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The effects of engineering discipline depth and specificity on occupational alignment, graduate school decisions, and engineering identity

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Retention of engineering students to graduation and career is important business for both United States (U.S.) industries and engineering education institutions alike. Industries need competent engineers dedicated to working in the field of engineering beyond graduation in order to achieve business success and national economic growth, while engineering education institutions need retention to graduation to achieve their own business goals.

This dissertation took a three-pronged approach to identifying relationships between depth and specificity of engineering and response factors related to graduation and career retention of engineers. Occupational alignment, graduate school decisions, and engineering identity were evaluated for relationships with specificity or depth of discipline within engineering degrees to evaluate if increasing the depth or specificity increased the response factors.

Using historical data analysis, occupational alignment and graduate school decisions were both found to be influenced by specificity of discipline. Traditional engineering disciplines were found to report the most occupational alignment after graduation, while specific engineering

disciplines were more likely to attend graduate school after graduation. Additionally, for all students reporting graduate school attendance, all specificities were most likely to align their graduate degree discipline to their undergraduate degree discipline.

A national survey of undergraduate engineering students revealed that engineering identity is related to depth of discipline. Students enrolled in more specific engineering curriculum, in the form of a discipline-specific major with a concentration, reported higher engineering identity. However, the discipline-specific depth of discipline followed closely behind, indicating the impact of depth of discipline is small. The largest difference in scores between the two depths of discipline was found in students' reports of a construct termed "interest".

Ultimately, this dissertation found statistically significant relationships between depth and specificity of discipline and occupational alignment, graduate school decisions, and engineering identity. Though these findings are statistically significant, they were incremental, meaning depth and specificity of discipline should not be considered the main factor of influence.

DEDICATION

This dissertation is dedicated to the generation before me – my mother, and the generation after me – my son. The past and the future give me such worthy reasons to strive in the present.

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I will never be able to repay my major professor, Dr. Lesley Strawderman, for investing in me as much as she has over the course of my doctoral studies. She has been more than an advisor; she has truly been my guide, accountability partner, a wealth of survey and statistical knowledge, the source of grace I needed but would not allot myself, and an incredibly patient teacher. I am tremendously grateful to have her as an advocate and mentor, and I hope to continue learning from her, even after my official tutelage is over.

Thank you to my husband, Zach, who has been fully supportive of every adventure I've asked him to undertake with me. This adventure was not quite as fun as some of our others, but we both know the outcome is worth the sacrifice. Now, let's go on vacation!

To the rest of my family – biological, church, and friend – who kept Rhett when needed, helped me gain perspective, and prayed continually for me – thank you. Collectively, your support helped me move mountains.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Undergraduate engineering education is serious business. Rather, undergraduate engineering education is serious *and* it is business.

Serious.

Undergraduate engineering education is a serious matter because a bachelor's degree is the only requirement for engineering students to become fully-qualified to work in the profession. This means educators have approximately four years with their students before releasing them into the wild. For a profession that designs, creates, and solves problems for the benefit of society, four years of education seems trivial, compared to the education of other impactful professions (e.g. doctors and lawyers). Additionally, because the United States is counting on engineering graduates to fill the increasing demand of engineering professionals needed in the nation (National Science Board & National Science Foundation, 2019), not only is quality important, but quantity as well.

Business.

Undergraduate engineering education is also a business. Without income from student tuition, engineering institutions cannot remain operable. Engineering education institutions continuously attempt to recruit and retain engineering undergraduates to improve the institution's financial standing so they can remain in the business of educating future engineers.

These factors alone are enough to warrant extensive research in engineering education, but an even more important reason is the student who has faith in engineering education. Each individual student trusting an engineering institution with their education has the potential to accomplish great things beyond graduation, and this dissertation aims to find out if there is an improved structure for engineering education that better sets those students up for success. This dissertation will examine the impacts of specificity and depth of engineering discipline. How does the specificity of a program of study impact occupational alignment after graduation, graduate school decisions, and student engineering identity? By exploring these questions, insights into the level of discipline depth and specificity engineering students really need to thrive may emerge.

CHAPTER II

STUDY 1: SPECIFICITY OF DISCIPLINE AS AN INFLUENCE ON ENTRY-LEVEL ENGINEERING OCCUPATIONAL ALIGNMENT

Introduction

When the Soviet Union successfully launched the world's first artificial satellite, the United States took the defeat as a challenge to increase the country's global technology and innovation presence (Lichtenstein et al., 2009). Since the dawn of the space age, the U.S. has placed an emphasis on producing its own highly qualified science, technology, engineering, and mathematics (STEM) professionals, as evidenced by the dedication of entire federally-funded entities, such as the National Science Foundation (NSF), to the progress of science and engineering. Even legislative actions, like the STEM Education Coordination Act of 2009 (House Resolution 1709, 2009) have been dedicated to the growth of the nation's STEM fields.

The 2020 National Science Foundation report on labor force indicates the need for engineers in the United States is estimated to increase by 8.2% between the years of 2016 and 2026 (National Science Board, 2019). To supply the country with more qualified engineers, academic institutions are expected to increase the output of degreed engineers. Usually, this is where discussions of recruitment and student retention enter, but what if there is another variable to consider? What if the engineering students are recruited and retained, but engineering graduates are not choosing careers aligned with their field of study, and thus, not entering into the engineering profession after graduation? This issue would not be one of recruitment or retention, as the students persisted to obtain an engineering degree; they simply did not utilize their degree after obtaining it. In these instances, students have spent approximately four or more years at an academic institution investing in a particular program of study, but upon graduation have made the choice to pursue non-engineering career paths. This mismatch in entry-level occupational alignment to academic discipline is the focus for this study.

Background

Theoretical Framework

Occupational Choice

The conceptual framework of occupational choice began as a discussion of two types of factors – individual and occupational (Taylor, 1979). According to Blau and colleagues (1956), these factors are inclusive of social experiences that shape personality development of potential workers and conditions of occupational opportunity that limit the realization of their choices. While these factors provided the beginning foundations for a theory, the authors stated that more empirical research was needed to facilitate a theoretical framework.

From Blau et al.'s (1956) conceptual basis, theoretical frameworks have since emerged. Super's (1957) theory suggests that "self-concept" impacts occupational choice and Taylor (1979) takes this theory two steps forward to include two additional features necessary to describe occupational choice. These features, describe by Taylor (1979), are:

1. "Occupational choice is not a random phenomenon, but is, to a greater or lesser degree, purposive.
2. It is a central mechanism of the occupational choice process that an individual's preferences tend to become aligned with their future expectations.

