as a pilot to study 3 which explored self-efficacy development in students from both DE and GE matriculation structures within one engineering department.

Chapter 4: Manuscript 3 – The Impact of FYE Matriculation Structures on Self-Efficacy Development in Electrical and Computer Engineering Students

4.1 Introduction

The retention of engineering students has been a focus for many years as national reports have called for improvements in order to fill the growing number of engineering positions with domestic talent (VanAntwerp & Wilson, 2015). To help meet this need, universities have conducted research to understand why exactly students leave engineering and what can be done to retain them in the field (Geisinger, N., & Raman, 2013, Miller et al., 2015). Despite the efforts of universities to increase retention, the current number of students persisting still does not resolve the workforce issue, and unlike other majors, few students transfer into engineering after their first year (Ohland et al. 2008). In fact, it is during the transition from the first to the second year of college that attrition is highest amongst engineering students (Daempfle, 2002).

One way to address this gap is to focus on the first year to improve retention between the critical first and second years. First-year programs are key in this transition. These programs have traditionally been designed to prepare engineering students with a solid foundation in their pursuit of an engineering degree (Ambrose & Amon, 1997; Bates, 2014; Courter et al., 1998; Pendergrass et al., 1999; Prendergast & Etkina, 2014). Since the 1990's, engineering programs began to redevelop their first-year engineering programs to include more hands-on learning activities in order to increase retention. However, while the redevelopment of individual engineering programs has been informed by specific teaching practices and feedback from internal stakeholders, very few studies have looked across matriculation structures to compare the impacts of different types of FYE matriculation structure structures. In particular, one key aspect of structure concerns major: first-year engineering matriculation structures can be described as either general engineering (GE), which offers generalized first-year matriculation structures that include all engineering majors together, or declared engineering (DE), which directly admits students into a specific discipline of engineering (Xingyu Chen et al., 2013).

Of the total number of engineering graduates, 93% of those students matriculate solely through engineering. Given that the curricula are often so tightly structured that switching majors even within engineering can be challenging, the first year represents a critical period of time to explore how in these two different types of matriculation structures support students' retention in their chosen major. One key construct that research has shown to be important in retention is self-efficacy. Self-efficacy is defined as – and influences the tasks and activities that a person may attempt and how much effort they will apply to those tasks and activities (Bandura, 1997). While prior research has shown that self-efficacy is closely linked to retention (Brainard & Carlin, 1998; Lent et al., 2003; Schaefers et al., 1997; Seymour, 1992), and studies have explored the way self-efficacy develops in FYE generally (Hutchison-Green et al., 2008; Hutchison et al., 2006), few if any, studies have explored differences and similarities on self-efficacy development across DE and GE matriculation structures for specific engineering majors, or considered the impact of those differences on students' intention to persist in a given major. In Lewis (2019a, 2019b), I explored how matriculation structures could impact expectancy by comparing changes within a single program and comparing self-efficacy development in a DE program to existing literature. Both studies suggested that matriculation structure did not have a statistically significant impact on expectancy and that self-efficacy development in the problem-based DE program resembled previous work on GE programs. However, these studies were both analyses of existing data that used expectancy rather than self-efficacy as the construct framing data collection; moreover, the quantitative study (Lewis 2019a) did not include a true DE program, and the exploratory qualitative study (Lewis 2019b) did not focus on electrical and computer engineering. Given these limitations, coupled with the fact that social cognitive career theory (Bandura, 1997) suggests that learning experiences should impact self-efficacy, a study intentionally designed to explore that impact within a single major could still prove useful. As a result, this current study still explores the relationship between matriculation structure and self-efficacy because unlike the previous studies, this study was designed to collect original data to explore the differences in matriculation structures specifically in one engineering discipline. This is different from the previous studies in that 1) it looked at two different universities that have different matriculation structures (unlike study 1); 2) it looks within the context of a single discipline (unlike study 2); and 3) sought to provide explanations to the patterns found in study 1. To provide a manageable context for this question, the study focuses on the specific major of electrical and computer engineering. The purpose of this study then is to understand how the different types of first-year engineering structures influence self-efficacy in students choosing to major in ECE. The overarching question for this study is: *How do different first-year major structures shape students' engineering self-efficacy?*

To address the overarching question this manuscript will answer the following research questions:

RQ1: How do electrical and computer engineering students from a general first-year matriculation structure develop engineering self-efficacy?

RQ2: How do electrical and computer engineering students from a declared first-year matriculation structure develop engineering self-efficacy?

RQ3: What experiences are similar and different in the development of engineering self-efficacy in students from DE and GE first-year engineering matriculation structures?

To address these questions, I conducted a multi-case study to investigate the qualitatively different ways that electrical and computer engineering students who matriculated through DE and GE programs develop self-efficacy and how that development impacts their persistence into their second year. In previous studies (Lewis 2019a, 2019b), used existing data to explore both quantitative and qualitative dimensions of self-efficacy and first-year engineering matriculation structures, this manuscript builds on the first two manuscripts to collect new data and provide direct comparison between DE and GE matriculation structures. The purpose in employing qualitative methods in this design was to capture a deeper understanding of how participants develop self-efficacy, which is most popularly studied through quantitative methods. The advantage of qualitative methods has enabled me to describe the development of self-efficacy more thoroughly and more personally than most previous quantitative studies conducted and seek explanations for the patterns found in my previous work (Lewis 2019a). In particular, that study found that there were not any significant differences in students' expectancy responses across matriculation structures. However, there were significant differences in students' intention to persist in an engineering major across matriculation structures hence the need for this study.

In this study, I interviewed upper-level electrical and computer engineering students from one DE and one GE matriculation structure (each at a different university) during the spring semester. Note that both universities have combined electrical and computer engineering departments and as detailed in the methods, low response rates led to accepting students in either major. Each participant was interviewed to identify their perceptions of their first-year program, development of self-efficacy, and thought process in determining their choice of major. Following data collection, interviews were analyzed using the codebook developed in study 1, along with emergent codes that capture the various perceptions of self-efficacy development as it pertains to the first-year engineering experience.

4.2 Review of Literature

4.2.1 First-Year Engineering Programs

In a related study regarding first-year engineering programs with a focus specifically on structure, Chen (p. 28 2014) conducted a "nationwide examination of the first-year engineering curricula and introductory engineering courses" of all ABET EAC-accredited programs, and investigated the degree to which these curricula and institutional characteristics varied by the matriculation policies. Based on this analysis, Chen defines engineering programs using three levels. The first level indicates whether students are admitted directly into their discipline, admitted to the college/school/department of engineering, or admitted to the university generally without admission to a specific college or department. The second level indicates the term when students are required to take their first engineering course and whether all engineering programs at the university require it simultaneously. The third level is similar to the second level but differs in terms that it indicates when students are required to take the first disciplinary engineering course and whether all engineering programs at the university require it simultaneously.

Of the 1,873 engineering programs included in her study, Chen reports that 88% of programs required students to take an engineering course within the first two terms; 12% required students to take a course in the 3rd term, and two programs don't require an engineering course until the 4th term. Moreover, that 70% of ABET accredited institutions have declared first-year engineering matriculation structures (DE) with students admitted directly to the major, while 18% of ABET accredited institutions have general first-year engineering matriculation structures (GE) (Chen, 2014) with students admitted to a college or school of engineering. Of the universities that do not employ either of these matriculation structures, 11% admit students into the university with no particular major, and 1% is undetermined. Given that both types of matriculation structures are widespread, this study specifically aims to understand the difference in self-efficacy development across those first-year engineering structures, and more importantly, how these differences in first-year engineering courses impact a student's decision to stay in engineering.

4.2.2 Self-Efficacy as a Guiding Framework

As a subset of personal factors within social cognitive theory, perceived self-efficacy is defined as a person's belief about their capabilities to produce a certain level of performance on a given task, and it can have influence over events that affect their lives (Bandura, 1997). Self-efficacy influences the tasks and activities that a person may attempt and how much effort they will apply to those tasks and activities. Positive or an increased perception of self-efficacy yields greater effort, persistence, and resilience; the opposite is true for lower or decreased perception of self-efficacy (Bandura, 1997).

Perceptions of self-efficacy are formed by four sources: mastery experience, vicarious experience, social persuasions, and somatic and emotional state (Bandura, 1997). *Mastery experiences* are developed from how successful one has been in completing an event or task. *Vicarious experiences* are influences through observing and/or modeling someone they can relate to completing the task (Schunk & Pajares, 2005). *Social persuasions* influence a person's self-efficacy through verbal responses from others towards a person's ability to complete a task. False inflation of a person's self-efficacy can quickly be diminished by disappointing results

(Bandura, 1997). Lastly, a person's self-efficacy is influenced by the *somatic and emotional state* they are in while completing a task. Generally, positive events or response to events typically yields higher self-efficacy. Conversely, negative events or response to events can lead to lower self-efficacy; however, an occasional failure along a path of success is deemed as an outlying event and has little negative effect on a person's self-efficacy (Schunk & Pajares, 2005).

4.2.3 Self-Efficacy in Engineering

In order to be a knowledgeable contributor to the discussion of self-efficacy in engineering, it is important to understand how it has been researched previously. There are a variety of studies that have been conducted exploring self-efficacy in engineering. Self-efficacy is particularly important in first-year engineering matriculation structures because those structures establish a key foundation for engineering students (Jones et al., 2014, 2010; Lin, Lund, & Morton, 2017). In 2006, a quantitative study explored factors influencing self-efficacy within first year engineering students (Hutchison et al., 2006). Soliciting first-year engineering students at Purdue University for their study, Hutchison et al. used a phenomenological approach to explore how various students experience learning. Purdue has a GE first-year matriculation structure where students take math, chemistry, physics, English, and a two-semester engineering sequence course that focuses on teamwork, engineering design process, ethics, and other skills related to engineering (Purdue University, n.d.). In the open-ended portion of the survey, students were asked to list up to ten factors influential to their self-efficacy within the course. Of the student responses yielded 9 factors: 1) understanding/learning; 2) drive and motivation; 3) teaming; 4) computing abilities; 5) help; 6) working assignments; 7) problem-solving abilities; 8) enjoyment, interest, and satisfaction; and 9) grades. Of these nine factors, motivation, understanding, and computing abilities were listed as the most influential to the students' self-efficacy. Hutchison et al.'s study reaffirmed that mastery experiences were the most influential for first-year engineering students' perception of self-efficacy through direct and/or indirect linking of the factors to this source. However, a limitation to this study is that the students' responses were very limited and did not examine how student perceived these factors as an influence, or whether students had similar first-year learning experiences.

Thus, a follow-up qualitative study was conducted by Hutchison-Green, Follman, & Bodner (2008) to explore more deeply how first-year engineering students perceive factors that influence their self-efficacy. This study was again conducted at Purdue University, a single institution with a single type of matriculation structure (GE), where twelve students volunteered for interviews. What Hutchinson-Green et al. did was useful for understanding self-efficacy development in the first year broadly in the context of the general engineering matriculation structure; however, they did not take into account the specifics of the course or, more importantly, how these learning experiences might be different if students were in a declared rather than general matriculation structure. Lewis (2019b) compares DE students and their self-efficacy development to Hutchinson-Green et al.'s GE students. In this study, I found that DE students developed self-efficacy very similarly to the GE students in Hutchinson-Green et al.'s study. This similarity in self-efficacy development suggests that pedagogy may have more of an impact on self-efficacy development than matriculation structure, given the similarities in course goals in both the course in Lewis' study and the course in Hutchinson-Green et al.'s study. However, because Hutchinson-Green et al. does not specify a major (or potential major) of the students in their study, it is difficult to determine whether the comparison by Lewis to Hutchinson-Green et al is a one to one in terms of student major. Moreover, in a quantitative study comparing expectancy and persistence for electrical and computer engineering majors in two different matriculation structures within a single university (Lewis 2019b), matriculation structure did impact persistence, suggesting that more work needs to be done to understand those differences. Thus, this particular study adds to this discussion by focusing on matriculation structure as the main difference between participants given that their major is the same. I expect there to be a difference in self-efficacy based on matriculation structure due to the differences in content taught in the first-year (e.g. general engineering content versus discipline specific content).

4.2.4 Electrical and Computer Engineering Rationale

While there are a few universities who grant electrical engineering degrees as a combination with another field such as computer science or biomedical engineering (ASEE, 2015), more than 10% of ABET accredited institutions combine electrical and computer engineering as the Electrical and Computer Engineering Department (Blandford & Hwang, 2007), which typically includes one department head and two program directors allowing for some degree of administrative efficiency. This combination is common due to the ability to provide students with a well-rounded education (a good electrical engineer should have knowledge of software and a good computer engineer should have knowledge of hardware), the similar foundational principles of the two fields, and enables students to change between the majors without losing time to degree completion (Blandford & Hwang, 2007).

Electrical engineering (EE) is the studying and application of the physics and math of electricity, electromagnetism and electronics to process information and transmit energy (College Board, n.d.-b; The University of New South Wales, n.d.). While most electrical engineering phenomena are invisible (such as electricity, light, and electromagnetic fields), they are the foundations of many modern capabilities. Almost every piece of modern technology relies on electrical engineering. These technologies include, but are not limited to: viewing images from inside the body in medicine; the recording, production, storing, and playing of music; exploring space and the ocean through signal sensing; and smart technology such as phones, alarms, and robotic household appliances (Virginia Tech, n.d.-b). Computer engineering (CPE) is similar to Electrical in that degree holders may design and test circuits and electronics but mainly as it pertains to computers and related equipment. CPE focuses on the interface between hardware in order to provide new capabilities to existing or new systems products (Career Cornerstore Center, n.d.; College Board, n.d.-a). Computer engineering expands modern technology through embedding computers in other machines and systems in order to transfer data, make faster, mobile and more efficient computers, and even embedding computers into fabrics and building materials. Computer engineering separates itself from electrical engineering through the understanding of the "body" and the "mind" of computing technology and determining solutions that could be adjusting the software or changing the hardware (Virginia Tech, n.d.-b).

The structural differences between DE and GE FYE matriculation structures become particularly important when considering the structure of electrical and computer engineering degree granting departments. If a student is considering an ECE degree but has not quite decided whether they prefer hardware over software and vice versa, having a DE matriculation structure enables students the opportunity to learn about both fields equally in the first-year, exploring both hardware and software applications, and learn which degree program aligns with their goals early in their college career (Wong, Holtzman, Pejcinovic, & Chrzanowska-Jeske, 2011). On the other hand, if a student has interests that falls outside of the scope of ECE, a DE FYE matriculation structure may limit the student's knowledge regarding other fields of engineering.

Exposing students to an array of engineering disciplines can be an advantage of a GE FYE matriculation structure if their interests expand beyond the field of ECE (Wong et. al, 2011). Literature has explained why a university would chose to incorporate one of the two types of FYE matriculation structures, but whether one matriculation structure influences self-efficacy, similarly or more than the other, particularly as it pertains ECE, is underexplored.

This major also pose key challenges with diversity because of the low number of women and people of color who are awarded degrees in these fields. According to *Engineering by the Numbers*, electrical and computer engineering has consistently awarded less than 16% of degrees to women (Yoder, 2017) in contrast, to 50% in environmental, 44% in biomedical, and 21.3% overall. However, the low number of degrees awarded to diverse populations are not solely due to attrition of those groups in ECE but rather an effect of the low entrance rate of these groups into the field (~9% entrance rate). The lack of diversity in this field suggest the need for more detailed research within the first year to learn how the curriculum structure of the first-year matriculation structure can better support underrepresented minorities who choose electrical engineering as a major. As outlined in study 2, the university used for analysis for that study (and this one as well) has consistently low numbers of diverse students in EE from Falls 2013 – 2017.

4.2.5 Summary

Research has demonstrated self-efficacy to be a good predictor of persistence in engineering. However, the lack of research conducted to explore how self-efficacy has been developed in FYE students across matriculation structures points to the need for more work here. Assessment of program changes have too often been evaluated using department created surveys and examinations as opposed to widely validated measures. Additionally, self-efficacy in engineering is usually measured quantitatively but rarely explored qualitatively. As mentioned previously, self-efficacy has not been explored across types of FYE matriculation structures, specifically that of general versus declared first-year engineering matriculation structures. It also has not been explored in regard to the persistence and retention of electrical engineering students specifically. This gap in research thus leads to the purpose for my study.

4.3 Methods

This study is an exploratory qualitative analysis of self-efficacy development in students in DE and GE FYE matriculation structures. In this section, I discuss the rationale behind choosing the case study methodology, my research design, including sites and recruitment methods, data collection and analysis, and to validity and reliability measures taken.