3. Occupational choice can be seen as a compromise between an individual's preferences and the labour market constraints of the occupational structure." (p. 42)

From these features, occupational choice can be further evaluated for engineering graduates, specifically. Since the engineering occupation requires degreed applicants and obtaining an engineering degree involves purposeful steps, feature one from Taylor's framework is fulfilled for engineering occupations, and requires no further analysis. Feature three of Taylor's framework can be disregarded for this time and place in history, as the U.S. Bureau of Labor Statistics' Employment Projections report has identified occupational growth in all twenty acknowledged engineering disciplines, except nuclear engineering, which indicates that the labor market is in favor of most every type of engineering discipline (BLS, 2020). This fulfillment of feature one and omission of feature three leaves feature two as an important area of study when applying Taylor's framework to engineering. Taylor's (1979) second feature implies that career preferences become aligned with future expectations, while Super's (1957) theory indicates that self-concept impacts occupational choice. As these two theories do not conflict, they might be considered complementary. The construct of self-concept is a broad one, as it encompasses perceptions of oneself reinforced by evaluative inferences (Shavelson et al., 1976). This generalized construct includes the more specific construct of self-efficacy, which deals primarily with perceived cognitive capability within a given domain (Bong & Clark, 1999). The construct of self-efficacy is a more ideal construct to evaluate, as Bandura states that self-concept combines too many attributes into a single index, and loses meaning if self-efficacy is not present (Bandura, 1997). Thus, the more precise construct of self-efficacy will replace self-concept in this analysis.

To understand how Taylor and Super's theories of preferences, expectations, and self-concept (or more specifically, self-efficacy) influence one another, social cognitive career theory (SCCT) paints an enlightening picture.

Social Cognitive Career Theory

To evaluate the impact preferences, self-efficacy, and outcome expectations impart on occupational choices, SCCT can be utilized. SCCT framework is based on Bandura's (1986) general social cognitive theory, but emphasizes how individuals act with motivation and direction in their career development (Lent et al., 1994). According to Lent and associates (2008), the three concepts of self-efficacy, outcome expectations, and preferences (called "interests" in SCCT) are interrelated, as seen in Figure 1, and impact major choice goals, or occupational choice. The relationships between the three variables are visible when structurally modeled, and can be described as each playing a role in achieving academic and career pursuits, though outcome expectations impact choice goals much less than the other two concepts. Lent and colleagues' (2008) research describes each relationship in the figure by a lettered path:

Path (a) – Self-efficacy promotes favorable outcome expectations

Path (b) – Students tend to develop interests in academic subjects for which they possess strong self-efficacy

Path (c) – Students tend to develop interests in academic subjects for which they have positive outcome expectations

Paths (d), (e), and (f) – Intent to persist at a course of action (choice goals) results from self-efficacy, outcome expectations, and interests (paths d, e, and f, respectively).

Path (g) – Social supports positively impact goals

Path (h) – Barriers negatively impact goals

Paths (i) and (j) – Supports and barriers indirectly impact choice goals by improving or hindering self-efficacy

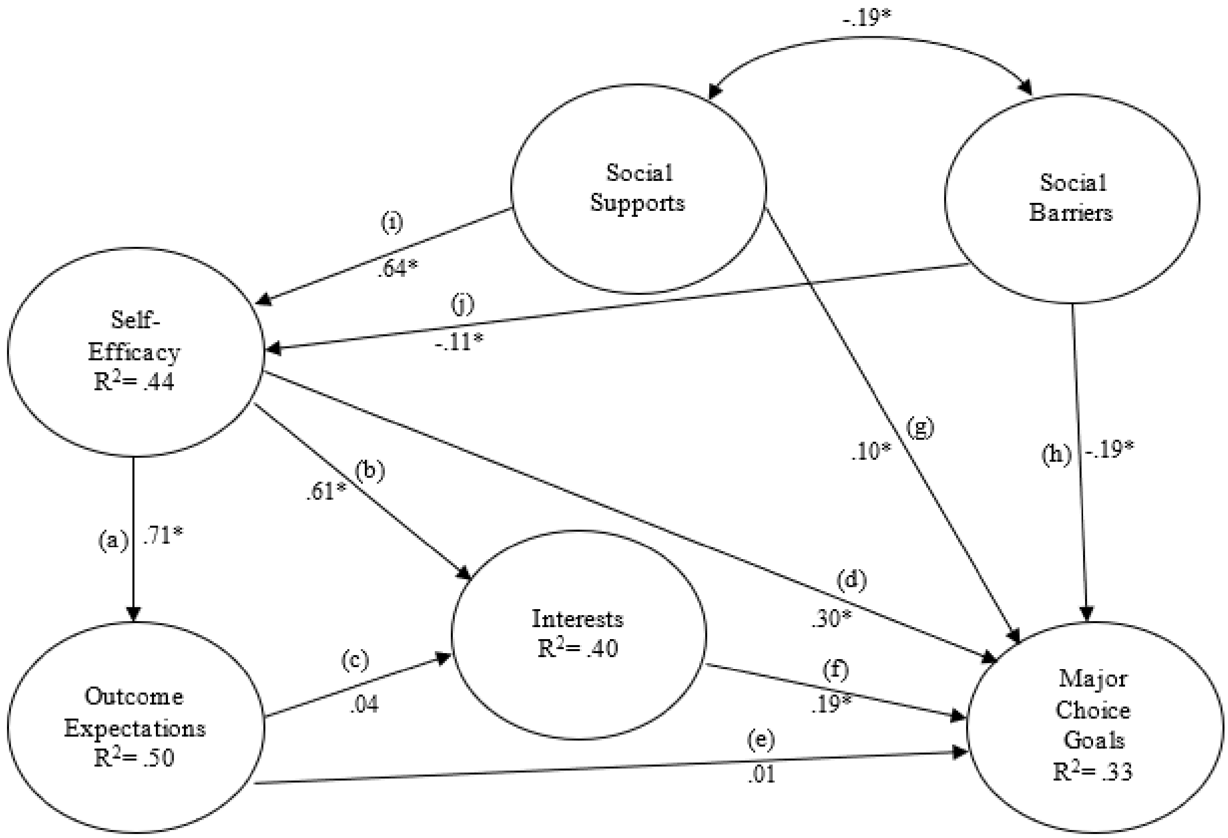


Figure 1 Social Cognitive Career Theory Structural Model * p < .05 (Lent et al., 2008)

The SCCT structural model shows correlations between variables along each lettered path as well as the percentage of the response variable variation (R^2) explained by the model on each node. This model indicates that self-efficacy largely influences outcome expectations, interests, and major choice goals (occupational choice).

While SCCT presents a valid model for how students make their occupational choices, student career decisions have been viewed through numerous perspectives at differing levels of theory and application. A summary of the literature findings is presented below.

Current State of Research

Literature guiding the previously described theoretical framework manifests a plethora of additional variables influencing engineering graduates' career decisions. After conducting a literature search, the current state of research investigating engineering occupational choice and alignment to academic discipline is described in the following section.