4.3.1 Case Study Rationale

To understand why the case study methodology was employed for this study, it is important to identify the major details that allow a research project to be classified as a case study. There has been confusion regarding case studies in that “the process of conducting a case study is often conflated with the unit of study (the case) and the product of the research” (Merriam, 2009, p. 40). Creswell (2006, p. 61) defines a case study as an “exploration of a ‘bounded system’ or a case (or multiple cases) over time through detailed, in-depth data collection involving multiple sources of information rich in context.” Similarly, Yin (2009) defines case study as an “empirical inquiry that investigates a contemporary phenomenon within its real - life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 18). However, Stake (2005, p. 443) implies that a case study is more about “a choice of what is to be studied” than a methodological choice, indicating case studies do not provide a guideline for how to approach a study but rather define the ways the unit of the study must allow for it to be investigated as a case within appropriate boundaries. The “case” of the study can be anything such as a person, a program, or an institution, that can be studied in a finite time set by the boundaries of the study (Miles & Huberman, 1994; Merriam, 2009). The fact that the unit of the study determines whether a study can be classified as a case study is what differentiates case studies from other qualitative methodologies such as ethnography or phenomenology. (Merriam, 2009). However, because a case study is conducted within a bounded system, case studies can include methods, such as ethnographies or grounded theory, that can be combined into a case study. The case study approach does not require any specific methods for data collection and data analysis and is instead open to the needs of the research questions themselves. Researchers traditionally use case study because of their interest in insight, discovery, and interpretation as opposed to hypothesis testing (Merriam, 2009).

According to Yin (2009) case studies are meant to "investigate a contemporary phenomenon (the "case") in depth and within a real word context, especially when the boundaries between phenomenon and context may not be clearly evident" (p.18). Self-efficacy development is a contemporary phenomenon that occurs over time as students move throughout the curriculum. The boundary between self-efficacy development and the context in which it develops (i.e., FYE matriculation structures) is not necessarily clear because the context shapes the phenomenon.

Given that the impact of the FYE matriculation structure on students' self-efficacy has been underexplored, a case study methodology is useful in understanding this phenomenon more clearly. The unit of study for this study lends itself to be characterized as a multi-site case study. The justification for using a case study for this research enables me to take broad results from works such as Jones et al. (2010, 2010), Hutchison-Green et al. (2006, 2008), and localize it into two specific contexts. Using a case study methodology, data can provide information about what is common and uncommon about a case, particularly relating to the nature of the case, historical background, and physical setting. Additionally, a multi-case study methodology enables me to understand students' experiences in different contexts. Since students will be enrolled in either a DE or GE matriculation structure, the multi-case study methodology enabled me to collect and analyze data to compare and contrast experiences within the same structure and across the different structures, thus expanding on the pilot study conducted for study 2. This is beneficial given that multi-case studies can provide insights into common experiences versus those of extreme, rare, or critical experiences typical of a single-case study. There are two institutions included in this study to provide variation and deeper insight into the phenomenon. The institutions, data collection, and data analysis will be discussed in the methods section.

4.3.2 Research Design

4.3.2.1 Research Sites

In this section I discuss the reasoning for selecting the research sites and cases for this study. Since the focus of this study is to explore the differences of self-efficacy development in students in DE and GE matriculation structures, there are two factors that have impacted the focus on electrical and computer engineering, as noted earlier: 1) it has low diversity; and 2) I have personal interest in this major. For this study, data will be collected at two public universities in the state of Virginia. The criteria that justified the selection of these institutions are as follows: 1) each has an accredited electrical or computer engineering program; 2) each has a general or declared first-year engineering matriculation structure. The purpose of criteria 1 is as discussed in section 4.2.4, electrical is one of the most common and most popular engineering majors (Meyers, Bucks, Harper, & Goodrich, 2015).

4.3.2.2 Electrical and Computer Engineering Major

For this study, each institution, college of engineering, and engineering department has its own policies, culture, and context that can impact students' experiences while enrolled, hence the need for criteria 2. Each case is bounded by two factors: the FYE matriculation structure and the choice to major in ECE. When developing cases, Yin (2009) recommends cases that allow for similar results (similarities between cases that support the researcher's ability to make comparisons). Both institutions in this study are large, public, state schools with a research 1 (i.e., very high research activity) profile (Indiana University School of Education, n.d.), with case 1 offering a DE FYE matriculation structure and case 2 offering a GE FYE matriculation structure. Having cases that are similar in terms of size, mission, and research profile, results in the reduction of variables that may impact the results of the study, but still provides enough opportunity for me to identify themes within a single site as well as analyze themes across sites (Creswell, 2007b). It has been referenced that advantages of attending a large university include affordability especially for in-state students, and opportunities for students such as on-campus employment, networking through extracurricular activities, and access to a variety of faculty members (Czarnecki, 2014; Scholarships.com, n.d.). Comparisons of key factors at each site is outlined in Table 4.1.

Table 4.1 – Comparison of Sites for Case Study

	Size	Research Profile	Type	College of Engineering	Overall Size
Case 1	Large	R1	Public	~2,000	31,000
Case 2	Large	R1	Public	~10,000	33,400

Case 1:

At the declared engineering institution, the Electrical and Computer Engineering department is the second largest department in the College of Engineering with about 300 undergraduate students as of Fall 2017. Although department specific data is unavailable, data for the College of Engineering shows enrollment of underrepresented minorities at 21%. At site 1, during the first year, students take chemistry, calculus, physics, introductory programming, and an introduction to electrical engineering course, along with general education requirements.

The Introduction to Engineering course focuses on orienting students within the ECE major. By providing a top-level overview of various topics in ECE, students learn baseline skillsets applicable to topics such as circuit analysis, signal processing, digital logic, and more. The lab component associated with the course (which is built into the 3-credits as opposed to being listed separately) introduces students to lab equipment essential to any ECE major such as digital multimeters, function generators, oscilloscopes, and electrical components such as resistors, diodes, and transistors. In addition to practical skills, this course also provides students insight to career options available to them as ECE majors through weekly guest speakers who are working in the field. The goals of this course are outlined in Appendix D.

Case 2:

At the general engineering institution, the Electrical and Computer Engineering department is the second largest department in the College of Engineering with about 1100 undergraduate students as of Fall 2017. The percentage of underrepresented minorities is just greater than 9%. For the College of Engineering, the percentage of underrepresented minorities is 13%. At site 2, in the first year, students take chemistry, calculus, physics, and a 2-course foundations of engineering sequence, along with general education requirements.

The Foundation of Engineering courses have objectives that focus on the development of professional and technical success. These objectives are usually met through working in teams, oral and written communications, and an introduction to common engineering software (Virginia

Tech Department of Engineering Education, n.d.). Because these courses serve a number of engineering disciplines, technical content applicable to any one major is limited. During the fall semester, students are required to attend information sessions hosted by engineering disciplines to aid in the major choice process. In the second course of the sequence, students participate in a semester-long engineering design project that reinforces communication, professionalism, and broad technical skills introduced in the first course of the sequence.

It is worth noting that while the size of the ECE departments at the two universities are vastly different, the number of students majoring in ECE at both institutions are equally proportionate (i.e. ~16% of all engineering students are ECE majors). As noted earlier, the topics taught in the FYE course in Case 1 are specifically tied to the ECE major whereas the topics taught in the FYE courses in Case 2 are not tied to any particular major. While both courses do attempt to provide students with an understanding of future career options, again, Case 1 scopes those options within the field of ECE whereas Case 2 provides a variety of career options that are not tied to any one discipline.

4.3.2.3 Quantitative Screening Survey

To avoid survey fatigue and maximize response rates, the screening survey for this study leveraged a survey already used at one of the institutions to collect data on first-year engineering students. The questions in the survey contained Likert-style responses ranging from Strongly Disagree (1) to Strongly Agree (5).This data may be used for internal research for the respective college of engineering or may be used in various research projects at the institution. The following survey was administered to first-year engineering students prior to the end of the spring semester and was used to solicit participants from institutions included in the study. This survey is the same survey administered and analyzed as outlined in study 2. Because of how difficult it can be to differentiate self-efficacy and expectancy quantitatively, these questions that asks about expectancy were still used for this manuscript (Eccles & Wigfield, 2002; Schunk & Pajares, 2005). Figure 4.3 lists the questions used for screening.

Question: Please rate your level of agreement with the following statements. When asked about "**engineering-related courses**," please refer to your **math, science, and engineering courses**. **(Expectancy)**
Compared to other engineering students, I expect to do well in my engineering-related courses this year.
I think that I will do well in my engineering-related courses this year.
I am good at math, science, and engineering.
Compared to other engineering students, I have high engineering-related abilities.
I have been doing well in my engineering-related courses this year.

Figure 4.1 – Survey Questions Used for Screening

4.3.2.4 Sample

Case study sampling does not require a large population for data collection. The goal for case study research is to purposefully select participants that may best provide the researcher with a meaningful understanding of the research question (Creswell, 2009b). Therefore, to purposefully sample and recruit participants for this qualitative study, a portion of the screening survey already in use at Site 2 was also administered at Site 1 – specifically, the questions outlined in Figure 4.3. Using the Spring 2018 survey data, this screening survey quantitatively measured participants' perception of their expectancy at the end of their first year. Since the survey was already in use at Site 2, the same questions were used at Site 1 to provide comparable data when screening and comparing participants.

The use of this criteria to identify interviewees is justified by the purpose of selecting cases that show different perspectives of the first-year matriculation structure influence on self-efficacy development and subsequent major choice Creswell (2007b). Creswell (2007) defines this approach as "purposeful maximal sampling" which is a sampling strategy that "represents diverse cases and fully describes multiple perspectives about the cases" (p. 129). Due to the low number of women and underrepresented minorities that receive degrees in these majors, I also attempted to oversample for those populations in order to obtain data of diverse perspectives by recruiting from minority-serving engineering organizations. Table 4.2 identifies the participants' self-efficacy tier placement, gender breakdown at each site, the number of students who are ethnic minorities (EM), the number of students who participated in pre-college engineering activities (PCE), and the number of students who identify as a first-generation college student (FG). While GE students in the top third of survey responses were invited to be interviewed, none responded to the request. Additionally, at the GE site, all participants were in their second year whereas at the DE site, participants were in different stages of their ECE degree program. This difference in the academic year of participants is due to the fact that during data collection at the GE site, the goal was to interview only second year students; however, due to recruitment difficulties at the DE site, the participant pool expanded to ECE students in any academic year.

Table 4.2 – Participant breakdown for interviews

# of Participants	Top 1/3	Middle 1/3	Lower 1/3	Gender	EM	PCE	FG	Year in School
DE ECE	3	2	2	6 M; 1 F	4	1	3	1st – 1; 2nd – 4; 4th – 2;
GE ECE	0	4	3	4 M; 3 F	2	6	0	2nd - 7

4.3.2.5 Recruitment

Case 1:

Recruitment for this site took place both in-person during a visit to a sophomore ECE class, and via an email sent to eligible students three times. Students were asked to answer the questions related to expectancy (outlined above) and list whether they would be interested in participate in an interview. This recruitment method yielded 28 total responses (9.3% total response rate). 25% of the students who completed the recruitment survey were interviewed for this study. Due to low response rate for interviews, the sampling criteria were not applied for interview recruitment; all individuals who volunteered were interviewed.

Case 2:

Recruitment for this site took place via an email sent to eligible students three times. Eligible students were chosen based on their responses related to the expectancy questions outlined above during the Spring 2018 survey administration. A total number of 99 students were eligible and invited to be interviewed. From that survey, a sample of 7 total participants, spread across the middle 1/3 and the lower 1/3 of engineering expectations for GE students majoring in ECE agreed to be interviewed.

All participants who sat for an interview were compensated with a $10 Amazon gift card.

4.3.2.6 Interview Protocol

The interviews conducted were semi-structured as this allowed for me as the researcher to ask a set pre-written questions but also allow the participant to truly describe their experience in their own words and allowing follow-up questions to be included dependent upon a response (Merriam, 2009). This protocol was developed based on the interview protocol Hutchinson-Green used in their 2008 qualitative study and designed specifically to explore both engineering self-efficacy – that is, participants' belief in their ability to be an engineer - and first-year course self-efficacy – their belief in their ability to be successful in their course. The results from a previous study (Lewis 2019b) also informed the development of this protocol by suggesting specific wording in questions in order to elicit responses that directly align with one or more of the ways self-efficacy is developed. Additional modification to the protocol included reducing the number of questions in order to keep the interview time to an hour. The following interview protocol was used as a general guide during the interviews conducted.

Beginning of 2nd Semester Sophomore Year

Updated screening information

1. Just to get your up to date responses, I'd like to know on a scale of 1-6 with 1 being Strong Disagree and 6 being Strong Agree, how would you respond to the following:
    a. I am confident in my choice of a specific major
    b. I have sufficient information to make an informed choice about a specific engineering major
    c. I am confident that I want to study engineering
    d. I plan to continue on in an engineering major
    e. I don't intend to change my major from engineering to a non-engineering major

Background information

1. Where are you from? What made you decide to try engineering?
2. What is your current engineering major? Why?
    a. How did you come about choosing this major?
        i. Is there anything about going directly into your major (or taking a general engineering course) that impacted your major choice?

Definition of success in first-year engineering course and course self-efficacy

1. I'm really interested in how students view success in class
    1.1. Can you tell me about your thoughts? How did you define success in your first-year engineering courses? What did you need to do to consider yourself successful?
    1.2. If you had to rank these things, which is most important?
2. I'm also interested in how you think your performance in your first-year engineering course is impacting your quest to achieve success in your current engineering course
    2.1. To what degree are you achieving success in your current engineering course?
        2.1.1. Why do you believe this?
        2.1.2. What lessons from your FYE are you finding most helpful in achieving this success?
    2.2. I'm also interested in understanding how you think the general population of your engineering class feels about success in the course
        2.2.1. How do you believe other people in your class define success in your current engineering course?
3. On what experiences are you basing your judgment? (mastery experiences)
4. How have other people influenced how you think you will do? (vicarious)
5. How have people (family, teachers, peers) encouraged you to succeed in the class? (social influences)
6. How does your first-year engineering course make you feel? (physiological) (When thinking about your first-year engineering course, how do you feel?) (physiological)
7. Of all of this feedback you're getting (list their mastery, vicarious, social, and physiological experiences), is there any one thing or any couple of things that really affects your beliefs about your abilities more than the others?

Class Efficacy – What is it? How do you assess it?

1. What grade did you earn in your FYE course?
2. What grade did you think you deserved in your FYE course? Why?
3. Fill in the blank: I believe that I will earn a grade of ____ in my current engineering course
    3.1. At the end of the semester, what grade do you think you will receive in your current engineering course?
        3.1.1. What is helping you earn it? Is there anything specific from your FYE that recall being useful?
    3.2. What makes it difficult to get an A in your current engineering course?

Engineering Degree Efficacy – What is it? How do you assess it? How is it different from class efficacy?

1. How has your FYE course prepared you for your major?
2. Do you believe you have the ability to earn an engineering degree in your discipline? Why?
    - Why are you *still* in your major?
3. Do you believe that your FYE program has prepared you for success in your engineering major? Why?
4. What concepts did you gain from your FYE course that you believe will be most useful in being successful in your current engineering course?
5. What experiences did you gain from your FYE course that you believe will be useful in being successful in your current engineering course?

Other

1. Is there anything else about your FYE course that you did not get a chance to share during the interview and would still like to share with me right now? Is there any question I did not ask that I should have asked?

The purpose of the interview protocol was to ask questions informed by the research questions that would elicit meaningful responses from the participants. To achieve this, the interview protocol focused on three major sections; course self-efficacy, class efficacy, and engineering degree self-efficacy. In the interview protocol, the course self-efficacy section asked questions to understand how students view success in their FYE course(s) and current courses, how students perceive that their success in their first-year engineering course impacted their ability to achieve success in their current engineering course, as well asking participants to identify specific instances mapping to mastery, vicarious, social, and physiological that supports their belief. The class efficacy focused on the grade received in the first-year engineering course, the grade the participant believes they would earn in their current engineering courses and is asked to identify information specifically related to their first-year engineering course they perceive will be most helpful in earning the grade they seek in their current engineering courses. The engineering degree efficacy asked participants about their belief in their abilities to obtain a degree in the discipline they are currently majoring in. Additionally, they are asked to identify specific concepts and experiences from their first-year engineering course that supports their belief of obtaining an engineering degree.

4.3.3 Data Collection

When conducting a multi-site case study Miles & Huberman (1994) and Bogdan & Biklen (2007) advises to collect data at one site at a time to avoid confusion across cases. Additionally, they mention that collecting data gets easier after the first site because the first case study will have provided a focus to define the parameters of the others" (p. 70). Given the locations of the universities included in this study, data were collected in person and via phone at one university at a time.

Interviews were conducted in person and via phone throughout the spring semester at both institutions. Interviews were audio recorded on multiple devices and transcribed using Otter.ai. Audio and transcription files were stored on Virginia Tech's secure Google Drive.

In order to promote better recollection of the first-year course, the goals for each of the first-year courses were printed and provided to participants at the interview to reference if necessary. Data collected through interviews included participants' expansion on their perceived self-efficacy relative engineering, how their matriculation structure (DE or GE) influenced their self-efficacy, and verbal and non-verbal (for in-person interviews) affective responses to the subject matter (do they seem somber, happy, hopeful, do they change their body language and/or position when talking about particular subjects, etc.) (Merriam, 2009).

4.3.4 Data Analysis

Modeling the deductive, qualitative data analysis done by (Hutchison-Green et al., 2008), data was analyzed using a priori codes developed from a previous study (Lewis 2019b). Emergent codes were developed to expand existing codes and develop new aspects to describe different ways each source of self-efficacy was experienced by the participants and how the first-year engineering matriculation structure impacted that development. Each code was expanded to encapsulate the nuanced ways participants developed self-efficacy within the major categories of mastery, vicarious, social persuasions, and somatic and emotional state. The evolved codebook is presented in Table 4.3. Codes denoted by "**" represents new emergent codes or sub-codes in contrast of Lewis (2019b).

Table 4.3 – Evolved Codebook for First-Year Student's Development of Self-Efficacy (** represents emergent codes or sub-codes in contrast of study 1)

Mastery Experiences		**Students describe experiences in which they succeeded or failed in an engineering context**
Sources	Guided Mastery	How mastery is developed: students develop mastery with the assistance of a supervisor (teacher, TA, etc.)
	Lab Related**	Students develop self-efficacy by performing tasks related to lab assignments
	Team Development	Students develop mastery through working in teams in order to achieve a common goal
	Negative or Failed Mastery Experiences	How students developed mastery: students' mastery development were stalled/halted due to poor performance on task
Evidence	Mastery vs. Performance**	Students discuss balancing understanding the material vs. performing the material for a grade
	Grades/Performance	Success discussed in reference to grades
	Understanding/Mastery	Success discussed in reference to understanding content
	Teaching Others**	Students describe various ways they felt they achieved mastery through retaining information
Focus: Practical or Transferable Experiences	Foundation Building**	Students develop mastery through the scaffolding of knowledge related to their major
	Communication Related	Students developed mastery in communication skills either via public speaking w/ projects or communicating with group members
	Ethics**	Students describe ethical considerations relating to learning and practicing (with school work).
	External Course Related	Students develop mastery in FYE was applicable in future courses (reflective)
	Non-Transferable**	Students describe skills and experiences that were not transferable to their in-major courses
	Technical or Industry Related	Students develop mastery in the form of technical skills development that will be useful in industry

Vicarious Experiences		**Students describe experiences in which they modeled their actions after observing someone doing an engineering related task**
Sources	Academic and Professional Examples**	Students reference instructors, grad students, and employers as people worth emulating (vicarious influences)
	Peer Examples	Students exposed to/following in the footsteps/confirmation in choice of engineering via peers

Social Persuasion		Students describe social interactions in which feedback on their engineering related task was provided
Type	Constructive Support and Criticism	Feedback from supervisors and/or peers supported students' SE development
	Discouragement	Students received negative feedback in relation to their SE development. Students generally took this feedback as fuel to do better rather than as a sign to quit.
Sources	Familial Influence	Students were encouraged to pursue engineering due to familial encouragement or familial employment as an engineer.
	Instructors, Facilitators, Supervisors	Students were encouraged to pursue engineering by instructors, facilitators, or job supervisors
	Peers	Students were encouraged to pursue engineering by peers.

Somatic Experiences		Students describe experiences in which their mood was impacted while completing an engineering task
Sources	Instructional Environment	Students describe somatic and emotional state experiences as it pertains to the class environment (e.g. grading, exams, assignments) as well as what's perpetuated by instructors of the course
Evidence/ Feelings	Negative Somatic Experiences**	Students express being scared, nervous, upset, stressed and more in completing engineering tasks in FYE course negatively impacting their SE.
Focus	Course Related	Students here express how they love and enjoy what they are doing. Focus of enjoyment is on the course
	Major or Career Related	Focus of enjoyment is on the student's major choice

4.3.5 Validity and Reliability

With any research study, the validity and reliability of data collection and analysis methods are important in ensure the generalizability, trustworthiness, credibility, and authenticity of a study (Creswell & Miller, 2000). In qualitative studies, validity and reliability are treated differently and more independently than in quantitative studies. In this section, I discuss the validity and reliability of this research study, as well as address my own biases regarding this study.

4.3.5.1 Validity

Validity is a strength of qualitative studies given the fact that findings are determined to be accurate either from the standpoint of the researcher, the participants, or the reader (Creswell & Miller, 2000). Measures that will be taken to ensure the validity of this study include triangulation, member checking, rich, thick description, and peer review.

Triangulation is defined as the use of different data sources to establish themes that ultimately converge, adding to the validity of the study (Creswell, 2007b). This is a strength of case study research in that data is sourced from multiple cases and can result in a rich and holistic explanation of the themes that emerge Merriam (2009). The data collected from interviews with students at different stages in their degree program provided various accounts of how the phenomenon was experienced. Course materials such as course objectives and syllabi were also used in comparing participants perceptions of their FYE matriculation structure with the objectives of the course.

Member checking is defined as taking cleaned data and interpretations back to participants to confirm that an accurate account of the narrative was conducted (Creswell & Miller, 2000). According to Guba & Lincoln (1994), member checking is the most important method of establishing credibility within a study. Member checking was conducted through emailing the final interview transcript to participants. Participants were asked to provide feedback or clarification through the use of the comment feature in Microsoft Word.

Peer review includes soliciting a peer to serve as a reviewer, inquiring about the study in order to aid the researcher to develop an understanding of the study from a different perspective.

This method of validation ensures that the results of the study resonates with readers beyond the researcher (Creswell, 2007b). After the data was analyzed, I petitioned a peer in the Engineering Education department to serve as a reviewer for this study. This reviewer reviewed codes, code definitions, and referenced quotes as they are developed in the study in order to provide additional feedback regarding whether the codes are appropriately defining the expressed experience.

4.3.5.2 Reliability

In qualitative studies, the reliability of a study is indicative of how consistent the researcher's approach is across different projects (Creswell, 2007b). Yin (2009) suggests that researchers should document the process of their case studies in as much detail as possible. Given that this is my first independent research study, I created an audit trail by documenting the process of this dissertation making note of things that worked well, developing better timelines for implementing back-up plans, and adjusting my interview style for future research studies. Furthermore, Creswell (2007) emphasizes that researchers should make sure that the definition of codes do not change drastically during the process of coding. This consistency was practiced through the refining of codes and using intercoder reliability to review the codebook developed and discussed in the data analysis section.

4.3.5.3 Researcher's Bias

It is especially important in qualitative research studies that I, the researcher, self-reflect and address the biases I have in conducting this study (Creswell, 2007b). I approach this study as a first-generation, African-American, female college graduate, from a low socioeconomic background, with an undergraduate degree in electrical engineering. The undergraduate institution I attended had a declared first-year engineering matriculation structure. While I am very appreciative of my undergraduate experience, if it were not for my plans to enter graduate study, I felt very underprepared to enter the engineering workforce given my academic struggles once in my major. Upon learning about a different first-year engineering matriculation structure while in graduate school, my curiosity about the topic for this dissertation piqued. As a first-generation student with no exposure to engineering prior to college, I became curious about whether my choices would have remained the same had I experienced a general first-year engineering matriculation structure as opposed to my declared matriculation structure. In fact, I began college as a computer engineering major and then switched to electrical in the middle of my sophomore year due to my not wanting to jeopardize my ability to get a degree based on my inability to comprehend coding. While my overall experience at my undergraduate institution was a positive one, I perceive my engineering self-efficacy to not be as high as I would like it to be.

The choice to study an ECE program, while motivated in part by the overall demographics of electrical and computer engineering, is therefore also a personal one based on my background. As an electrical engineer, I have a personal interest in understanding students' perceptions regarding the field of electrical engineering. Obtaining a degree in electrical engineering was not an easy undertaking and had a negative impact on my own self-efficacy. When I learned about more engineering disciplines after receiving my degree, my curiosity surrounding first-year engineering matriculation structures piqued and has been a major impetus behind designing this study.

In summary, I have biases as a former confused engineering student in a declared engineering matriculation structure with lower engineering self-efficacy. However, having these biases may enable me to connect with my participants due to this potentially shared experience which may illicit responses I may not have otherwise received. The advantage of conducting semi-structured interviews allowed me to hone in responses that provided fruitful information for this study, which I could quickly recognize given my background.

4.3.5.4 Limitations

A limitation of qualitative studies are the sensitivity and integrity of the researcher (Miles & Huberman, 1994). Having a sole instrument of collecting and analyzing data for a case study is usually advantageous, it can also be a huge undertaking for inexperienced case study researchers. While I have experience in conducting interviews and coding data, I recognize that I have a lot to learn in this independent research project and plan to rely on the expertise of my advisor, committee members, and other research mentors for support in areas that still need strengthening.

Another limitation is that these two sites have different FYE approaches and the participants from each site have different backgrounds regarding year in school, pre-college experiences, gender and ethnic diversity, and first-generation status. These differences thus make it difficult to do a one to one comparison between students across sites in order to attribute self-efficacy development solely to the type of FYE matriculation structure. However, this study is still important in understanding how self-efficacy is developed in different academic contexts. Given that few studies have explored the relationship between self-efficacy and matriculation structure within electrical and computer engineering, this study was designed to prompt participants about their experiences within their FYE course particularly as it pertained to the structure. While participants' backgrounds can impact their learning experiences, the purpose of designing an interview protocol focused on the FYE course was to encourage participants to respond to questions as it pertained to their FYE course. Background experiences did emerge during the interviews but those experiences were more related to participants' interest in the field versus their self-efficacy. Additionally, this study may provide first-year program designers additional ways to consider how course content can support self-efficacy development in students.

Lastly, there is a limitation of expanding the recruitment pool for this study. Initially, this study was to focus solely on the responses of sophomore electrical engineering majors. However, due to the need to change sites and the new site having a significantly smaller population of engineering students overall, the recruitment pool was expanded to include computer engineering majors as well as juniors and seniors. While I was unsure how this change would affect this study, the inclusion of upperclassmen provided rich responses regarding how the declared first-year engineering matriculation structure impacted self-efficacy development beyond the second-year courses. Given that the GE FYE matriculation structure had no impact on technical preparation for the ECE degree program and that most students were majoring in both electrical and computer engineering (whether as a double major or with one as a major and the other as a minor), this change did not adversely affect the study since data were already collected from the general first-year institution.

4.3.6 Results

The goal of this study was to explore the impact different FYE matriculation structures have on the development of self-efficacy in electrical and computer engineering students. In the second round of coding, excepts from interviews were examined more thoroughly in order to determine emergent codes from the data. Most of the codes from Lewis (2019b) were present in similar ways and thus are not detailed here. As identified in Table 4.3 emergent codes and their definitions were developed from the data representative of the respective category. The results will focus on 1) new emergent codes and 2) the DE/GE comparisons.

4.3.6.1 The Tasks of Self-Efficacy

Given that self-efficacy development is task-specific, it is important to note that the tasks in this study change depending on the context participants were describing. These tasks have been newly reported as foci of self-efficacy development, with the context being the dimension of self-efficacy development the participants were discussing. Students related various tasks to engineering because they took place in their FYE program. While participants were interviewed specifically regarding their course self-efficacy and their engineering self-efficacy, analysis of the data revealed that course self-efficacy and engineering self-efficacy intersected as students reported a positive engineering self-efficacy due to their positive course self-efficacy (which in this context is an engineering course). An example of this intersection was reported by two participants as:

> *I believe that the courses were definitely helpful to building me as an engineer, or building me as someone who could work as an engineer for an engineering company. That was the point of general engineering courses, it would also break down individual sections of the course. And they would tell you that 'if you were good at proficient at or if you enjoyed this session, perhaps you should try this major'. And one that I like the most happens to relate to computer and electrical engineering, which was circuit design, or these power electronics building, if the research you are conducting interested, you go try this course and next semester, so the that was what I gained from the courses. [GE07 - BS]*

I mean, this is… this will set me up to do whatever I want later on, you know, this, sort of, this computer engineering degree, this learning, this knowledge that I'm getting. It's not just learning about circuits. It's learning how to learn as well. And that will set me up for whatever I want to do. And that's, that's what I'm trying to figure out moreso now, where do I want to go after I graduate. Do I want to go to industry? So being in an internship this summer to try and figure that out, you know, but we'll see about that. Do I want to go into industry, do I want to go do research, do I want to do something completely different… But either way, computer engineering is something that will allow me those options and won't box me in [DE01 – TK]

The same is also true for those who reported lower self-efficacy in their engineering course:

I feel like I should be understanding everything I'm learning. But I don't. And that kinda worries me because like, in the future, I'm getting a job or something, you know, if you don't understand what's going on, you're gonna get fired. So I mean, right now, I can make mistakes. It's fine. But when I'm out in the real world get fired. It's just, it's gonna be harder. [DE02 – KD]

While half of the participants reported this interrelation of course and engineering self-efficacy (both positive and negative), more DE students reported this interrelation compared to GE students. Additionally, GE students discussed this interrelation as it pertains to being an engineering broadly whereas DE students discussed this interrelation specifically as it pertains to being an engineering in their discipline (i.e. an electrical or computer engineer).

4.3.6.2 Mastery Experiences

In this section, I discuss how students describe their development of self-efficacy through mastery experiences. Participants described one additional source (Lab-Related), two additional sources of evidence (teaching others and mastery/performance), and three new foci (foundation building, ethics, and non-transferable skills and experiences.

Source: Lab Related

For the code of "Lab Related," students described mastery development through their participation in lab related exercises. One student expressed this development as:

> *I think probably the labs were the most helpful. Um [long pause], Yeah, they, they sort of helped me figure out how I like, you know, how I visualized circuits and stuff and how I visualized making things. [DE01 - TK]*

Every single DE participant reported developing mastery through lab related experiences. In fact, it was one of the most discussed themes that emerged in mastery development. In contrast, one student from the GE matriculation structure discussed lab related experiences, and those experiences occurred in their in-major courses as opposed to their FYE course.

Evidence: Teaching Others

For the code of "Teaching Others," students described mastery development through the retention of course material most notably through the actions of being able to teach their peers. One student expressed this development as:

> *I can also see it as like it benefits me to, to help others like with like homework and other stuff because then it helps me study more, it gives me more, helps me to explain things or make sure I know exactly what I'm talking about. Like, I don't know exactly, like I can't help someone out I need to study more myself. [DE03 - GA]*

Several (~30%) participants in both matriculation structures reported their awareness of their mastery development through “Teaching Others”.

Evidence: Mastery vs. Performance

For the code of “Mastery vs. Performance,” students described mastery development, or the lack thereof, by defining their (or what their perception of their peers’) definition of success in their courses. These definitions were related to either 1) Grades/Performance or 2) Understanding/Mastery.

1) For grades/performance, students reported their mastery development through receiving high marks on an assignment or having at least a 3.0 GPA.

    I define success as just like, being able to like, score, well, in each course just like doing well academically as a student. [DE02 - KD]

    Students also reported performance goals as it pertains to getting an internship or job.

    Essentially during my freshman year success was basically just like getting A's in my classes and doing well in school, having extracurriculars, and hopefully getting like an internship before the end of the day before I graduate [DE04 - NP]

    Every participant reported that they believe their peers focus solely on grades as a measurement of mastery development.

    I think most people define it based off of tests grades scores GPA, um, Some I know this one guy who works really hard. He's always studying because he has like a below 3.0 and thinks the world is over. [GE04 - MB]

2) In contrast to the conversation around grades, some students reported their mastery development by understanding and/or valuing course related material regardless of the grade received.

> *I definitely registered what was going on and how to apply the skills that we learned, and um, in order to feel satisfied with what I learned, regardless of what grade I got. I mean, ultimately, I got satisfactory grades, but, I don't treat grades as a determining factor of whether success is uh, whether I succeeded in the class or not. [GE01 - ZZ]*

The theme of "Mastery vs. Performance" was the most common theme that emerged from this data. What is interesting about this theme is that every participant across both matriculation structures identified grades as a measurement of success while in their FYE course, but each of those participants' views shifted towards mastery when referencing their in-major courses.

> *there was a point where, like, I would consider my or I was, like, what I would call like an immature student, where I was like, focused on, like, passing, because it was just too hard and too much time, like spend. But I feel like, once I decided to, like, put the time in, like, take it seriously, and aim to master the material. I think that's when the benefits of my peers and my good professors, that's when all those things began to, like, spur me, like forward, but it wasn't until I changed my, my, my mode of thinking that all those things became a benefit to me. [DE06 – DM]*

Regardless of FYE matriculation structure, students define their mastery development as a function of grades or learning. However, after FYE, once students learned that course material builds upon itself, their mindsets shifted more towards understanding the concepts of the course.