Many questions regarding retention of engineering students to graduation have been answered, but not as many studies have focused on the retention of engineering students in the field of engineering *after* graduation. Of the studies conducted in relation to engineering occupational choice, many focus on the characteristics and traits of the person choosing, rather than the content of choice (McDonough & Wagstaff, 1983). Work by both Roe (1956) and Holland (1966) describe matching particular personality traits to occupational categories as a means of occupational choice. Studies of occupational choice viewed through cultural, psychological, and sociological lenses are more prevalent than those questioning the role of engineering education in defining an engineering student's career path. However, researchers are looking at how educational *experiences* impact occupational choice. Korte and Smith (2007) argue that poor learning environments constructed by engineering programs negatively affect students' values about the profession of engineering, and influence their decisions to leave engineering.

One study by McDonough and Wagstaff (1983) focused on the content of choice instead of the traits of the choosing individual. This study evaluated the perceptions of 16- to 18-year-old students in regards to degree relativity (how closely the occupation pursued after graduation is related to the degree), utility (how useful the degree would be for obtaining employment), and the probability of employment in the field. Findings indicate that perceptions of utility (i.e. usefulness of the degree for obtaining employment) are significant predictors of obtaining employment in that field after graduation. Engineering degrees were found to be the second most useful degree (tied with computer science), of 16 options listed. This study sheds minimal light on if these perceptions correlate with actual choices of students after graduating with a degree, as the study surveyed students entering college, rather than exiting. The concept of the study, however, opens the door to exploration of how specificity of discipline impacts occupational alignment.

More recently, Ro (2011) conducted work to include an investigation into the influence of pre-college characteristics, academic program experiences, and student perceptions on post-graduation plans. This study discovered that compared to mechanical engineering, those who major in general engineering have greater odds of pursuing non-engineering careers (Ro, 2011). Similarly, Sheppard and colleagues (2014) found that civil and environmental engineering majors were more likely to have engineering-focused plans after graduation, as opposed to bio-x engineering majors.

Brunhaver (2015) took a different approach and studied recent engineering graduates' self-described occupational titles and compared them to the graduates' perceptions of how related their position was to engineering. Brunhaver found those individuals reporting to work in an engineering position tended to perceive themselves as working in engineering and those who reported employment in non-engineering positions tended to perceive themselves as working in a non-engineering occupation (Brunhaver, 2015). This conclusion does lend itself to support the supposition that engineers are normally rational in their situational perceptions. However, this study did not include the graduate's major as a variable of interest.

This incomplete picture of specificity of discipline impacting occupational alignment is the catalyst for the study at hand, which aims to reveal relationships between differing specificities of engineering disciplines and occupational alignment for engineering graduates.Research Question

This study aims to build upon Ro's (2011) investigation into post-graduation plans to answer the following research question:

Does undergraduate specificity of discipline influence engineering occupational alignment upon graduation?

Specificity of Discipline

For this study, three levels of discipline are examined. These levels, each deemed a "specificity of discipline", refer to the breadth of focus conveyed within the program of study.

1. *General engineering.* This is the broadest level considered. In this level of specificity, the focus is interdisciplinary, and students are expected to be able to apply knowledge of engineering to design experiments and solve problems.
2. *Traditional engineering.* This level of discipline is more specific than general engineering, as there is an applied focus in each discipline not found in a general

engineering discipline. This level considers the more traditional engineering disciplines of mechanical, electrical, chemical, industrial, and civil engineering, due to their long-standing acceptance as engineering disciplines and their historical associations. Horikawa and Guo (2009) assert that civil engineering is the oldest established engineering discipline, and defined traditional engineering as applied science and mathematics concerned with building structures, machines, numerous products, systems, and processes. The traditional engineering disciplines, according to Horikawa and Guo, included all the listed disciplines of this level, minus industrial engineering. However, industrial engineering is the engineering discipline concerned with systems and processes (Bureau of Labor Statistics, 2021), so it seems logical to include this discipline, based on Horikawa and Guo's definition. Historically speaking, civil engineering dates back to early 18th century (Horikawa and Guo, 2009), while mechanical, electrical, chemical, and industrial engineering were born just before or during the Industrial Revolution of the 19th century (Smith, 2021). Because of the historical association to industry of mechanical, electrical, chemical, and industrial engineering, these disciplines are appropriate to group together. Though not created in the 19th century, civil engineering is what some would describe as the "original engineering discipline", and fits into the traditional grouping, as well. Additionally, between 1966 and 2012, these five engineering disciplines were consistently awarded the most degrees per year, as indicated in the National Science Foundation's detailed statistical report, *Science and Engineering Degrees: 1966–2012* (NSF, 2015). This longevity of consistency in awarded degrees indicates that these disciplines have been generally accepted as engineering disciplines. Combining these five engineering disciplines to create a grouping titled "traditional engineering" is based on their historical similarities and longevity of the degree programs.

3. *Specific engineering.* This level considers all engineering disciplines not considered in the "traditional engineering" or "general engineering" categories. These disciplines have been created through modification of the traditional engineering disciplines or through an identified gap in traditional engineering disciplines, and thus could be considered narrower in focus. This level includes engineering disciplines such as aerospace engineering, petroleum engineering, computer engineering, metallurgical engineering, and biomedical engineering.

Implications

If the United States is to address the growing engineering shortage (National Science Board, 2019), identifying engineering majors with high attrition levels upon graduation could be helpful in directing students to the engineering discipline specificity they feel aligns with their interests. This alignment to interests is a foundational concept of SCCT and may aid in retaining graduates in engineering careers. The findings of this study could be used to support the development of more personalized academic guidance for those engineering majors found to have higher levels of attrition from the field after graduation. This guidance could come in many forms, ranging from increased faculty involvement to program entry questionnaires, used much like the Armed Services Vocational Aptitude Battery (ASVAB) test. Since a potential reason for engineering graduates seeking employment in a field other than their degree may be due to a misalignment between student interests and degree choice, an ASVAB-like test may assist in identifying domain strengths and interests of entering undergraduate engineering students for placement into a major.

Methods

Quantitative research methods were used to analyze historical data. The purpose of analyzing survey response data is to determine how the independent variable, specificity of discipline, impacts the dependent variable, occupational alignment.

Data Source

The National Survey of College Graduates (NSCG) published by the National Center for Science and Engineering Statistics (NCSES) was utilized. The United States Census Bureau is responsible for administering the survey under National Science Foundation guidance and sponsorship through web surveys, mail surveys, and computer-assisted telephone interviews (NCSES, n.d.). The data is available in a digital format biennially, and survey responses between 2010 and 2019 were used. This year selection intentionally omits participant responses for surveys conducted on or before 2008, as a survey design change occurred after the 2008 survey. Other than the larger design change after 2008, only small changes to survey questions have occurred throughout the years, such as occupation or education title adjustments to reflect more recent taxonomies and variable name adjustments.