Focus: Practical or Transferable Skills

For the code of “Practical or Transferable Skills,” students in this study described mastery development in three additional ways: 1) Foundation Building, 2) Ethics or 3) Non-Transferable Skills.

1) For the code of “Foundation Building,” students described mastery development in their FYE course through learning the basics of a subject and building their knowledge form those fundamental concepts. Participants’ self-efficacy was developed the most through their mastery experiences, which is supported by the fact that curriculum is usually designed to develop self-efficacy through mastery. One student expressed this development as:

    I would definitely say I think I actually think that to this day [DE FYE course] is one of the best classes that I had taken like in any Department or anything. And I think it's because of the like attitude, sort of, that the professor taught us towards approaching problems. And like thinking about things in a very sort of rational way and thinking about them systematically and breaking down a large problem into solvable steps and just going back to basics and starting from there. I think that like literally whenever I'm faced with sort of like a very convoluted. Task or like I have to debug something that's really complicated. I, I do, actually, like, go back and think, okay, like what would this professor tell me to do so. I think the mindset is like the single most important thing I have from [DE FYE course]. [DE05 - SP]

Notably, all of the DE participants reported their mastery development through the development of fundamental knowledge, whereas only three GE participants reported mastery development in this manner.

2) For the code of “Ethics,” students described the applicability of ethical considerations and practices learned in their FYE course.

> *ethics, definitely. That's probably the first time I’ve ever been introduced in ethics and engineering. And the ethical dilemmas we were presented in class, were very, very fascinating to think about and thus I’ve been a lot more conscious of how we use ethics in the world of engineering as I go through my classes. [GE01 – ZZ]*

Most of the participants who reported ethics as a salient skill were those from the GE matriculation structure. Only one DE student recalled ethics being taught in their FYE course and found it useful.

3) For the code of “Non-Transferable,” students reported experiences and/or concepts learned in their FYE course that was not relevant to their in-major course.

> *I don't have the highest opinion of the [GE FYE course] and I'll just say that to begin with, um, and to be honest I, I can't think of one thing that I learned in one of the courses that I'm currently using now [GE02 - ES]*

All GE participants except one reported course content being irrelevant and did not prepare them for their in-major courses. Only one DE participant reported course content not preparing them for their major, but attributes it to cramming a lot of material in at the surface level, which made it difficult to see future applicability of those concepts.

4.3.6.3 Vicarious Experiences

In this section, I discuss how students describe their development of self-efficacy through vicarious experiences. Students newly discussed their vicarious experiences through Academic and Professional Examples.

Academic and Professional Examples

For the code of "Academic and Professional Examples," students referenced instructors, graduate students, and employers as people worth emulating and inspiring them in their pursuit of their engineering degree. For example, a participant reported how influential their department chair is:

> *our department chair and he is the one of the nicest guys I've ever known. He's very successful very, very, very smart. And he's very caring for the students. I, I remember during our first year. The [DE FYE course] back in freshman year he came in one time to do like a quick Friday, just like a presentation on welcome to engineering This watch you'll learn stuff like that and he had a very personal story. And so just that like. Without going into details. Basically, he just said like he came in alone. He didn't have anybody, really. But he was still here working hard trying to get everything set for himself. And so, he told us that if you ever need anybody to talk to if you ever need help, or anything like that reach out to him and he'll always be there. And so, I've always wanted to be like him because he always does look out for everybody else. And at the same time, he is doing well for himself. [DE04 - NP].*

Academic and Professional examples was the most common way students newly reported vicarious experiences. Half of the total participants reported admiration of mentors and described these mentors as people they would like to be in the future.

4.3.6.4 Somatic and Emotional State Experiences

In this section, I discuss how students describe their development of self-efficacy through their somatic and emotional states. Students' somatic and emotional state were newly influenced by Negative Somatic Experiences.

Negative Somatic Experiences

For the code of "Negative Somatic Experiences," students reported being scared, nervous, upset, stressed, etc. in completing engineering tasks in their FYE and in-major courses, thus negatively impacting their self-efficacy. Several instances where participants described their negative experiences in their FYE courses are as follows:

> *I thought I was very stressed. Even though I got through all the material and the classes, and I felt like I understood the concepts properly, I felt like I wasted too much time on stuff that I shouldn't have be doing and should've been focusing on what I was doing to reduce stress levels. [GE02 - ES]*

> *I get to the test room. And I'm like, just stressed and looking at everyone type thing. And I usually, all, a lot of the weight is placed on the tests and that also puts more stress on them like I need to do so well, and usually like I just thought I just would rather like if it were based on concepts and application and understanding what you're doing and why you're doing it, rather than doing a perfect example over again all for some degree [GE04 – MB]*

> *like one of the classes like very hard. class was hard. Also, like, I have like dyslexia. So like, when I like read, like, programming language, I can get caught up, like in the words*

and the letters. Yeah, so I'll say it's hard. And like, sometimes I can, like, not comprehend everything in a very, like stressful environment. [DE06 – DM]

Reported by 70% of the participants, "Negative Somatic Experiences" became the most common way students' from both matriculation structures somatic experiences were impacted. It is important to note that there were instances where the instructional environment also influenced affected students negatively. The reason these experiences were not coded as "Negative Somatic Experiences is because "Instructional Environment" referenced negative emotions related to the course materials (e.g. harshness of grading, frequency or difficulty of assignments and test) and negative vibes introduced by the instructor; whereas "Negative Somatic Experiences" referenced anxiety, depression, stress, etc. as it relates to tasks or the major more broadly.

4.3.6.5 Addressing the Research Questions

The results show that overall, GE students develop self-efficacy in more robust ways than DE students. Table 4.4 summarizes the results of this study in the context of the research questions. Reporting of codes are presented as a gradient: frequent codes are shaded black, in frequent codes are shaded grey, and no discussion is shaded white. The purpose of this gradient is to demonstrate how, for example, both GE and DE students reported foundation building as a mastery experience, DE students reported it more frequently and thus is shaded black.

Table 4.4 – Summary of Study 3 Results

		GE (RQ1)	DE (RQ2)	Both (RQ3)
Mastery Experiences	Foundation Building			
	Guided Mastery			
	Teaching Others			
	Lab Related			
	Mastery vs. Performance			
	Negative or Failed Mastery Experiences			
	Communication Related			
	Ethics			
	External Course Related			
	Non-Transferable			
	Technical or Industry Related			
	Team Development			
Social Persuasions	Familial Influence			
	Instructors, Facilitators, Supervisors			
	Peers			
	Discouragement			
Vicarious Experiences	Academic and Professional Examples			
	Peer Examples			
Somatic and Emotional State Experiences	Instructional Environment			
	Negative Somatic Experiences			
	Course Related Enjoyment			
	Major or Career Related Enjoyment			

4.3.7 Discussion

4.3.7.1 The Tasks of Self-Efficacy

Participants in this study described course self-efficacy regarding skills learned in their FYE course and how this development influenced engineering self-efficacy in both positive and negative ways. This relation of tasks as reported by participants demonstrates the intersection of course self-efficacy and engineering self-efficacy when the course is in engineering. While skills such as teamwork is commonly associated as an engineering skill, other skills such as communication and ethics are not; yet, these were skills reported by GE students when reporting their course and engineering self-efficacy development. This finding adds to the existing literature regarding 1) how we actually define engineering and 2) the lines of course self-efficacy and field self-efficacy are blurred when the course is in the field. However, DE students reported this interrelation between course and engineering self-efficacy in terms transferable skills obtained in their FYE program.

In regard to how engineering is defined, due to the broad nature of the field there is no set definition of what it means to be an engineer. Bunhaver et al. (n.d.) attempts to create a definition of what it means to be an engineer in which participants in their study reported technical skills as engineering work and teamwork and communication skills as non-engineering work. While their findings are consistent with how DE students defined engineering skills (technical), it is a contrast to how GE students defined engineering skills (teamwork and communication).

Secondly, the lines of course self-efficacy and engineering self-efficacy are blurred in this context given that the course in this study is an engineering course. Bandura (1997, 2006) states that there are instances where self-efficacy development can co-vary or can be interrelated when different spheres of activities are governed by similar sub-skills. According to Bandura, in this context, engineering self-efficacy and course self-efficacy can be distinct spheres of activities. However, because the sub-skills in each of these spheres are very similar and not distinguished independently by participants, the relationship between these two spheres change as depicted in Figure 4.1.

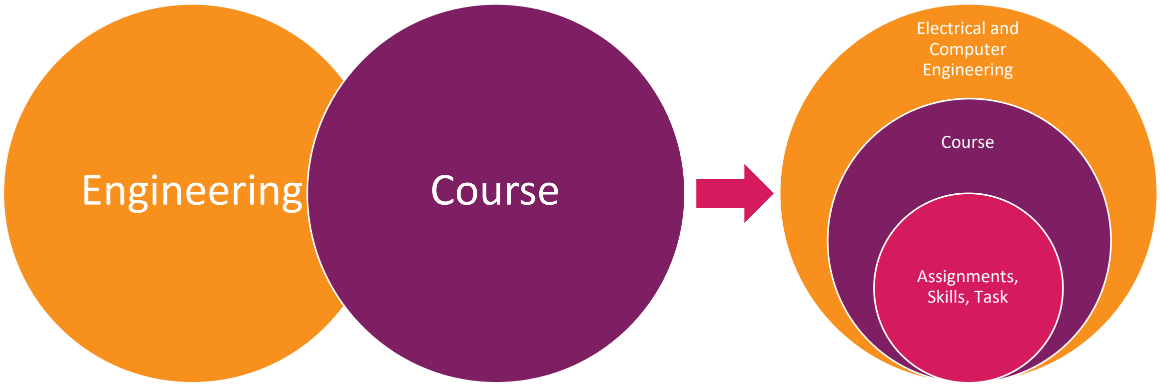

Figure 4.2 – The relationship between the tasks of self-efficacy

This relationship is even more apparent when comparing the interrelation of self-efficacy between GE and DE students. Generally, GE students reported less of an interrelation of their course and engineering self-efficacy in their FYE course. While they reported having a high course self-efficacy, they did so without connecting it to their engineering discipline. This may be due to the fact that many GE student did not find their FYE program applicable to their in-major courses. This finding supports Bandura's (1997, 2006) theory in that GE students did not find the sub-skills in their FYE program to be similar to the sub-skills in their in-major courses. Thus, for GE students who did report this interrelation did so in reference to being an engineer broadly as opposed to be a specific type of engineering (i.e. an electrical or computer engineer). In contrast, DE students reported more of an interrelation of their course and engineering self-efficacy in their FYE course specifically mentioning their increased self-efficacy of being an electrical or computer engineer based on having a high self-efficacy in their FYE course. In reference to Figure 4.1, GE students are more on the left side of the arrow whereas DE students are more on the right.

4.3.7.2 Research Question 1: GE FYE Matriculation Structure

Electrical and Computer Engineering students from a general first-year matriculation structure reported engineering self-efficacy development most commonly through concepts strongly related to engineering professional skills such as teamwork and ethics. Teaming is one of the factors that Hutchison-Green et al. (2006) reported FYE students listing as an impact to their self-efficacy. Given that Hutchison-Green et al.'s study was conducted in a GE matriculation structure, the theme of teamwork is consistent with existing literature especially within the GE context. However, the theme of ethics did not emerge in either of Hutchison-Green et al.'s studies, thus demonstrating how students believe ethics to be applicable to their development as an engineer.

While there were some who found the concepts of teamwork and ethics fascinating and looked forward to a course where they can practice those skillsets again, others found these concepts an unnecessary redundancy to concepts they had been exposed to prior to coming to college. This is similar to Hutchison-Green et al. (2008) whose participants also largely attributed their self-efficacy development to their performance in high school.

While participants had a strong sense of self-efficacy during their first-year, that self-efficacy did not translate directly to the second year for most participants. Each participant reported that their FYE matriculation structure provided little to no preparation for their pursuit of a degree in EE or CPE and most reported a decreased engineering self-efficacy by their fourth semester of college. This decrease was largely attributed to difficult subject material coupled with harsh learning environments created by professors of the courses. Despite an overall decrease in self-efficacy of the participants, at least half of the participants reported staying in

ECE due to their maintained interest in the subject. On the other hand, some participants reported staying in ECE due to it simply being “too late” to change their major without increasing time to graduation. The latter of these participants reported holding on to the opportunities available to one who receives an engineering degree as a reason to continue their pursuit. This reduction in self-efficacy goes beyond the scope of Hutchison-Green et al.’s studies which focused solely on self-efficacy development in the first-year, whereas this study explores how the first-year impacts self-efficacy in more advanced students.

While initially these themes seem similar, there are slight differences between how Hutchison-Green et al. (2008) reported course policies and how this study does (instructional environment). Hutchison-Green et al. reported course policies in reference to documents (syllabi, grading) administered by the instructor creating a negative non-verbal social persuasion. However, Hutchison-Green et al. does report students’ responses to their learning environment as a theme, however as Hutchison-Green et al. stated, those experiences could have also been coded as mastery, vicarious, or social persuasion experiences had they not caused frustration for the participants. This study, on the other hand, reports grading and instructors’ attitudes as an impact to students’ somatic and emotional state. Students in this study specifically reference harsh grading, high volume of coursework, and friendliness (or lack thereof) of instructors of the course as impacts to their somatic and emotional state.

4.3.7.3 Research Question 2: DE FYE Matriculation Structure

Electrical and Computer Engineering students from a declared first-year matriculation structure reported engineering self-efficacy development most commonly through foundation building and lab related experiences. academic concepts strongly related to engineering professional skills such as teamwork and ethics. Many participants reported their self-efficacy development from their FYE matriculation structure included preparation for circuits courses and seminar speakers that discussed various career pathways for someone with an ECE degree. Most participants recalled specific lab assignments as beneficial to their learning in their first-year and spoke very strongly about the contrast in their self-efficacy and performance in classes with an associated lab versus those without, where participants had higher self-efficacy in classes with labs. Additionally, participants were generally able to recall how specific concepts from their FYE prepared them for courses taken later in the major. Foundation building slightly aligns with Hutchison-Green et al.'s (2008) reporting of successful mastery experiences. While Hutchison-Green et al. reports successful mastery experiences as it pertains to technical and professional skills, foundation building is based on successfully mastering the building block concepts taught in the DE FYE matriculation structure. These concepts may include technical and professional skills but did not emerge in this particular code.

Most participants reported having strong vicarious experiences supporting their self-efficacy. These experiences manifested through the character of faculty members who generally created a learning environment where participants felt comfortable learning and asking questions, as well as being a role-model participants were hopeful to emulate in the future. One the other hand, one participant persisted despite having negative experience during their time in their major. However, while this participant faced experiences in their major that could have had a negative impact on their self-efficacy, experiences external to their degree program supported their self-efficacy through mastery development, social persuasions, and mentorship.

4.3.7.4 Research Question 3: Similarities and Differences in Self-Efficacy Development

Almost all of the participants from the GE matriculation structure reported having formal exposure to engineering prior to college (through summer camps, high school programs, etc.)

whereas only a few participants from the DE matriculation structure reported having any of those experiences. However, these pre-college experiences seemed to have the most impact on self-efficacy during the first-year; by the second year, students regardless of matriculation structure, experience a decrease in self-efficacy in one form or another. Due the participants of this study being advanced students, this is consistent with Hutchison-Green et al.'s 2007 doctoral findings that advance students were able to recognize their mastery experiences as they occurred (Hutchison et al., 2006).

Given the different academic years of participants, particularly DE students, it is important to note that recollection of the FYE program was not diminished due being further away from the semester in which they took the course. However, more advanced DE students reported in more detail how their FYE program impacted their self-efficacy development both during and beyond their first year, specifically in terms of their in-major courses. This trend is consistent with existing literature that states older students are more likely to not only recall specific tasks and course content from their first-year, but also situate those experiences in the broader picture of their major (Knott & Matusovich, 2012). For GE students, who were all in their second year, the ability to situate their FYE experiences in the broader picture of their major seemed more difficult. This may possibly be due to the design of the GE matriculation structure and lack of transferrable experiences from the first-year to the second year in-major courses. Perhaps, as Knott and Matusovich suggested, with time and more experiences, GE students may be able to contextualize their FYE learning experiences similarly to the older DE students.

Additionally, most of the participants from the GE matriculation structure are not first-generation college students (and some were not first-generation engineers) whereas about half of the students from the DE matriculation structure are first-generation college students. Interestingly, despite not having exposure prior to college and possibly being the first person in their family to receive a college degree, students from the DE matriculation structure had a more optimistic view regarding their current success and progress towards getting an ECE degree whereas participants from the GE matriculation structure have a less optimistic view regarding success thus far and progress in their degree program. This optimism is based on the low number of negative mastery and somatic experiences reported by DE students relative to the GE students. This was also observed by the enthusiasm regarding DE participants' responses to their ability to get a degree in their major during the interview.