Survey Reliability and Validation

As the NSCG contains only demographic questions and does not claim to measure constructs, validation and reliability evidence was not required for this survey.

Procedure

Survey response data from the NSCG was downloaded from the Scientists and Engineers Statistical Data System data download website (https://ncsesdata.nsf.gov/datadownload/). These files are available for public use as a Statistical Analysis Software (SAS) file, meant for use with the SAS statistical software suite. However, this file type can be converted into a Microsoft Excel file, and was converted for ease of data clean up.

Data Clean Up

Before analysis took place, the original data set was first decoded and cleaned. The major responses of interest and their NSCG descriptions are shown in Table 1. These responses were kept and combined for the 2010, 2013, 2015, 2017, and 2019 NSCG data sets. Only engineering majors having a bachelor's degree as their highest degree type were included, as to not address graduate school influences on occupation in this study. Also, returning participant responses were deleted, leaving only first-time participant responses.

Table 1 Major Responses of Interest - Names and Descriptions for Decoding

NSCG data variable name	Description
Demographic/General	
GENDER	Gender
COHORT	Survey cohort
Education	
BSDGN	Number of bachelors or higher degrees
DGRDG	Highest degree type
NDGRMED (2010 - 2017)	Field of study for highest degree
N2DGRMED (2019 only)	Field of study for highest degree
Job variables	
OCEDRLP	Extent that principal job is related to highest degree
JOBSATIS	Job satisfaction
NRREA	Most important reason for working outside field of highest degree

Missing information was coded in the original data as "998", "9998", "9999998", or "Logical Skip". If the numerically-coded missing information was for a response of interest from Table 1, the entire participant response was omitted from the data.

Participants

Participant overlap exists from 2010 to 2019, as a major change in the design after the 2008 survey allows for participants, beginning in 2010, to complete a baseline survey and three biennial follow-up surveys (NCSES, n.d.). Thus, survey participants can complete up to four surveys over approximately a six-year period. For this study survey data between 2010 and 2019 was used, and participant redundancy was removed. Only participants' first survey responses were analyzed, as relatedness of career choice upon graduation was of interest and first responses capture this information.

The target population for the NSCG includes individuals who meet the following criteria:

1. Earned a bachelor's degree or higher prior to January 1 of the year before the survey was administered.
2. Are United States residents younger than 76 years old as of February 1 of the year the survey was administered.
3. Are not institutionalized as of February 1 of the year the survey was administered.

After removing participant responses beyond their initial survey participation by utilizing the "COHORT" variable, 194,571 responses were available for analysis. Excluding participants who earned above a bachelor's degree yielded 100,896 responses. Finally, including only those participants who earned a bachelor's degree in an engineering discipline left 18,841 responses for analysis. The breakdown for demographics of interest for remaining participants is shown in Table 2.

Table 2 Participant Structure by Cohort and Gender

Cohort year	Gender		Total
	Male	Female	
2010	3,425	542	3,967
2013	4,444	758	5,202
2015	2,377	426	2,803
2017	2,440	483	2,923
2019	3,278	668	3,946
Total	15,964	2,877	18,841

Variables

The variable of interest, or dependent variable, was occupational alignment. This variable was denoted in the NSCG data as "OCEDRLP", which represents the responses to the survey question "To what extent was your work on your principal job related to your highest degree?". This variable contains three levels - not related, somewhat related, and closely related. The independent variable, specificity of discipline, was also analyzed at three levels. The discipline levels are general engineering, traditional engineering, and specific engineering. These levels were populated from decoding the NSCG data using the variable "NDGRMED" or "N2DGRMED" (for 2019 data), which was the field of study for participant degree (major). The "NDGRMED" and "N2DGRMED" survey responses were categorized based on the specificity of discipline guidelines established in the previous "Research Question" section, but are summarized as follows:

1. *General engineering* – Consists of only general engineering majors
2. *Traditional engineering* – Consists of mechanical, electrical, chemical, industrial, and civil engineering majors

3. *Specific engineering* – Consists of all other engineering disciplines not considered in the "traditional engineering" or "general engineering" categories

Demographic Variables of Interest

Because women are less likely to have plans to enter engineering practice after graduation and are less likely to be retained in the field (Frehill, 2007), gender was analyzed in this study. Cohort year was also examined to account for labor market variations over time.

Analysis

Statistical Package for Social Sciences software (IBM Corporation, 2020) was used for analysis after data clean up in Microsoft Excel (Microsoft Corporation, 2019). Significance was tested using a chi-square test. If the calculated chi-square significance value was less than the chosen significance alpha level of .05, the variables were determined to be related (dependent). Analysis of the proportions was completed using crosstabulation with percentages for the levels of variables found to have a relationship. The percentages were used to evaluate the degree of relation between occupational alignment and specificity of degree.

Results

A total of 18,841 responses were analyzed to determine the extent that current job is related to degree earned. Responses were grouped based on specificity of the engineering degree earned by the respondent. The percentages of each occupational alignment response for each specificity of engineering degree are shown in Table 3.

Table 3 Occupational Alignment Proportions for Each Specificity of Discipline

Occupational alignment	Specificity of discipline			
	Specific engineering (N = 3,068)	Traditional engineering (N = 15,593)	General engineering (N = 180)	Total (N = 18,841)
Closely related	62.3% $_a$	65.9% $_b$	48.9% $_c$	65.1%
Somewhat related	27.2% $_a$	27.3% $_a$	37.8% $_b$	27.4%
Not related	10.5% $_a$	6.8% $_b$	13.3% $_a$	7.5%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

The general engineering degree specificity had the lowest percentage of respondents in jobs closely related to their degree earned and the largest percentage of respondents in jobs not related to their degree earned. The opposite is true for the respondents earning traditional engineering degrees. Traditional engineering possessed the highest percentage of respondents in jobs closely related to their degrees and lowest percentage of respondents in jobs not related to their degrees.

A chi-square test of significance was used to determine the existence of any statistically significant relationships between specificity of discipline and occupational alignment. The null hypothesis of no statistically significant difference between specificity of disciplines for occupational alignment should be rejected, $\chi^2(4, N=18{,}841) = 73.30, p < .001$. We can conclude that there exists a statistically significant relationship between specificity of discipline and occupational alignment.

The subscripts in Table 3 – a, b, and c – on the response count in each specificity indicate that SPSS found the column proportions to differ significantly from each other at the 0.05 level for each level of occupational alignment. Therefore, each occupational alignment level – closely, somewhat, and not related – is analyzed independently from the other levels using the pairwise analysis method with subscripts. As such, columns should be compared across columns, but not across rows. The “Closely Related” level encompasses 65.1% of the overall responses to the survey. The largest percentage at this level is seen in the traditional degree specificity. The “Somewhat Related” level includes 27.4% of the total responses, with general engineering specificity leading that level in responses, followed by both specific and traditional engineering specificities, as there is no statistically significant difference between the two at that level. The “Not Related” level held the smallest proportion of responses (7.5%). This level had more proportion contained in both the specific and general engineering specificities and less proportion in traditional engineering.