4.3.7.5 Overall Comparison to Hutchison-Green et al.

Hutchison-Green et al. conducted both a quantitative (2006) and qualitative (2008) study exploring self-efficacy development in GE FYE students. These studies served as a foundation to this study which explores self-efficacy development in students from both a GE and DE FYE matriculation structure within electrical and computer engineering. The results of this study show that aside from the vicarious experience of comparison by speed reported by Hutchison-Green et al. (2008), participants in this study developed self-efficacy similarly to the participants in their study. Table 4.5 is a matrix that summarizes similarities between the results reported by Hutchison-Green et al.'s studies and this study, with their study being represented by columns and this study being represented by rows. Aspects that are similar between this study and Hutchison-Green et al.'s are denoted by a "X". The last row and column of the table represents a tally of similarities for the respective aspect (e.g., "Foundation Building" from this study is similar to four aspects of Hutchison-Green et al.'s study and "Drive and Motivation" from Hutchison-Green et al.'s study is similar to five aspects of this study).

Table 4.5 – Codebook Comparison of Hutchison-Green et al. and Study 3

		Teaming	Understanding/	Drive and motivation	Computing Abilities	Help	Working Assignments	Problem-solving abilities	Enjoyment, interest, and satisfaction	Technical skills	Professional Skills	Comparison by speed	Comparison by contribution to team	Comparison by amount of mastery relative to peers	Comparison by grades of peers	Verbal Persuasions	Non-Verbal Persuasions	Course Policies	Frustration with policies	Satisfaction from success	Character traits	**Total Discussion of Codes**
Mastery Experiences	Foundation Building		X		X		X	X														4
	Guided Mastery					X																1
	Information Retention		X				X	X														3
	Lab Related		X							X												2
	Mastery vs. Performance		X	X			X	X						X	X					X		7
	Negative or Failed Mastery Experiences						X															1
	Communication Related										X											1
	Ethics										X											1
	External Course Related				X						X											2
	Non-Transferable										X											1
	Technical or Industry Related									X												1
	Team Development	X									X		X									3
Social Persuasions	Familial Influence			X												X						2
	Instructors, Facilitators, Supervisors															X						1
	Peers															X						1
	Discouragement															X	X					2
Vicarious Experiences	Academic and Professional Examples			X																		1
	Peer Examples			X									X	X	X							4
Somatic and Emotional State Experiences	Instructional Environment																X	X	X			3
	Negative Somatic Experiences															X						1
	Course Related Enjoyment								X											X		2
	Major or Career Related Enjoyment			X					X											X		3
Total Discussion of Codes		**1**	**4**	**5**	**2**	**1**	**4**	**3**	**2**	**2**	**5**	**0**	**2**	**2**	**2**	**5**	**2**	**1**	**1**	**3**	**0**	

4.3.7.6 Bandura's Self-Efficacy Development

Mastery Experiences

Participants in this study described one additional source of mastery and that was through performing laboratory tasks. DE students reported more lab related sources describing the experience as the ability to translate FYE lecture material to hands-on applications. This is a contrast to GE students who reported mastery sources with regard to team development. Many DE and GE FYE matriculation structures attempt to integrate mastery through teamwork skills (Ambrose & Amon, 1997; Morgan & Bolton, 1998; Pendergrass et al., 1999). However, lab related sources are a potential new source for mastery development given the limited exploration of self-efficacy in a DE context.

Additional evidence of mastery reported by students were through understanding (mastery approach), grades (performance approach) (Hulleman, Durik, Schweigert, & Harackiewicz, 2008) and teaching others. Both GE and DE students reported this evidence as the ability to help peers understand course content material. However, DE students reported this evidence more as understanding material taught in their FYE class, whereas GE students reported this evidence more in regard to high marks received on assignments.

Participants in this study described three additional focuses of mastery with regard to foundation building, ethics, and non-transferable FYE course material. DE students reported this focus largely as the foundational concepts taught in their FYE program and how those concepts were applicable to their in-major courses. However, GE students described this focus largely as non-transferable beyond their FYE program and with no immediate applicability in their in-major courses. On the other hand, they did understand the practicality of some FYE course topics such as ethics.

Vicarious Experiences

Participants in this study described one additional source of vicarious experiences and that was from academic and professionals in the field. DE students described this source with regard to the seminars conducted in their FYE course which included presentations from current faculty and local alumni. A previous study that redesigned a GE FYE by integrating seminars, reported an increase or reinforcement in students' confidence regarding major choice (McNeil & Thompson, 2016). Both GE and DE students described sources with regard to peer and familial examples, however, instances of these sources took place in the first year, but not directly related to the FYE course.

Somatic and Emotional State

Participants in this study described one additional evidence of somatic and emotional experiences and that was from negative somatic experiences. While both GE an DE students discussed this as evidence of their somatic and emotional state, GE students reported more negative experiences with regard to their FYE program, whereas DE students reported more positive ones. Additionally, GE students described this evidence with regard to their mental health which was sometimes negatively impacted by their FYE program. Consistent with existing literature, students' negative somatic and emotional state, particularly as a result of the course or task, typically leads lower self-efficacy (Bandura, 1997).

4.3.8 Implications

There are several implications the results of this study may have on the engineering education community which includes broadening a conversation typically dominated by quantitative studies, potentially uncovering better practices for first-year engineering matriculation structures and understanding how impactful the matriculation structure of the first-year can be on a student's major choice. First, as discussed in section 4.2, there are various studies that use quantitative methods to explore self-efficacy but very few that use qualitative methods. Additionally, there have been few, if any studies that focus solely on the development of self-efficacy in one major, as explored in study 1. Through the use of qualitative methods to explore this phenomenon, the results of study 2 and 3 have provided a deeper insight into the development of self-efficacy of first-year engineering students. Second, given that very few have explored self-efficacy development in first-year engineering matriculation structures (GE vs DE), study 3 begins an entirely new discussion regarding first-year engineering matriculation structure and may encourage engineering departments and colleges to seek motivational constructs for support in future program changes. While the results of this study indicate that FYE structure has little impact on how self-efficacy is developed in electrical engineering students, FYE program developers can still refer to Table 4.3 as a guide to positively influence self-efficacy in their students.

4.4 Summary

As previously discussed this manuscript is a qualitative case study was conducted to explore how first-year engineering matriculation structures (GE vs. DE) impact self-efficacy in electrical and computer engineering students. Results of this study show that there are few differences between how GE and DE matriculation structures impact self-efficacy development. As outlined in Table 4.3, each of Bandura's four sources of self-efficacy development are influenced in various nuanced ways (e.g., mastery: sources, evidence, focus; social persuasion: type, sources, etc.).

The findings of this study show that mastery experiences continue to be the most common way in which self-efficacy is developed, followed by somatic and emotional experiences. Specifically, reports of self-efficacy development by GE students in their FYE program was largely attributed to the mastery of engineering professionalism skills, and to negative somatic experiences. DE students largely attributed their self-efficacy development in their FYE program to lab related assignments and enjoyment.

Moving forward, it is important for program developers to consider how readily applicable learning objectives are for students pursuing engineering. While students find value in learning broad concepts, this study indicates that students respond positively when exposed to their major early. In addition to exposing students to specific major concepts in the first-year, it is just as necessary to expose them to engineering professionalism concepts and engineering careers to assist them in identifying the type of engineer they would like to be. Additionally, while toxic learning environments have not deterred participants in this study from pursuing engineering, some of the experiences these participants have had should encourage a major cultural shift to positively improve the instructional environment in electrical and computer engineering.

Chapter 5: Conclusion

5.1 Introduction

The goal of this dissertation was to answer the overarching question of how first-year engineering experiences shape the self-efficacy of engineering students and how those patterns differ between DE and GE matriculation structures. In order to address this question, I approached this dissertation using three studies. The first study is a quantitative analysis of secondary data exploring the differences in expectancy and persistence scores for first-year GE and quasi-DE students who stayed in electrical engineering, left electrical engineering, or switched into electrical engineering. The second study is a qualitative secondary analysis to explore how self-efficacy is developed in students from a DE first-year matriculation structure, a contrast to prior studies that explore self-efficacy in a GE first-year matriculation structure or in engineering broadly. The third study is a qualitative case study to explore how different first-year engineering matriculation structures (GE vs. DE) impact self-efficacy in electrical and computer engineering students. In this section I summarize for each of the studies, discuss implications of this research for practice and research, present ideas for future work, and reflect on my experience in conducting this research.

5.1.1 Manuscript 1

The purpose of this manuscript was to conduct an exploratory quantitative data analysis in order to answer the research question: *How do GE and DE first-year matriculation structures affect expectancy and major-choice outcome variables for students who enter college intending to major in electrical engineering?* Data used in this analysis included responses to a survey administered to first-year engineering students enrolled in a GE matriculation structure between from Fall semester entry years 2013 – 2017 and listed their intended major as electrical engineering. Data were parsed into five different groups: 1) DE Persisters; 2) DE Leavers (first-year students enrolled in the 2013-2014 academic year); 3) GE Persisters; 4) GE Leavers; and 5) GE Switchers (first-year students enrolled in the 2014-2017 academic years). With the results, I partially rejected the null hypothesis by demonstrating statistical ($p < .05$) and practical differences (Cohen's d) for the persistence variable in the spring semester for GE vs DE Persisters and GE vs DE Leavers. Similar to the findings reported by Orr et al. (2012), there is no difference in persistence and expectancy scores of GE and quasi-DE students in the fall semester. The small differences in the persistence score in the spring semester indicated that the removal of the spring semester DE required FYE course impacted DE Leavers' persistence, as their score was higher than GE Leavers. From this, I hypothesize that by the end of the first year, DE Leavers knew they still wanted to pursue engineering but did not want to do so in electrical and computer engineering. However, the removal of the spring semester DE required FYE course did positively impact GE Persisters' persistence score in comparison to the DE Persisters. The reason for this may be that by removing the DE required FYE course, GE Persisters were allowed additional time to make an informed decision about their choice of major which increases the likelihood of those students persisting in their first choice major, which in this case, is electrical engineering (Orr et al., 2012).

A limitation to this study includes the fact that this data is captured before students are accepted into their engineering discipline and thus Leavers (Groups 2 and 4) are simply those who "left" electrical and computer engineering but possibly not left the college of engineering entirely. Additionally, due to the period in which this data is captured, there is no way to determine if students who persisted in electrical engineering actually matriculated into the major.

With that said, data from the 2017-2018 academic year were used to recruit participants for study 3 which qualitatively explored how self-efficacy is developed in electrical and computer engineering students across FYE matriculation structures (GE vs. DE).

5.1.2 Manuscript 2

As previously discussed, this manuscript is a qualitative secondary data analysis to explore how self-efficacy is developed in students from a declared first-year engineering matriculation structure. This study was conducted to add to the results of the study conducted by Hutchison-Green et al. (2006, 2008) who explored the same phenomenon but in the context of a general first-year engineering matriculation structure. Data were coded initially using Bandura's theory of self-efficacy and pattern level coding was conducted to report themes that emerged from responses. Results of this study demonstrate that students in the DE matriculation structure studied developed self-efficacy in much the same manner as GE students do as reported by Hutchison et al. (2006). Ways in which DE students of this study develop self-efficacy similarly to the GE students in Hutchison et al.'s (2006) study include team development, figuring it out, vicarious familial examples, interest, practical or transferable experiences, guided mastery, and enjoyment. The only difference between these two studies is that Hutchison et al. reported grades as an emergent factor from students whereas participants in this study did not mention grades.

Similarities of aspects in comparison to Hutchison-Green et al.'s qualitative study (2008) included negative or failed mastery experiences, team development, practical or transferable experiences, constructive support and criticism, discouragement, and enjoyment. Differences between these two studies are that students in Hutchison-Green et al.'s study reported vicarious comparisons to peers through speed of task completion, contribution to team work, level of mastery, and grades; social persuasions through non-verbal persuasions and course policies; and somatic experiences through frustrations with course policies, whereas in this study, participants did not report any of those aspects impacting their self-efficacy. Reasons for this may be due to the fact that the interview protocol used for the original study was designed using expectancy-value as the theoretical framework as opposed to self-efficacy, and thus did not ask questions in great detail regarding success in courses, problem-solving efficacy, and beliefs their FYE course, which is a limitation of this study. Another reason for these differences may be attributed to the pedagogy in each course, particularly regarding the PBL practices implemented in the DE course which focused on solving open ended problems and students generally did not know where they stood regarding grades to report comparisons in that aspect. While this study was fruitful in exploring self-efficacy development in DE students, additional work to explore self-efficacy development across types of FYE matriculation structures (DE vs. GE) and within the same engineering major may provide an understanding of engineering self-efficacy within the context of a discipline and add to the discussion around the relationship between motivation and retention. With that said, this study served as a pilot to study 3 which explored self-efficacy development in students from both DE and GE matriculation structures within one engineering department.

5.1.3 Manuscript 3

As previously discussed this manuscript is a qualitative case study was conducted to explore how first-year engineering matriculation structures (GE vs. DE) impact self-efficacy in electrical and computer engineering students. GE students largely attribute the impact their FYE matriculation structure had on their self-efficacy development to the learning of engineering professionalism skills and to negative somatic experiences. DE students largely attribute their self-efficacy development from their FYE program to foundation building and lab related assignments. While teamwork and ethics were big themes for GE students in their first-year, it was hardly reported as relevant in the second year whereas students from the DE program reported teamwork as a major theme in their second year. Regarding somatic and emotional state, students from the GE program reported more negative experiences, particularly surrounding course climate as facilitated by the instructor, whereas students from the DE program reported more positive experiences. The results of this study are similar to those reported in both of Hutchison-Green et al.'s studies (2006, 2008), so much so that the only differences in self-efficacy development in first-year students between this study and theirs are those attributed to working assignments, problem-solving abilities, comparison by speed, contribution to team, non-verbal persuasions, and character traits. These differences may be attributed to difference in pedagogies in the programs in question as well as background differences of participants.

5.1.4 Synthesis of Manuscripts

This dissertation was designed as a quasi-sequential explanatory mixed methods project, where the quantitative analysis from study 1 provided higher level insight into whether the FYE matriculation structure impacts self-efficacy in first-year ECE students. Subsequently, the two qualitative studies help us understand how that impact might be occurring and whether it differs across the two major structures. In study 2, the impact was explored by looking closely at a single DE matriculation structure to learn how self-efficacy develops in that context, contrasting those findings to prior work in a GE matriculation structure. The third study then combines the previous studies to look specifically at self-efficacy development in ECE students in their first-year. Figure 5.1 shows how this project follows the sequential mixed methods design (Creswell, 2009a). Note that this project is a quasi-sequential mixed methods approach because of the secondary analyses conducted on the data.

Figure 5.1 – Quasi-sequential explanatory mixed methods where the arrows indicates a sequential form of data analysis, with one building on the other (Creswell, 2009a)

Based on this design, study 1 addressed the question of whether there a difference between how FYE matriculation structures impact self-efficacy development, to which the answer was no, there are no differences in how the FYE structure impacts self-efficacy development in ECE students. From that answer, studies 2 and 3 addresses what kinds of differences or similarities are present in how the FYE structure impacts self-efficacy development, as detailed in the next.

5.1.4.1 Competency Beliefs Measured Qualitatively

As previously mentioned, this dissertation uses self-efficacy as the main theoretical framework. However, in study 1 and study 2, expectancy was the motivational construct used to explore the impact FYE matriculation structure has on students' self-efficacy. While self-efficacy and expectancy are individual motivational constructs, they are measured very similarly empirically (Eccles & Wigfield, 2002; Schunk & Pajares, 2005). Both expectancy beliefs and self-efficacy "stress the role of personal expectations as a cognitive motivator" (Schunk & Pajares, 2005, p. 90). However, expectancy is the judgement of an outcome an individual expects to receive when completing a task whereas self-efficacy is the belief or confidence in one's ability to do a task. This subtle, yet important nuance is an example of motivational theorists' inability to agree on how to conceptualize perceived competence, thus several similar constructs, such as self-efficacy and expectancy, exist in the literature (Schunk & Pajares, 2005). This inability to distinguish between these two constructs became apparent in studies 2 and 3. Although the original interview protocol used in study 2 was develop to measure expectancy-value, data were coded for self-efficacy and produced a codebook centered around the four sources of self-efficacy development and associated tasks. This codebook was then expanded in study 3 which used an interview protocol designed specifically to measure self-efficacy. While there were some differences in the results between DE2 students and DE3 students, due to the nature of these studies it is difficult to determine if those differences were due to the interview protocols measuring different constructs, the program, or the engineering major of the students.

5.1.4.2 Bandura's Self-Efficacy Development Across Studies

The results of this study show that the impact FYE matriculation structure has on self-efficacy development is multifaceted. Table 5.1 provides an overview of the nuanced ways in which self-efficacy is developed in DE and GE students. Given that the results from study 3 was built upon study 2, only the new aspects that emerged are listed in the study 3 column (note that all aspects in study 2 are also in study 3 except those denoted by "^").

Table 5.1 – Bandura’s Self-Efficacy Development Across Studies

		Hutchison-Green et al. (2006)	Hutchison-Green et al. (2008)	Study 2	Study 3
Mastery Experiences	Sources	Teaming		Guided Mastery	Lab Related
		Help		Team Development	
				Figuring It Out^	
	Evidence	Grades		Negative or Failed Mastery Experiences	Mastery vs. Performance
					Information Retention
	Focus	Computing	Technical Skills	Practical or Transferable Experiences	Foundation Building
		Working assignments	Professional Skills	Communication Related	Ethics
		Problem-solving abilities		External Course Related	Non-Transferable
				Research Related^	
				Technical or Industry Related	
Social Persuasions	Sources		Course Policies	Familial Influence	
				Instructors, Facilitators, Supervisors	
				Peers	
	Type		Verbal Persuasions	Constructive Support and Criticism	
			Non-Verbal	Discouragement	
	Focus		Frustration with policies		
Vicarious Experiences	Sources			Peer Examples	Academic and Professional Examples
	Focus		Comparison by speed		
			Comparison by contribution to team		
			Comparison by amount of mastery relative to peers		
			Comparison by grades of peers		
Somatic and Emotional State Experiences	Source				Instructional Environment
	Evidence	Enjoyment, interest, and satisfaction	Satisfaction from success	Comfort^	Negative Somatic Experiences
				Fear or Uneasiness^	
	Focus		Frustration with policies	Course Related Enjoyment	
				Major or Career Related Enjoyment	

(^ indicates an aspect that emerged from study 2 but not in study 3)

For the purpose of the following discussion, DE students from study 2 will be referred to as DE2 and DE students from study 3 will be referred to as DE3. GE students from Hutchison-Green et al.'s studies (2006, 2008) will be referred to as GE2 and GE students from study 3 will be referred to as GE3.

The Tasks of Self-Efficacy

In study 2, a finding that emerged was how DE2 students related their course self-efficacy to their engineering self-efficacy. Bandura (1997, 2006) states that there are instances where self-efficacy development can co-vary or can be interrelated when different spheres of activities are governed by similar sub-skills. According to Bandura, in this context, engineering self-efficacy and course self-efficacy can be distinct spheres of activities. However, because the sub-skills in each of these spheres are very similar and not distinguished independently by participants, the relationship between these two spheres change as depicted in Figure 5.2.

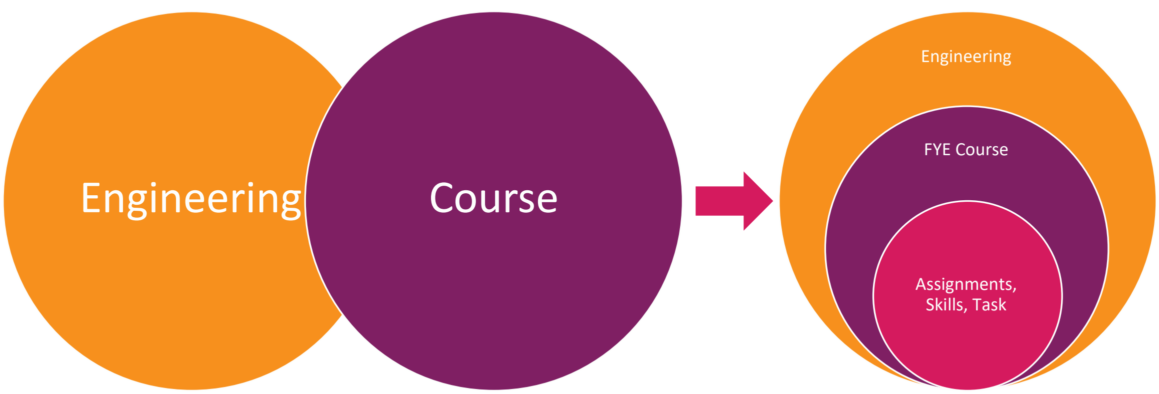

Figure 5.2 – The relationship between the tasks of self-efficacy

This finding also emerged in study 3 with an added nuance; GE3 students related their FYE course self-efficacy to their engineering self-efficacy broadly whereas DE3 students related their FYE course self-efficacy to their specific engineering major. This finding is a shift from how it is discussed in study 2, particularly related to DE students. The DE2 students related their course self-efficacy to their engineering self-efficacy generally. Given that study 2 was a secondary data analysis, it is difficult to determine if the difference in how the DE2 and DE3 students make this relationship is due to the different interview protocols used, the nature of the two courses, or the specific major of each study. Thus, with these findings, Figure 5.3 presents a general understanding of how students can relate course self-efficacy to engineering self-efficacy with the spheres on the left representing the relationship of the course to engineering broadly and the spheres on the right representing the relationship of the course to the specific engineering major with a total interrelationship.

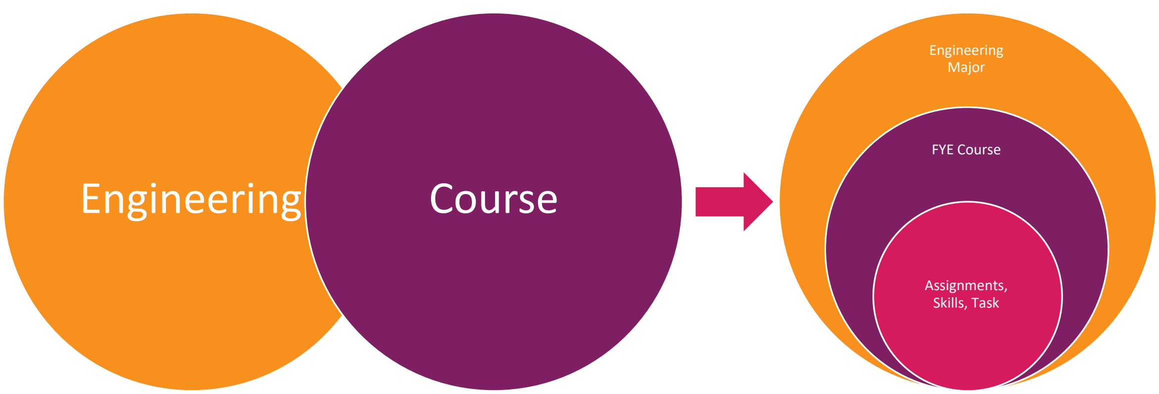

Figure 5.3 – The Interrelationship of Course and Engineering Self-Efficacy

Mastery Experiences

While sources of mastery experiences were reported similarly between the DE2, GE2, and GE3 students, DE3 students reported an additional source of their mastery development. Outlined in Table 5.1, GE2, DE2, and GE3 students reported sources of mastery in their FYE program with regard to guided mastery (with instructor assistance), and with through teamwork. DE2 students were the only ones to report figuring it out (doing it on their own) as a source of mastery development. DE3 students were the only ones to report participating in a lab as a mastery source. It is not surprising that DE3 students reported lab related experiences given that lab work are an effective form of incorporating hands-on projects in to a class (Prince & Felder, 2006; Wong et al., 2011). This is a contrast to how the DE2 students describe their sources of mastery specifically the figuring it out. This source may be due to nature of the PBL pedagogical approach (Matusovich et al., 2011) used in the FYE course in study 2 which focus on students working in teams to solve ill-structured problem, a pedagogical approach that is different in the DE3 FYE course which focuses on orienting students within the major (Virginia Commonwealth University, n.d.).

The evidence in which students recognized their mastery development were similar across all the studies. Aside from the DE2 students, participants across study 3 and Hutchison-Green et al.'s studies recognized their mastery development through grades. DE2 students reported a different evidence of mastery as negative or failed mastery experiences. DE3 and GE3 reported evidence of their mastery two-fold: the first via grades as previously mentioned, and the second via understanding the material. This understanding was reported in terms of shifting from a performance approach to their FYE courses to a mastery (Hulleman et al., 2008) , as well as reported that the ability to help their peers with FYE course content was evidence that they made the shift to a mastery approach mindset regarding their FYE course. Reasons why this shift was only reported in study 3 may be a result of: 1) GE1 students were interviewed in their first-year whereas GE3 and DE3 students were further along in the program indicating that maturity may play a role in how students discuss evidence; 2) DE2 students FYE course included several week long projects which did not provide students with immediate feedback regarding performance; and 3) study 2 was originally designed to explore the impact of project-based learning on the motivation of first-year students as opposed to exploring FYE structure on self-efficacy development and thus the interview protocol used in study 2 does not ask questions extensively relating to performance.

The focus on which mastery experiences were described were similar across studies. While GE2 students reported this focus broadly through technical and professional skills, DE2, GE2, and DE3 also reported similar focuses but more specifically in terms of practicality of those skills (such as communication skills, usefulness in other courses beyond the FYE, and industry related skills). An even more nuanced way in which DE2 students reported this focus with regard to research related skills; GE3 students reported this focus with regard to ethics; and DE3 students reported this focus with regard to foundation building. The main contrast in which this focus was discussed were from GE3 students who reported little to no transferability of concepts taught in their FYE course to other courses. Jones et al.'s MUSIC model of Academic Motivation, includes both usefulness and self-efficacy as a means to describe students' motivation and subsequent persistence. Thus, the lack of transferability reported by GE3 students could have potentially negative impacts on self-efficacy, especially if other factors in the MUSIC model are not positive. One reason for this emergent difference, particularly in comparison to the GE2 students, may be because the protocol for study 3 probes specifically about whether concepts learned in the FYE course prepared students for their major, whereas the protocol used in study 2 probes only with regard to the FYE while students are still in their first year.

As stated previously, due to the PBL pedagogical choice for the DE2 FYE course, the difference in teaching methods employed adds a level of difficultly in making a true comparison between the two DE courses given that the mastery experiences in both instances are related to how the FYE course is structured.

Social Persuasions

DE2, DE3, and GE3 students reported family, instructors, and peers as sources of self-efficacy development. Sources of social persuasions from peers with regard to the FYE program were generally positive which may also be related to developing a sense of belonging, a construct that has emerged in previous studies exploring engineering self-efficacy (Carrico & Tendhar, 2012; Jones et al., 2014; Marra et al., 2012; Virgüez, 2017). However, DE2 students reported their FYE instructors as a source of social persuasions relative to their FYE course, whereas study GE3 and DE3 students reported instructors and family as a source of social persuasions broadly during their first-year rather than directly related their FYE course. This is a contrast to how GE2 students described sources of social persuasions which were reported as course policies.

The types of social persuasions reported by students across all studies and FYE structures were communicated verbally and were either constructive support or discouragement. DE2 students reported more non-verbal sources of social persuasions. Students across all studies and FYE structures reported positive persuasions that positively impacted their self-efficacy development. On the other hand, DE2, GE3, and DE3 students reported negative persuasions in which had an inverse effect on their self-efficacy development. Existing literature that defines self-efficacy compares positive persuasions to increased self-efficacy and negative persuasions to decreased self-efficacy. However, study 2 and study 3 demonstrates that an inverse relationship can occur where negative persuasions inversely increase self-efficacy with participants reporting a “prove you wrong” mantra (Eccles & Wigfield, 2002).

The focus of which social persuasions was on were only reported by GE2 students with regard to frustration with course policies. Students reported this frustration as non-verbal negative persuasions in which they perceived their FYE course to be a “weed-out” course (Geisinger et al., 2013).

Vicarious Experiences

Sources of vicarious experiences were reported by students across all studies and FYE structures with regard to peer examples. DE2 students described peer examples positively references instances where upperclassmen and alumni visited their FYE course to present about where they are currently. DE3 and GE3 reported also academic and professional examples as an additional source of vicarious experiences. Academic and professional sources were introduced to DE3 students formally through their FYE course seminar, whereas GE3 students were unknowingly assigned to an instructor (instructors for GE3 FYE course are not revealed until the start of the semester), or were introduced to a professional in the field during their first-year, but not through their FYE course. The GE3 and DE3 participants generally reported these sources has having positive influences on their self-efficacy.

GE2, GE3, and DE3 reported the focus of their vicarious experiences as performance comparison to their peers. As noted previously, this is a contrast to how DE2 students described vicarious experiences with regard to peer examples. GE2, GE3, and DE3 all report this performance comparison as using their peers as benchmarks for their own understanding of the material and success in their FYE course. The only difference reported is that GE2 students also describe this focus with regard to speed (how quickly they finish a task compared to peers) and by contribution to team.

Somatic and Emotional State

Sources of somatic and emotional state were reported by students across all studies and FYE structures with regard to the instructional environment. The instructional environment was a broad theme that encapsulated both positive and negative experiences for students across all studies and FYE structures.

Evidence of somatic and emotional state experiences varied across FYE structures. GE2 reported this evidence with regard to enjoyment, interest, and satisfaction. GE2 students described this evidence of being excited, feeling good, or having an increased interest in engineering after successfully completing their FYE course related tasks. DE2 students reported their evidence in two ways: comfort and fear or uneasiness. DE2 students describe comfort as the ability to ask for assistances from instructors or being able to rely on their team for support. However, fear or uneasiness (which was also reported more broadly by GE3 students), were described as instances where they were scared or nervous to do oral presentations in their FYE course. GE3 students reported negative somatic experiences as a source of self-efficacy development with regard to their FYE program, particularly as it related to poor attitudes from instructors and an overall dislike for the course.

The focus of which somatic and emotional state experiences impacted self-efficacy development varied across studies. While GE2 students reported their focus through their frustration with course policies, DE2 and DE3 students reported this focus with regard to their enjoyment of their FYE program, major, and overall happiness being in their major. This discussion of focus for the DE students may be due to their ability to connect with their major earlier than their GE counterparts (Orr et al., 2013; D. Verdin & Godwin, 2018). GE3 students reported much fewer instances of enjoyment with regard to their FYE program or to their major and most students referenced positive outcomes related to getting their degree as a coping mechanism to their negative experiences.

5.2 Implications

Self-efficacy has been widely used to explore motivation in engineering students. However, this dissertation explores this construct within the bounds of first-year engineering matriculation structures (DE vs. GE) and, studies 2 and 3 within the field of electrical and computer engineering. Implications of this dissertation with respect to these bounds are two-fold with respect to practice and research. In regards to practice, it is important to develop programming that allows students to learn about their major as early as possible and create positive learning spaces for students to thrive. With regards to research, exploring somatic and emotional state experiences of students can provide fruitful information in addressing the culture of engineering broadly. Jones et al. (2010, 2014) does discuss responses to course climate in terms of caring but solely in relation to the instructor of the course as opposed to a broader scope which would include person struggles and stress brought on by a collection of courses and activities.

From this study, we can conclude that there are some similarities in how the FYE matriculation structure impacts self-efficacy development in DE and GE students. This qualitative analysis of a DE FYE matriculation structure adds to existing literature of previous studies that have explored self-efficacy more broadly in engineering (e.g., Lent et al. (2005), Patrick, Care, & Ainley (2011), Salzman, Callahan, Hunt, Sevier, & Moll (2015), Tendhar (2015), Virgüez (2017), Mamaril, Usher, Li, Economy, & Kennedy (2016)), confirming that mastery experiences is still a common form of self-efficacy development in FYE students. Additionally, this study contributes to the current understanding of self-efficacy in DE students as a contrast to a GE matriculation structure (e.g., Hutchison-Green et al.).

5.2.1 Implications for Practice

The results of this study may have on the engineering education community includes broadening a conversation typically dominated by quantitative studies, potentially uncovering better practices for first-year engineering matriculation structures and understanding how impactful the matriculation structure of the first-year can be on a student's major choice. Through the use of qualitative methods to explore this phenomenon, the results of these studies have provided more insight into the development of self-efficacy of first-year engineering students. An example of this insight comes from mastery experiences, which is still the most common way in which students report self-efficacy development. But, in addition to knowing that mastery experience is a common form of self-efficacy development, the results of this study show that there are three sources of this development (they figure it out independently, they get assistance, and learn through teamwork), students recognize this development (through trial and error), and students communicate their understanding of content material when the content is practical immediately (other courses) or in the future (career focus). This addition to existing literature will hopefully encourage FYE program designers to consider curriculum development along the axes outlined in Table 5.1.