Analysis by Gender

The percentages were then analyzed by gender. The percentage reporting occupational alignment for both males $\chi^2(4, N = 15{,}964) = 54.00$, $p < .001$ and females $\chi^2(4, N = 2{,}877) = 13.37$, $p = .010$ differed by specificity of discipline. Out of the 18,841 responses, 2,877 were from females and 15,964 from males. Table 4 shows the post hoc analysis results.

Table 4 Occupational Alignment Proportion Relationships by Gender

Occupational alignment	Post-hoc comparison – significant differences	
	Male	Female
Closely related	Traditional > Specific > General	Traditional & Specific > General
Somewhat related	General > Specific & Traditional	General > Specific & Traditional
Not related	General & Specific > Traditional	Specific > Traditional (No difference between General and Specific or General and Traditional)

At the "Closely Related" level females show no statistically significant difference between traditional and specific engineering, while males show differences between all three levels of specificity. At the "Somewhat Related" occupational alignment level, both genders show the same trend of general specificity having the largest percentage, followed by both specific and traditional engineering specificities, as there is no statistical difference between the two for both genders. At the "Not Related" level of occupational alignment, males have a statistical difference between both general and specific and traditional. General and specific engineering specificities both have larger proportions of "Not Related" occupational alignment than traditional engineering. For females, there is no statistically significant difference between general and specific and general and traditional engineering. However, there is a statistically significant difference between specific and traditional, with specific having a larger proportion of "Not related" responses than traditional engineering.

For both genders, the traditional engineering discipline had the highest proportion of "Closely Related" occupational alignment, either followed by or tied with specific engineering. General engineering had the lowest proportions of "Closely Related" responses for both genders.

Analysis by Cohort

Responses for all participants were analyzed by cohort year in order to look for corresponding trends with the job market and economic factors. Of the five cohort years analyzed, only 2017 possessed no statistically significant differences between specificity of discipline in relation to occupational alignment. All other cohort years studies found statistically significant relationships, as seen in Table 5.

Table 5 Chi-Square Tests of Significance for Cohort Years

Cohort year	Pearson chi-square value	df	Asymptotic significance (2-sided)
2010	46.58	4	<.001
2013	9.85	4	.043
2015	19.67	4	.001
2017	6.08	4	.186
2019	18.51	4	.001

Statistically significant differences in proportions were analyzed via crosstabulation post hoc analysis. Results from this analysis are displayed in Table 6.

Table 6 Occupational Alignment Proportion Relationships by Cohort Year

Occupational alignment	Post-hoc comparison – significant differences				
	2010	2013	2015	2017	2019

Closely related	Traditional > Specific & General	None	Specific & Traditional > General	None	Traditional > General (No difference between Specific and Traditional or Specific and General)
Somewhat related	General > Specific & Traditional	None	General > Specific & Traditional	None	None
Not related	Specific > Traditional (No difference between General and Specific or General and Traditional)	Specific > Traditional (No difference between General and Specific or General and Traditional)	Specific > Traditional (No difference between General and Specific or General and Traditional)	None	General > Specific > Traditional

As shown in Table 6, the highest percentage of "Closely Related" responses was reported by the traditional specificity group in three cohorts. For cohort year 2015, no statistically significant difference was found between specific and traditional engineering, but otherwise the traditional engineering discipline had the highest proportion for all years reporting statistically significant differences. At the "Somewhat Related" level, general engineering specificity had the highest proportion, though three years showed no statistically significant differences between specificities for this level. At the "Not Related" level of occupational alignment, specific engineering had the highest percentage of responses for the earliest three years, and general engineering had the largest proportion for cohort year 2019.

Analysis of Reasons for Working Outside of Field

Of the 18,841 usable survey responses, 1,414 (7.5%) reported that their job was not closely related to their degree field. Those participants were then asked to provide the most important reason for working outside their field of study from a standardized list of options, seen in Table 7. Across all specificities, "job in highest degree field not available", "pay or promotion opportunities", and "change in career or professional interests" were the most reported responses. For specific engineering specificity of discipline, approximately 25% of respondents indicated they were working outside of their field of study because a job in their field was not available. For general engineering, the same percentage reported working outside of their field for pay or promotion opportunities. Traditional engineering's most commonly reported reason for working outside of their degree field was due to a change in career or professional interest.

Table 7 Percentage of Each Specificity of Discipline Reporting Reasons for Working Outside of Field of Study

Reason for working outside of field of study	Specific engineering	Traditional engineering	General engineering	Total
Job in highest degree field not available	25.2%	19.8%	20.8%	21.0%
Pay, promotion opportunities	18.9%	19.9%	25.0%	19.8%
Change in career or professional interests	17.1%	20.6%	20.8%	19.8%
Family-related reasons	14.3%	11.0%	8.3%	11.7%
Working conditions	8.7%	10.8%	8.3%	10.3%
Other reason for not working	8.1%	9.5%	8.3%	9.1%
Job location	7.8%	8.4%	8.3%	8.3%

Analysis of Job Satisfaction

Job satisfaction was viewed across both levels of occupational alignment and specificity of discipline. The highest percentage of "Very Satisfied" responses was found in the "Closely Related" occupational alignment. The highest percentage of "Somewhat Satisfied" responses was found in the "Somewhat Related" occupational alignment. The highest percentage of "Not Satisfied" responses was found in the "Not Related" occupational alignment. These observations can be seen in Table 8. Across specificities of discipline, traditional engineering leads in "Very Satisfied" job satisfaction scores, though by less than one percent. Specific engineering specificity has the highest percentage of "Very Dissatisfied" job satisfaction scores, which is found in the "Not Related" section of occupational alignment.