Moving forward, it is important for program developers to consider how readily applicable learning objectives are for students pursuing engineering. While students find value in learning broad concepts, this study indicates that students respond positively when exposed to their major early. In addition to exposing students to specific major concepts in the first-year, it is just as necessary to expose them to engineering professionalism concepts and engineering careers to assist them in identifying the type of engineer they would like to be. Additionally, while toxic learning environments have not deterred participants in this study from pursuing engineering, some of the experiences these participants have had should encourage a major cultural shift to positively improve the instructional environment in electrical and computer engineering.

5.2.2 Implications for Research

There are several implications the results of this study may have on the engineering education community which includes broadening a conversation typically dominated by quantitative studies, potentially uncovering better practices for first-year engineering programs and understanding how impactful the matriculation structure of the first-year can be on a student's major choice. As previously discussed, there are various studies that use quantitative methods to explore self-efficacy but very few that use qualitative methods. Additionally, there are few if any studies that focus solely on the development of self-efficacy in one major, as explored in study 1. Through the use of qualitative methods to explore this phenomenon, the results of study 2 and 3 have provided a deeper insight into the development of self-efficacy of first-year engineering students.

Quantitative implications include: 1) measuring persistence of students within ECE longitudinally; 2) measuring persistence and expectancy across two different institution with a

GE matriculation structure and a true DE matriculation structure; and 3) exploring the impact FYE matriculation structure has on persistence (or the intention to persist) given the lack of changes in expectancy across the groups. First, in order to explore persistence and not just the intention to persist, data beyond the first year needs to be collected and analyzed to explore the longitudinal impacts FYE structure has on persistence. Secondly, given that this study was conducted at a single institution comparing a one-year quasi-DE matriculation structure to a three-year GE matriculation structure allows for future work to explore the FYE matriculation structure impact across two different universities with a DE or GE FYE matriculation structure in order to develop more meaningful conclusions regarding the findings presented in this study. Lastly, expectancy may not be a critical factor in understanding persistence. This study suggests that FYE matriculation structure has little impact on students' expectations for majoring in engineering. Given the lack of changes in expectancy, the results of this study indicate that additional research needs to be conducted to understand how learning experiences impact students' intention to persist.

Qualitative implications include: 1) exploring somatic and emotional state experiences of students; and 2) exploring the impact of FYE matriculation structure on students' persistence through a different theoretical lens. Somatic and emotional state experiences is the branch of self-efficacy that is least reported in studies that use the construct. This is possibly due to the overwhelming number of studies that explore self-efficacy quantitatively as opposed to qualitatively where themes in this branch seem to more likely emerge. These experiences were reported by students at the same frequency that mastery experiences. This may suggest that students of the current and future generation are caring just as much about their well-being and happiness as they are about learning. With the rise in discussions surrounding mental health more broadly in the United States, it is no surprise that this conversation impacts how students approach their academics. Jones et al. (2010, 2014) does discuss responses to course climate in terms of caring which is one of the five components in the MUSIC model of academic motivation; however, this study reinforces that somatic and emotional states are impacted by a variety of factors, such as mental health struggles, learning disabilities, and stress related to a semester broadly, thus lending cause for further exploration of these experiences. Given how many negative experiences students experience in engineering, it would be worthwhile to now learn about how these negative experiences can be mitigated and incorporate them into the academy.

Although negative somatic experiences emerged from the results which is an important implication, given that the results of this project indicate that there are no differences in how FYE matriculation structure impacts self-efficacy development might imply that self-efficacy was not the best lens to explore this phenomenon. Based on previous literature and the findings of this study, it may seem that self-efficacy development is independent of FYE matriculation structure. Future research will need to be conducted to explore this phenomenon through a difference theoretical lens.

5.3 Future Work

5.3.1 Quantitative Work

A future expansion of this work could be to capture the perceptions of students who leave the field of electrical and computer engineering and/or engineering more broadly. Given that a limitation to study 1 was the inability to follow-up with where students ended up after their first-year yields room to explore why students switched their major from ECE or engineering in general. As a community, the viewpoint of students who leave engineering is looked at from a deficit standpoint. While there is no debate of how rigorous the field of engineering is, rigor may not be the only reason students leave given that this research has shown that in spite of extreme rigor and poor learning environments, students persist in the field.

Another future exploration to build upon the results of the study could include exploring student responses from the second survey and the third survey given the change in persistence scores across the spring semester for the GE students and quasi-DE students which may provide a better comparison of the GE and DE experiences in this study. We could also explore correlations between expectancy and persistence scores to see if there are any differences in those measures between the GE and DE experiences. Exploring responses to the second and third survey would provide useful insight to the switching pattern of DE and GE students from December to May.

Study 2 could also be advanced by considering actual eventual major choice of students and exploring their persistence across their first-year. This data could then be linked to institutional data regarding majors and graduation rates to provide an in-depth analysis of students' persistence in electrical and computer engineering.

Another future exploration of this work could be to do a correlation analysis between persistence and expectancy responses for the GE and quasi-DE students to understand if there are any differences in how the variables correlate across students in the different FYE matriculation structures. From this I may learn that expectancy and persistence variables have a stronger positive correlation in the spring semester for GE Persisters given that their persistence scores were higher than the DE Persisters. Similarly, I hypothesize that there will be a stronger negative correlation between persistence and expectancy variables for DE Leavers vs. GE Leavers given their higher persistence score in the spring semester (and the fact that they still left ECE).

5.3.2. Qualitative Work

Because these studies are all exploratory and the number of institutions included were limited, there is a lot of future work to do to explore this phenomenon. While the findings of this research have reported that there is no difference in self-efficacy development in students from GE and DE matriculation structures, it is worth noting that recruiting minority participants in electrical engineering, particularly African-American and Hispanic-American, was practically impossible even after utilizing personal networks for recruitment (i.e. recruiting via the National Society of Black Engineers and the Society of Professional Hispanic Engineers chapters at each site). Given the inability to truly capture diverse voices, future work includes conducting study 3 again with more institutions in order to capture a wider range of experiences.

Another future study could be to conduct study 3 again with more than two institutions but still within electrical and computer engineering. Because the institutions in this study have different pedagogical approaches to their FYE program, it is difficult to discern whether self-efficacy development is truly attributed to the different type of FYE matriculation structure (GE or DE), or if it is attributed to the pedagogical choices made in the two programs studied.

5.3.3 Mixed Methods Work

While there are pieces of each study of this dissertation that could be strengthened, overall this study could be replicated to explore the impact FYE matriculation structure has on students' persistence. To create a true sequential explanatory mixed methods study, quantitative data could be collected longitudinally (5 or 6-year period), across multiple institutions with electrical and computer engineering departments using a survey that includes constructs related to persistence (values, interest, belonging, etc.). Similarly, to the design of study 3, interview participants would be sampled from the quantitative data results using low, medium, and high quartiles. Interviews would be conducted with the same students towards the beginning of the fall semester of each year. The potential of this future study could provide in-depth insight regarding this phenomenon with a cohort of electrical and computer engineering students, following them from their first year to their last year (hence the 5 to 6-year study period)(Orr et al., 2012). Students who happen to change majors while the study is ongoing will still be included in both methods of data collection, in order to compare findings of persisters to that of leavers.

A slight modification to a future mixed methods study could also be to explore this phenomenon across engineering disciplines.

5.4 Researcher Reflection

Conducting this research was an emotional rollercoaster. In conducting the analysis for study 2, I begin to explore my love for research and was excited to apply what I had learned from that analysis to study 3. Having the original researchers on my committee was a positive experience as they were able to communicate with me regarding my approach to coding and ultimate theme development.

Study 1 had to (initially) be the most difficult study to approach. While obtaining the data and cleaning it for analysis was simple, finding out what to do with the data once it was prepared was no easy fit. Attempts to reduce out of pocket expenses led me to attempt to analyze the data using MATLAB and R. However, online information became limited for my particular situation (which ***should*** have been a sign…). Resorting to SPSS definitely made data analysis quick and easy especially upon learning how to use the syntax feature. As difficult as it was to learn which analysis to conduct, it was even more difficult to learn how to properly interpret and communicate my results. However, when I did figure out how to interpret my results, I was able to better understand the purpose of the analyses and how to communicate my findings.

Study 3 was my baby given that this was the study I designed with the support of my advisor. From methods, to IRB, recruitment, and data collection, this was my entire brain child. However, being a new parent is not without its challenges – after spending Fall 2018 identifying a second site to conduct research, in March 2019 my site had to change due to inconsistent communication with the original site. Thus, what were supposed to be beginning of semester interviews, ended up being interviews conducted during the week of graduation. I am forever grateful to those at my second site for pulling all the strings they could in order to help me complete this dissertation.

This dissertation was inspired by the fact that I attended participated in a DE matriculation structure for my undergraduate degree and began to question my experience in electrical engineering upon learning that there were other FYE matriculation structures. During my interviews I met a participant who reminded me of my best friend in EE, participants that reminded me of peers, and participants that reminded me of myself. While I as the researcher was asking students to reflect on their experiences, I found myself doing the same. Like some of my participants I had interests all over the place while I was in undergrad but ultimately the goal was to get an engineering degree. Through my participants I learned that my low engineering self-efficacy was not due to the fact that I was "dumb," but rather the fact that I was enrolled in a rigorous curriculum coupled with sometimes poor learning environments. Some of my participants' experiences were heartbreaking to hear and yet unfortunately I was able to relate to them even being 6-8 years removed from their current position in school. However, like some of my participants, I recognized that though I did not realize it at the time, I also prioritized having a work life balance while in undergrad to which I believe wholeheartedly paid off for me at this point in my life. While my undergraduate experience was not perfect, I have always said that I would not have exchanged that experience for anything else. Through my research, I believe I now know why.

5.5 Final Remarks

I have now learned that when I began this study, I was biasedly in favor for GE first-year matriculation structures to support retention of engineering students. While there are studies that do support this notion, I have since learned through this study that it may not be the matriculation structure that impacts students' self-efficacy but rather the learning environment at the university. This study has taught me that through the rigor, setbacks, and even uncaring faculty, students will persist towards their engineering degree if it is what they desire (I managed to get 3!). This research encourages me to continue to create a learning environment that enables students to learn with reasonable stress levels in order to prepare future engineers. I am also encouraged to explore other themes that emerged from this study such as ideas relating success and assistance and engineering being a weed-out field. My next steps post dissertation will take me to Georgia where I can continue to have an impact on students both in the classroom and more broadly through research.

Appendix A – Manuscript 2 Interview Protocol

Interview 1 (End of the course)

Introductory/Warm-up Questions (also address some beliefs about engineering):

Why did you choose to come to Georgia Tech/Virginia Tech?

Why have you chosen engineering as a major? (General Motivation as well as Values for engineering)

BME1300: How did you choose your major? Or ENGE1114: What factors will you consider as you choose your major? General Motivation as well as Values for engineering)

Beliefs about your FYE course

Before taking your FYE course, how certain were you of your major? Did your participation in your FYE course change this in anyway?

Tell me about your experience in your FYE course. What do you like best? What do you like worst? (General Motivation as well as Values for course)

Do you find this course interesting? Why or Why not? (Interest)
Is this course or the content of the course important to you? Why or Why not? (Utility)
How does this course fit or fail to fit your perception of what an engineering does? (Affinity)

What do you think are the learning goals in your FYE course?

Do you feel in control of your learning in this class? Why or Why not? (Autonomy)

Do you feel supported in this course? In what ways? Do you have all the tools and resources that you need to succeed? (Expectancy, Belongingness, Autonomy)

Describe your interactions with the faculty/workshop/team leaders in this course. Are they available? Do they help you? If so, how? (Expectancy, Belongingness, Self-determination)

How would you define success in this course? How confident are you that you can succeed in this course? (Expectancy/ability)

Prompts as needed:

Did you feel like you knew what was expected to get a high grade in this class? Did you feel like you could do what was expected?

Describe your PBL (or design project for VT) team to me. How do the team members interact? How do you interact with your faculty leader/instructor? (Belongingness, Self-determination)

Do you feel like you belong or fit in your FYE course? Why or why not? (Belongingness)

Is your facilitator (or workshop leader for VT) a man or a woman? Does this matter? (Belongingness, Self-determination, Gender)

What is it like being a man (or woman) in this class? How about in engineering in general?

Beliefs about Engineering

At the beginning of the interview, we talked about why you chose engineering as a major. Now that you are here, what keeps you majoring in engineering? (Engineering Values)

How confident are you that you can succeed in earning an engineering degree? (Engineering Expectancy/ability)

Think of the engineering students you know. How similar or different from them are you? (Engineering belongingness)

Prompt:

Do you feel like you belong or fit in engineering as a major? Why or why not? (Belongingness)

Retention/Career

Do you plan to graduate with a degree in engineering? Why or why not? If not, what degree will you pursue?

What do you plan to do when you complete your undergraduate degree?

Prompt:

Do you plan to practice engineering? Why or Why not?

What is your ideal job? What do you think that job entails on a daily basis?

Is your degree preparing you to do this job? If yes, how so? If no, why not?

Interviews 2 and 3 (One and Two Years After the Course)

Introductory/Warm-up Questions (also address some beliefs about engineering):

When we last spoke, we talked about the reasons you decided to pursue an engineering degree. Tell me about those reasons again? Now that you are farther into your engineering major, what keeps you in engineering? (Values for engineering)

Beliefs about your FYE course

Do you ever think about your FYE course? If so, what do you think about?

Think back on your FYE course. How are your current engineering classes the same or different than your FYE course? (Values)

Did your experience in your FYE course prepare you for classes you are taking now? Why or Why not?

Do you think your experience in your FYE course is preparing you for your career? Why or Why not?

Beliefs about Engineering

How confident are you that you can succeed in earning an engineering degree? (Engineering Expectancy/ability)

Think of the engineering students you know. How similar or different from them are you? (Engineering belongingness)

Retention/Career

Do you plan to finish a degree in engineering? Why or why not?

What do you plan to do when you complete your undergraduate degree?

What is your ideal job? What do you think that job entails on a daily basis?

Is your degree preparing you to do this job? If yes, how so? If no, why not?

Interviews 2 and 3 (One and Two Years After the Course)

Introductory/Warm-up Questions (also address some beliefs about engineering):

When we last spoke, we talked about the reasons you decided to pursue an engineering degree. Tell me about those reasons again? Now that you are farther into your engineering major, what keeps you in engineering? (Values for engineering)

Beliefs about your FYE course

Do you ever think about your FYE course? If so, what do you think about?

Think back on your FYE course. How are your current engineering classes the same or different than your FYE course? (Values)

Did your experience in your FYE course prepare you for classes you are taking now? Why or Why not?

Do you think your experience in your FYE course is preparing you for your career? Why or Why not?

Beliefs about Engineering

How confident are you that you can succeed in earning an engineering degree? (Engineering Expectancy/ability)

Think of the engineering students you know. How similar or different from them are you? (Engineering belongingness)

Appendix B – Comparison of Hutchison-Green et al.'s and Matusovich et al.'s interview protocols

Hutchison-Green et al. (2008)	Matusovich et al., (2011)
Pre-Semester Interview **Background information** Where are you from? What made you decide to try engineering? Are you enrolled in a first-year engineering course?	<u>Beliefs about your FYE course</u> Before taking your FYE course, how certain were you of your major? Did your participation in your FYE course change this in anyway?

Definition of success in first-year engineering course and course self-efficacy
• I'm really interested in how students view success in class
  o Can you tell me about your thoughts? How do you define success in your first-year engineering courses? What do you need to do to consider yourself successful?
  o Anything else?
  o If you had to rank these things, which is most important?
• I'm also interested in how successful you think you will be in your first-year engineering course
  o To what degree do you think you will be able to fulfill your definition of success in your first-year engineering course?
  o Why do you believe this?
• On what experiences are basing your judgment? (mastery experiences)
• How have other people influenced how you think you will do? (vicarious)
• How does your first-year engineering course make you feel? (physiological) (When thinking about your first-year engineering course, how do you feel?)
• Of all of the things you've discussed (list their mastery, vicarious, social, and physiological experiences), is there any one thing or any couple of things that really affects your beliefs about your abilities more than the others?
Success (in college, and does it "fit-in")
• Finish this statement: When I'm looking back on my college days, I'll think I was successful if _________________.
	How would you define success in this course? How confident are you that you can succeed in this course? (Expectancy/ability)
	Prompts as needed:
	Did you feel like you knew what was expected to get a high grade in this class? Did you feel like you could do what was expected?

Problem Solving Efficacy – What is it? Why? How do you assess it? • How would you rate your math/chemistry/physics problem-solving abilities? (are you excellent at solving problems, good, fair, poor?) Why? • How do you go about solving a problem (i.e. homework or test)? How do you know that you've solved a problem? How do you rate your abilities with each of these aspects and why?	
Professional School Efficacy – What is it? How do you assess it? How is it different from class efficacy? • What professional school do you want to go to? • Do you believe you have the ability to fulfill	<u>Beliefs about Engineering</u> At the beginning of the interview, we talked about why you chose engineering as a major. Now that you are here, what keeps you majoring in engineering? (Engineering Values)

the freshman engineering requirements and gain admission to the professional school of your choice? Why? **Engineering Degree Efficacy – What is it? How do you assess it? How is it different from class efficacy?** Assuming you get in to the professional school of your choice. Do you believe you have the ability to earn an engineering degree from that school? Why? **Engineering Career Efficacy – What is it? How do you assess it? How is it different from class efficacy?** • Do you think you'll be successful as an engineer in the "real world"? Why? • How are defining success? • Are there any other thoughts, feelings, or concerns you have about your first-year engineering course that we haven't discussed? • What aspects are you exciting about as you begin your engineering education?	How confident are you that you can succeed in earning an engineering degree? (Engineering Expectancy/ability)
•	Tell me about your experience in your FYE course. What do you like best? What do you like worst? (General Motivation as well as Values for course) Do you find this course interesting? Why or Why not? (Interest) Is this course or the content of the course important to you? Why or Why not? (Utility) How does this course fit or fail to fit your perception of what an engineering does? (Affinity) Do you feel in control of your learning in this class? Why or Why not? (Autonomy) Do you feel supported in this course? In what ways? Do you have all the tools and resources that you need to succeed? (Expectancy, Belongingness, Autonomy) Describe your interactions with the faculty/workshop/team leaders in this course. Are they available? Do they help you? If so, how? (Expectancy, Belongingness, Self-determination) Describe your PBL (or design project for VT) team to me. How do the team members interact? How do you interact with your faculty leader/instructor? (Belongingness, Self-determination) Do you feel like you belong or fit in your FYE course? Why or why not? (Belongingness) What is it like being a man (or woman) in this class? How about in engineering in general? **Interviews 2 and 3 (One and Two Years After the Course)** Introductory/Warm-up Questions (also address some beliefs about engineering): When we last spoke, we talked about the reasons you

	decided to pursue an engineering degree. Tell me about those reasons again? Now that you are farther into your engineering major, what keeps you in engineering? (Values for engineering) Beliefs about your FYE course Do you ever think about your FYE course? If so, what do you think about? Think back on your FYE course. How are your current engineering classes the same or different than your FYE course? (Values) Did your experience in your FYE course prepare you for classes you are taking now? Why or Why not? Do you think your experience in your FYE course is preparing you for your career? Why or Why not?

Appendix C – Survey

Beginning of Semester Questionnaire ENGE 1215 - Fall 2017

Start of Block: Student Information

Q8 Although completing this questionnaire counts as a homework assignment, the questions themselves are designed to help the Engineering Education Department evaluate the course. As a result, your course instructors will not have access to the individual answers you provide. They will know only whether you completed the assignment.

Q1 Your First Name:

____

Q10 Your Last Name:

____

*

Q3 Your VT ID number (90xxxxxxx)

____

Q2 Your Virginia Tech email: (pid@vt.edu)

____

Page Break

Q4 A1. What is your intended major?

- Aerospace Engineering (1)
- Biological Systems Engineering (2)
- Chemical Engineering (3)
- Civil and Environmental Engineering (4)
- Computer Engineering (5)
- Computer Science (6)
- Construction and Engineering Management (7)
- Electrical Engineering (8)
- Engineering Science and Mechanics (9)
- Industrial and Systems Engineering (10)
- Materials Science and Engineering (11)
- Mechanical Engineering (12)
- Mining and Minerals Engineering (13)
- Ocean Engineering (14)
- Undecided (I don't know) (15)

Page Break

Q6 Please rate your level of agreement with the following statements.	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
A1. What is your intended major? != Undecided (I don't know)						
A1b. I am confident in my choice of a specific major. (1)	○	○	○	○	○	○
A2. I have sufficient information to make an informed choice about a specific engineering major. (2)	○	○	○	○	○	○
A3. I am confident that I want to study engineering. (3)	○	○	○	○	○	○
A4. My eventual career will directly relate to engineering. (4)	○	○	○	○	○	○
A5. In the future, I will have a career that	○	○	○	○	○	○

requires me to have engineering skills. (5)						
A6. I plan to continue on in an engineering major. (6)	○	○	○	○	○	○
A7. I don't intend to change my major from engineering to a non-engineering major. (7)	○	○	○	○	○	○

End of Block: Student Information

Start of Block: Engineering Information

Q9 Please rate your level of agreement with the following statements. In answering, please **think about engineering as a field**, not any one particular course.	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
B1. Being good at engineering is an important part of who I am. (1)	○	○	○	○	○	○
B2. Doing well on engineering tasks is very important to me. (2)	○	○	○	○	○	○
B3. Success in engineering school is very valuable to me. (3)	○	○	○	○	○	○
B4. It matters to me how well I do in engineering school. (4)	○	○	○	○	○	○
B5. Knowing about engineering does not benefit me at all. (5)	○	○	○	○	○	○

B6. I see no point in me being able to do engineering. (6)	○	○	○	○	○	○
B7.Having a solid background in engineering is worthless to me. (7)	○	○	○	○	○	○
B8. I have little to gain by learning how to do engineering. (8)	○	○	○	○	○	○
B9. After I graduate, an understanding of engineering will be useless to me. (9)	○	○	○	○	○	○
B10. I do not need engineering in my everyday life. (10)	○	○	○	○	○	○

Page Break

Q10 As a student in ENGE 1215 working towards admission into a degree granting engineering major you are enrolled in the General Engineering Program at Virginia Tech. Please rate your level of agreement with the following statements as you **think about the General Engineering program overall**.	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
C1. I feel like a real part of the General Engineering program. (1)	○	○	○	○	○	○
C2. Sometimes I feel as if I don't belong in the General Engineering program. (2)	○	○	○	○	○	○

C3. People in the General Engineering program are friendly to me. (3)	○	○	○	○	○	○
C4. I am treated with as much respect as other students in the General Engineering program. (4)	○	○	○	○	○	○
C5. I feel very different from most other students in the General Engineering program. (5)	○	○	○	○	○	○
C6. The instructors in the General Engineering program respect me. (6)	○	○	○	○	○	○
C7. I wish I were in a major other than engineering. (7)	○	○	○	○	○	○
C8. I feel proud of belonging in the General Engineering	○	○	○	○	○	○

program. (8)						
C9. The amount of effort it takes to do well in my engineering program is worthwhile to me. (9)	○	○	○	○	○	○

Page Break

Q11 Please rate your level of agreement with the following statements. When asked about "**<u>engineering-related courses,</u>**" please **<u>refer</u> to your math, science and engineering courses**.	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
D1. Compared to other engineering students, I expect to do well in my engineering-related courses this year. (1)	○	○	○	○	○	○
D2. I think that I will do well in my engineering-related courses this year. (2)	○	○	○	○	○	○
D3. I am good at math, science, and engineering. (3)	○	○	○	○	○	○
D4. Compared to	○	○	○	○	○	○

other engineering students, I have high engineering-related abilities. (4)						
D5. I have been doing well in my engineering-related courses this year. (5)	o	o	o	o	o	o

End of Block: Engineering Information

Start of Block: Block 2

Q23 Please rate you level of agreement with the following statements.	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree nor Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
E1. I tend to avoid talking to strangers (9)	○	○	○	○	○	○	○
E2. I prefer a routine way of life to an unpredictable one full of change. (10)	○	○	○	○	○	○	○
E3. I would not describe myself as a risk-taker. (11)	○	○	○	○	○	○	○
E4. To avoid making a mistake, I do not like taking too many chances. (12)	○	○	○	○	○	○	○
E5. I find it difficult to function without clear directions and instructions. (13)	○	○	○	○	○	○	○
E6. I prefer specific instructions to broad guidelines. (14)	○	○	○	○	○	○	○
E7. I tend to get anxious easily when I don't know an	○	○	○	○	○	○	○

outcome. (15)							
E8. I feel stressed when I cannot predict consequences. (16)	◯	◯	◯	◯	◯	◯	◯

End of Block: Block 2

Start of Block: Block 3

Q12 Questions in this section are intended to help us evaluate the use of Tablet PCs in the first-year engineering program. Some Windows laptops have touchscreens or can be converted to a tablet form factor but do not have active digitizer pens; for the following questions a Tablet PC is a Windows computer with an active digitizer pen used for digital inking.

Q15 F1. What type of laptop do you primarily use in your engineering courses?

◯ Tablet PC (with active pen for inking (1)

◯ PC Laptop (without active pen, but with touchscreen) (2)

◯ PC Laptop (with neither active pen nor touchscreen) (3)

◯ Macintosh Laptop (4)

◯ Other (5) ____

Display This Question:

If F1. What type of laptop do you primarily use in your engineering courses? != Tablet PC (with active pen for inking

Q16 F1a. What type of device do you use that provides inking capabilities?

○ I have a secondary Windows device with an active pen that allows on-screen inking. (1)

○ I have an external device without a screen that attaches to my primary computer (such as a Wacom tablet) to provide inking capability. (2)

○ I do not use any device with inking capability (3)

○ Other (4) ____

Page Break

Q17 F2. How often do you expect to use **writing or drawing input** (using active pen, touchscreen, or external device) on your computer in the following situations?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)
During your EngE class using Dyknow (1)	○	○	○	○
Other uses during your EngE class (2)	○	○	○	○
In your other classes (3)	○	○	○	○
Completing homework assignments (4)	○	○	○	○
Personal or extracurricular activities (5)	○	○	○	○

Page Break

Q18 F3. Please rate your level of agreement with the following statements regarding you use of **writing or drawing input**.

	Strongly Disgagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)
Having the ability to write and draw on my computer is valuable to me (1)	○	○	○	○
I will continue to use my computer's writing and drawing capabilities in the future (2)	○	○	○	○
My computers writing or drawing input is sufficient for my needs (3)	○	○	○	○
The College of Engineering should continue to require Tablet PCs (4)	○	○	○	○

Page Break

Q19 F4. Please use this space to include any other feedback you have regarding your laptop or tablet use:

____

____

____

____

____

Display This Question:

If F1. What type of laptop do you primarily use in your engineering courses? != Tablet PC (with active pen for inking

Q20 F1b. I am at a disadvantage because I do not have a Tablet PC

- ○ Strongly Disagree (1)
- ○ Disagee (2)
- ○ Agree (3)
- ○ Strongly Agree (4)

End of Block: Block 3

Appendix C – Manuscript 3 Interview Protocol

Beginning of 2nd Semester Sophomore Year

Updated screening information

1) Just to get your up to date responses, I'd like to know on a scale of 1-6 with 1 being Strong Disagree and 6 being Strong Agree, how would you respond to the following:
   a) I am confident in my choice of a specific major
   b) I have sufficient information to make an informed choice about a specific engineering major
   c) I am confident that I want to study engineering
   d) I plan to continue on in an engineering major
   e) I don't intend to change my major from engineering to a non-engineering major

Background information

1) Where are you from? What made you decide to try engineering?
2) What is your current engineering major? Why?
   a) How did you come about choosing this major?
   b) Is there anything about going directly into your major (or taking a general engineering course) that impacted your major choice?

Definition of success in first-year engineering course and course self-efficacy

1) I'm really interested in how students view success in class
   a) Can you tell me about your thoughts? How did you define success in your first-year engineering courses? What did you need to do to consider yourself successful?
   b) If you had to rank these things, which is most important?

2) I'm also interested in how you think your performance in your first-year engineering course is impacting your quest to achieve success in your current engineering course
    a) To what degree are you achieving success in your current engineering course?
        a) Why do you believe this?
        b) What lessons from your FYE are you finding most helpful in achieving this success?
    b) I'm also interested in understanding how you think the general population of your engineering class feels about success in the course
        a) How do you believe other people in your class define success in your current engineering course?
3) On what experiences are you basing your judgment? (mastery experiences)
4) How have other people influenced how you think you will do? (vicarious)
5) How have people (family, teachers, peers) encouraged you to succeed in the class? (social influences)
6) How does your first-year engineering course make you feel? (physiological) (When thinking about your first-year engineering course, how do you feel?) (physiological)
7) Of all of this feedback you're getting (list their mastery, vicarious, social, and physiological experiences), is there any one thing or any couple of things that really affects your beliefs about your abilities more than the others?

Class Efficacy – What is it? How do you assess it?

1. What grade did you earn in your FYE course?

2. What grade did you think you deserved in your FYE course? Why?
3. Fill in the blank: I believe that I will earn a grade of ____ in my current engineering course
    a) At the end of the semester, what grade do you think you will receive in your current

engineering course?

a) What is helping you earn it? Is there anything specific from your FYE that recall being useful?

b) What makes it difficult to get an A in your current engineering course?

Engineering Degree Efficacy – What is it? How do you assess it? How is it different from class efficacy?

1) How has your FYE course prepared you for your major?
2) Do you believe you have the ability to earn an engineering degree in your discipline? Why?
    a. Why are you *still* in your major?
3) Do you believe that your FYE program has prepared you for success in your engineering major? Why?
4) What concepts did you gain from your FYE course that you believe will be most useful in being successful in your current engineering course?
5) What experiences did you gain from your FYE course that you believe will be useful in being successful in your current engineering course?

Other

Is there anything else about your FYE course that you did not get a chance to share during the interview and would still like to share with me right now? Is there any question I did not ask that I should have asked?

Appendix D – Case 1 FYE Course Goals

Upon successful completion of this course, the student will be able to:

1. Think analytically;
2. Design simple circuits that conform to specific constraints or perform a specific function;
3. Understand how to develop code and achieve a specific goal;
4. Expand his or her educational outlook to go beyond the constraints of one class and to link current learning themes to previous and anticipate their use in future educational activities;
5. Work efficiently and effectively on a team;
6. Develop and deliver effective written and oral reports;
7. Understand the imperative to apply high ethical standards to his or her professional and personal actions;
8. Learn to set high personal expectations and prioritize to optimize the outcome.

Appendix E – Case 2 FYE Course Goals

FYE Course 1 Outcomes:

1. Compare and contrast the contributions of different types of engineers in the development of a product, process, or system
2. Articulate holistic issues that impact engineering solutions
3. Solve problems using systematic engineering approaches and tools
4. Model an engineering system
5. Communicate solutions and arguments clearly
6. Develop teamwork skills

FYE Course 2 Outcomes:

1. Demonstrate the ability to use various engineering tools in solving design problems
2. Demonstrate proficiency with implementing an engineering design process
3. Communicate engineering decisions to technical managers
4. Contribute effectively to an engineering team
5. Evaluate ethical implications of engineering solutions

Appendix F – IRB Approval Letter

WIRB
Global Leader | Proven Expert

October 21, 2018

Marie Paretti, PhD
Virginia Tech
357 Goodwin Hall
635 Prices Fork Road
Blacksburg, VA 24060

Dear Dr. Paretti:

SUBJECT: REGULATORY OPINION—IRB EXEMPTION
Protocol Title: First-Year Programmatic Influences on Electrical Engineering Students' Self-Efficacy
Investigator: Marie Paretti, PhD
IRB No.: 18-804

This letter is in response to your request to Western Institutional Review Board (WIRB) for an exemption determination for the above-referenced research project. WIRB's IRB Affairs Department reviewed the exemption criteria under 45 CFR §46.101(b)(2):

> (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:
> (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

We believe that the research fits the above exemption criteria. The data will be collected in a way so that the subjects can be identified, directly or through identifiers linked to the participants. However, any disclosure of the human subjects' responses outside the research will not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. You have also confirmed that the results of this study will not be submitted to the Food and Drug Administration (FDA) for marketing approval.

This exemption determination can apply to multiple sites, but it does not apply to any institution that has an institutional policy of requiring an entity other than WIRB (such as an internal IRB) to make exemption determinations. WIRB cannot provide an exemption that overrides the jurisdiction of a local IRB or other institutional mechanism for determining exemptions. You are responsible for ensuring that each site to which this exemption applies can and will accept WIRB's exemption decision.

Western Institutional Review Board®
1019 39th Avenue SE Suite 120 | Puyallup, WA 98374-2115
Office: (360) 252-2500 | Fax: (360) 252-2498 | www.wirb.com

Please note that any future changes to the project may affect its exempt status, and you may want to contact WIRB about the effect these changes may have on the exemption status before implementing them. WIRB does not impose an expiration date on its IRB exemption determinations.

If you have any questions, or if we can be of further assistance, please contact Zach Burr at (360) 252-2475, zburr@wirb.com, or e-mail RegulatoryAffairs@wirb.com.

ZHB:jca
B2-Exemption-Paretti (10-21-2018)
cc: VA Tech, WIRB, Virginia Polytechnic Institute and State University
Racheida Sharde Lewis, Virginia Tech
WIRB Accounting
WIRB Work Order #1-1123843-1

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