Table 8 Job Satisfaction across Occupational Alignment and Specificity of Discipline

Occupational alignment	Job satisfaction	Specificity of discipline: Specific engineering	Traditional engineering	General engineering	Total
Closely related	Very satisfied	48.0%	48.7%	46.6%	48.6%
	Somewhat Satisfied	45.4%	45.1%	47.7%	45.2%
	Somewhat dissatisfied	5.2%	5.1%	5.7%	5.1%
	Very dissatisfied	1.4%	1.0%	0.0%	1.1%
Somewhat related	Very satisfied	35.3%	34.7%	41.2%	34.9%
	Somewhat Satisfied	52.2%	53.1%	47.1%	52.9%
	Somewhat dissatisfied	10.5%	10.2%	10.3%	10.2%
	Very dissatisfied	1.9%	2.1%	1.5%	2.0%
Not related	Very satisfied	32.3%	27.9%	37.5%	29.1%
	Somewhat Satisfied	44.7%	50.8%	41.7%	49.3%
	Somewhat dissatisfied	14.3%	15.0%	16.7%	14.9%
	Very dissatisfied	8.7%	6.3%	4.2%	6.8%

Discussion

Over 93% of respondents from the five degrees that make up the traditional specificity are reported working in jobs that were at least somewhat related to their degree, while almost 90% of specific engineers and 87% of general engineers reported working in occupations at least somewhat related to their degrees. These percentages indicate that the traditional specificity finds some level of occupational alignment most and general engineering specificity finds some level of occupational alignment least. At this overarching level, the practical implication for practitioners in the academic advising realm is to advise students into a traditional engineering specificity for the most probability of some level of occupational alignment. If engineering institutions want a *high* level of occupational alignment for their students after graduation, responses for "closely related" occupational alignment should be the variable of interest. Analysis of "closely related" responses shows the same findings as the overarching level of analysis - Engineers with traditional engineering degrees are working in closely related jobs the highest proportion (65.9%) of all specificities. Engineers with general engineering degrees are working in the lowest percentage (48.9%) of closely related jobs. These results are consistent with the findings by Ro (2011) which indicated that students majoring in general engineering have greater odds of pursuing non-engineering careers. A high percentage of specific engineering degree recipients (62.3%) reported working in jobs closely related to their field of study. However, this percentage is lower than traditional engineering degree recipients (65.9%). More specific does not lead to the most closely related jobs, necessarily. Traditional engineering degrees appear to be specific enough to be attractive to employers but also broad enough to provide a larger number of employment opportunities in related jobs. These findings are consistent with results from a previous study by Sheppard and colleagues (2014) which found that the traditional engineering major was more likely to have an engineering-related plan after graduation than a more specific engineering major. Because traditional engineering disciplines have a longer history than some specific and general engineering disciplines, there may be a bias in industry toward traditional engineering specificities, making occupational alignment for the traditional specificity easier. This is further discussed in following sections, and could be the reason why general and specific engineering specificities report higher proportions of "not related" occupational alignment (13.3% and 10.5%, respectively) than the traditional specificity (6.8%).

Gender

The female respondents in this study represented only 15.3% of the total respondents. This small sample size supports the literature stating that women are less likely to plan to enter engineering careers and are less likely to be retained in the engineering profession (Frehill, 2007). The occupational alignment percentages across specificities showed that females find “closely related” occupational alignment in *both* specific and traditional specificities most, while males find “closely related” occupational alignment most in the traditional specificity alone. This may be due to survey response variations related to personal perception of occupational alignment. Since all data is self-reported in the NSCG, personal perceptions influence responses. However, if the data is taken at face-value, then these results indicate that females have more engineering discipline options available that potentially yield close occupational alignment. Conversely for females, the highest level of “not related” occupational alignment is also found in the specific specificity. Thus, recommendations for females to major in specific disciplines for the highest possibility of close occupational alignment may not be the best path, as specific disciplines lead in both the “closely related” and “not related” levels of occupational alignment for females. The traditional specificity may be a more reliable option for guiding both genders of students to occupational alignment after graduation.

Cohort

When the results were broken down by cohort, the proportions mostly mirrored the overall results for all the years. All but one of the years showed significantly different percentages between at least one of the specificities. Only one cohort year, 2017, showed no statistically significant relationship between occupational alignment and specificity of discipline. The traditional engineering specificity had the highest percentage of closely related jobs for all of the cohort years showing statistically significant relationships, followed by specific engineering degrees.

Economic recessions and variations in the number of job openings from year to year could cause engineering majors to enter into non-related jobs. This could explain the differences in proportions from year to year. The Bureau of Labor Statistics reported no recession and an increase in engineering jobs needed for the United States in 2017 (Torpey, 2018), so those two reasons should not be considered for the non-significant relationship between occupational alignment and specificity of discipline for 2017. The reported job outlook for engineering and architecture positions between 2010 and 2020 saw a growth of 252,800 positions, or a 10.4% increase (Lockard, 2012). This growth included positive values in all but nuclear engineering (BLS, 2020), which falls within the specific engineering specificity, and may slightly attribute to differences between specific engineering specificity and the two other specificities, though nuclear engineering is a very small portion of the specific level of discipline. The most recent economic recessions documented by the Federal Reserve Bank (Sahm, 2021) occurred between 2008 and 2009, and then more recently in 2020. These recessions are before and after the cohort years evaluated in this study, thus should not be a valid reason for differences between cohort years, except for cohort year 2010, which may have been impacted from the recession ending in 2009.

Based on the Bureau of Labor Statistics data (BLS, 2020), economic conditions and job availability seem to have equitably impacted all engineering disciplines, except for nuclear engineering. This may be the reason for similar trends shown in each year with statistically significant differences between depths of discipline. The one interesting difference that stands out is encompassed in the "not related" occupational alignment category. In 2019, general engineering took the lead over specific engineering for the largest proportion of "not related" occupational alignment. The reason for the takeover is unknown, but may relate to the changing industry and political climate of the nation at the time. The focus of the administration of that time focused more on increasing manufacturing in the country (DeVore, 2019), which may lend itself to more traditional and specific depths, rather than the general engineering depth. Reasons for Working Outside of Field of Study

Reasons for Working Outside the Field of Study

Only 7.5%, or 1,414 participants, reported that their occupation did not align with their degree. Out of seven standardized choices, the top three reasons engineering graduates reported for working outside of their fields were:

1. A job in their degree field was not available (21.0%)
2. A change in career or professional interest (19.8%)
3. Pay or promotion opportunities (19.8%)

Of those individuals not working in their field of study, the most prominent reason for specific engineering disciplines to work outside of their field was due to a job in their field of study not being available. This connotates being forced outside of their field of study, rather than choosing to do so of their own desire. Academic advisors assisting in student major selection should be acutely aware that 10.5% of specific engineering graduates do not work in an occupation closely related to their degree, and of that percentage, about a quarter do so because an occupationally aligned job was unavailable.

Traditional engineering disciplines reported working outside of their field of study most because of a change in career or professional interests. However, closely following this leading reason were the reasons of "pay, promotion opportunities" and "job in highest degree field not available". The less than one percent difference in response proportions for the three reasons indicates that traditional engineering graduates work outside of their field due to both positively and negatively associated reasons.

General engineering specificity participants reported pay or promotion opportunities as the most prominent reason for working outside of their degree field. While this response may seem like a positive reason, it could also indicate that more broad engineering jobs do not pay as well as engineering jobs aligning with more specific depths of discipline, thus driving general engineers to other career paths.

These reasons for working outside of their field of study give engineering institutions insight into obstacles their students may face after graduation. While engineering institutions may not be able to mitigate challenges to obtaining occupationally aligned jobs, they could impart this knowledge to incoming students, so students know their probabilities of occupational alignment and potential hurdles they face in obtaining such employment before they commit to a major.

Job Satisfaction

Job satisfaction seemed to correlate with occupational alignment, though not formally tested. "Closely Related" occupational alignment had the highest reporting of "Very Satisfied" job satisfaction, "Somewhat Related" had the highest reporting of "Somewhat Satisfied" job satisfaction, and "Not Related had the highest reporting of "both "Somewhat Dissatisfied and

"Very Dissatisfied" job satisfaction. These findings indicate that occupational alignment and job satisfaction are positively related. Differences in job satisfaction between specificity of discipline were minimal. These results suggest that if engineering students want to be satisfied in their careers, they should strive to find a job that is aligned with their field of study, whatever specificity of discipline that might be.

Limitations

Analysis in this study was performed on self-reported survey data from respondents. While respondents were asked to answer as accurately as possible, the survey results are based on respondents' *perceptions*, and individual perceptions do differ. Therefore, two participants choosing between "closely related" and "somewhat related" occupational alignment may perceive their current occupations as the same level of occupationally aligned, but may judge the two levels of alignment differently, based on their perceptions of what each option means, and thus choose different responses from one another.

A large number of respondents were analyzed, but the number of respondents in each of the engineering specificities should be noted. Out of the 18,841 responses analyzed, only 180 of them represented general engineering majors. That means that only 0.96 percent of respondents fell into the general engineering specificity of discipline. Though the results were consistent with previous studies, the small number of general engineering respondents means that general engineering majors are not well represented in the data as compared with specific and traditional majors.

Future Work

This study examines the number of engineering majors working in jobs related to their major at the time of the survey. Additional factors to be researched include the length of time engineering graduates work in an engineering field as well as career paths taken over the lifetime of an engineering career. Reasons for not pursuing an engineering major-related job at all after graduation could also be investigated. The most beneficial results may come from a deeper qualitative assessment, potentially in the form of interviews, that extract the reasons and circumstances surrounding occupational decisions. Additionally, comparison to other science, technology, engineering, and math graduates may find that occupational alignment for engineering graduates may not differ substantially from the other three branches of STEM. If this is true, the findings and recommendations of this study may be generalizable across all STEM degrees.

Conclusion

This study included analyzing data from the National Survey of College Graduates published by the National Center for Science and Engineering Statistics for a subset of 18,841 responses from engineering graduates. The purpose of the study was to identify any relationships between occupational alignment and specificity of discipline.

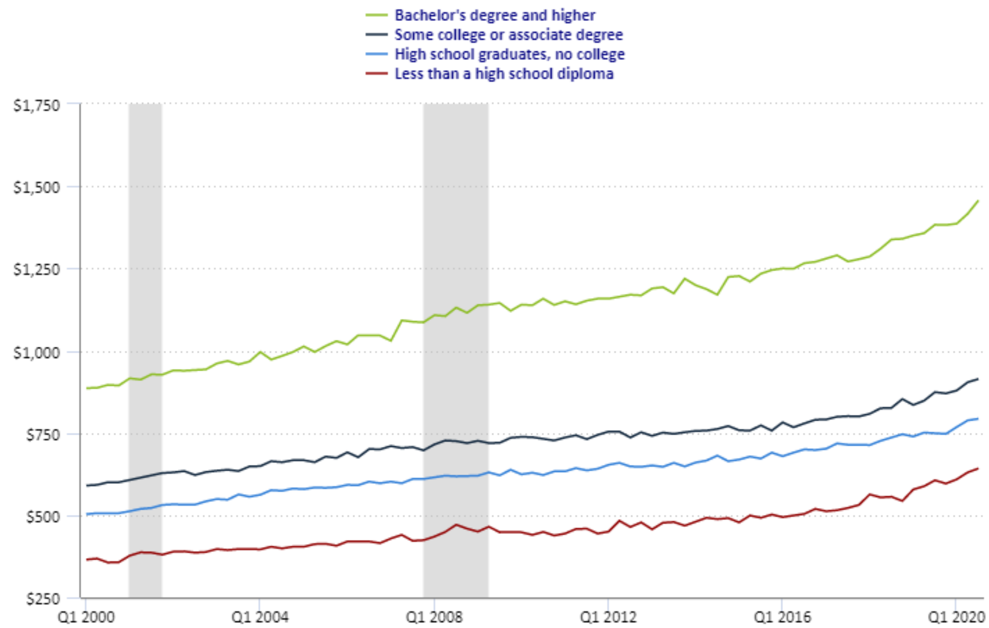
Analysis included chi-square tests of significance as well as crosstabulations to compare proportions of responses. Ultimately, the study found that specificity of discipline does impact occupational alignment, however not in the linear, monotonic relationship expected. Traditional engineering is found to have the most occupationally aligned graduates, followed closely by specific, and then general engineering. Occupational alignment is of importance, because job satisfaction seems to be positively correlated to occupational alignment. As alignment increases, so does job satisfaction. These results indicate that engineering institutions offering traditional engineering degrees prepare students for available employment positions that most align with their degrees. It is recommended that engineering institutions continue to offer the five engineering majors that comprise traditional engineering, and any specific engineering majors to give students the best possibility for occupational alignment after graduation. General engineering majors should be offered with caution, as this major finds the least amount of occupational alignment.

CHAPTER III

STUDY 2: SPECIFICITY OF DISCIPLINE AS AN INFLUENCE ON ENGINEERING GRADUATE SCHOOL DECISIONS

Introduction

Post-graduate alternatives for engineering majors abound, as students obtaining an undergraduate degree in engineering become fully-qualified to work in the profession with only a bachelor's degree. This is somewhat unique, as most degrees considered "professional" are not fully-qualified until a terminal degree is obtained (Kam & Peskin, 2007). While there is argument to transform engineering into a learned profession, like medicine or law, which require a graduate degree (Dorato, 2008; Duderstadt, 2008), at present engineers need only a bachelor's degree to work in the profession. The United States Bureau of Labor Statistics indicates people with a bachelor's degree out-earn people with no high school diploma by 57% (U.S. Bureau of Labor Statistics, 2020b), as seen in Figure 2.



Note: Shaded areas represent recession, as determined by the National Bureau of Economic Research

Figure 2 Median Weekly Earnings of Full-time Wage and Salary Workers 25 Years and Older, by Educational Attainment, Quarterly Averages 2000-2020 (U.S. Bureau of Labor Statistics, 2020b)

Even more impressive is that in 2019 engineers with undergraduate degrees earned a median $1,817 weekly (U.S. Bureau of Labor Statistics, 2020a), as opposed to the $1,357 weekly median for college graduates in 2019, shown in Figure 2. This would seem to indicate that earning an engineering degree is a great value, as working in the profession does not require graduate school, and yields higher than average salaries over all college graduates.

With such a positive career outlook for undergraduate engineering majors, do engineering undergraduate students normally choose to attend graduate school? A graduate degree comes with its own benefits, including; additional domain knowledge gain, additional career opportunities available to only those with graduate degrees, and extra earning potential

(Anderson-Rowland et al., 2005), to name a few. This study aims to examine which engineering majors attend graduate school, and if they do, are they supplementing their undergraduate domain or complementing their undergraduate domain with a different domain?

Background

Current State of Research

Research endeavors to study the reasons engineering students pursue graduate degrees do exist. These studies look at many influencing factors, though most examine the issue through undergraduate responses on surveys of their *expected* plans after graduation, not on actual outcomes. The state of research is limited in quantity, but rich in quality.

Ro, Lattuca, and Alcott (2017) studied the connection between mathematics proficiency, match between qualifications and interests, and effect of college experiences on graduate school decisions. After surveying 1,403 engineering undergraduate students across multiple institutions, mathematics proficiency prior to college was confirmed to influence enrollment in a graduate program. In agreement with social cognitive career theory (Lent et al., 2008), they found interests cultivated from undergraduate research exposure positively affected graduate school enrollment. Higher self-reported leadership skills increased the likelihood of attending graduate school, whereas students with a higher self-report of teamwork skills were less likely to attend graduate school (Ro et al., 2017). These leadership and teamwork skills findings align with self-efficacy theory (Bandura, 1986), indicating that students persist in domains in which they feel confident. If students feel confident in teamwork, they are likely ready to experience an entry-level engineering position, but those who are confident in leadership skills are likely to desire further preparation to better their chances of gaining a leadership role (Ro et al., 2017).

In 2011, Ro completed a study analyzing influences on engineering student post-graduation plans. Ro considered pre-college characteristics, academic program experiences, and self-assessment of engineering abilities in the survey-based experiment. According to the study, pre-college characteristics do not significantly impact plans for graduate school. Within academic program experiences, six engineering disciplines were considered, plus a group considered "other" engineering. Table 9 and Table 10 show parameter estimates from Ro's 2011 survey results regarding graduate school attendance in relation to discipline. It is important to note that each program calculation is a comparison to mechanical engineering, and each parameter estimation is a comparison to the survey response option *Definitely Won't*.

Table 9 Parameter Estimates for Graduate School Plans for Engineering Faculty Jobs (Ro, 2011)

	Probably Won't[8]				Not Sure[8]				Probably Will[8]				Definitely Will[8]			
	Coef.	Robust Std. Err.	z	p-value	Coef.	Robust Std. Err.	Z	p-value	Coef.	Robust Std. Err.	z	p-value	Coef.	Robust Std. Err.	z	p-value
Academic Program Exp.																
Bio Eng.[6]	-0.214	0.299	-0.72	0.474	1.545	0.319	4.85	0.000	1.327	0.404	3.28	0.001	1.982	0.706	2.81	0.005
Chemical Eng[6]	0.112	0.208	0.54	0.590	0.955	0.269	3.55	0.000	0.823	0.400	2.06	0.040	1.383	0.586	2.36	0.018
Civil Eng.[6]	0.418	0.230	1.82	0.069	1.137	0.300	3.79	0.000	0.789	0.425	1.86	0.063	1.228	0.663	1.85	0.064
Electrical Eng.[6]	0.020	0.267	0.08	0.939	1.206	0.318	3.79	0.000	1.195	0.444	2.69	0.007	1.942	0.626	3.10	0.002
General Eng.[6]	-2.395	0.556	-4.31	0.000	1.118	0.457	2.45	0.014	-1.162	0.595	-1.95	0.051	-2.145	1.175	-1.83	0.068
Industrial Eng.[6]	0.088	0.312	0.28	0.779	0.150	0.435	0.35	0.730	0.011	0.625	0.02	0.986	2.228	0.861	2.59	0.010
Other Eng.[6]	0.226	0.453	0.50	0.617	1.811	0.478	3.79	0.000	1.566	0.608	2.57	0.010	2.287	0.942	2.43	0.015

6. Compared to Mechanical Engineering students
7. Compared to junior students
8. Compared to reference category *Definitely Won't*

Table 10 Parameter Estimates for Graduate School Plans for Engineering Professions (Ro, 2011)

	Probably Won't[8]				Not Sure[8]				Probably Will[8]				Definitely Will[8]			
	Coef.	Robust Std. Err.	z	p-value	Coef.	Robust Std. Err.	z	p-value	Coef.	Robust Std. Err.	z	p-value	Coef.	Robust Std. Err.	z	p-value
Academic Program Exp.																
Bio Eng.[6]	0.445	0.457	0.97	0.330	-0.449	0.325	-1.38	0.167	0.298	0.377	0.79	0.430	0.713	0.525	1.36	0.174
Chemical Eng[6]	0.202	0.311	0.65	0.516	-0.360	0.302	-1.19	0.234	0.008	0.341	0.02	0.982	0.513	0.475	1.08	0.280
Civil Eng.	0.138	0.363	0.38	0.703	0.351	0.344	1.02	0.309	1.041	0.386	2.70	0.007	0.903	0.490	1.84	0.065
Electrical Eng.[6]	0.117	0.404	0.29	0.772	0.046	0.383	0.12	0.903	1.244	0.418	2.98	0.003	2.083	0.542	3.84	0.000
General Eng.[6]	1.620	0.593	2.73	0.006	-0.799	0.409	-1.95	0.051	1.913	0.412	4.64	0.000	0.275	0.675	0.41	0.684
Industrial Eng.[6]	0.269	0.529	0.51	0.612	0.316	0.492	0.64	0.521	0.396	0.558	0.71	0.479	0.720	0.818	0.88	0.379
Other Eng.[6]	1.945	0.769	2.53	0.011	1.811	0.666	2.72	0.007	2.731	0.674	4.05	0.000	2.868	0.829	3.46	0.001

6. Compared to Mechanical Engineering students
7. Compared to junior students
8. Compared to reference category *Definitely Won't*

To summarize Ro's findings: bio engineering, chemical engineering, civil engineering, electrical engineering, industrial engineering, and "other" engineering have positive relationships with attending graduate school for academia, compared to mechanical engineering. Civil engineering, electrical engineering, general engineering and "other" engineering have positive relationships with attending graduate school for engineering professions, compared to mechanical engineering. It seems majoring in civil engineering, electrical engineering, or "other" engineering programs increased the odds of graduate school plans, overall (Ro, 2011).

Self-assessments determined that low perceived contextual competence (i.e., understanding broader social contexts) was negatively related to graduate school plans, while high perceptions of fundamental skills (i.e., skills regarding applying math and science to engineering problems) positively impacted plans to attend graduate school (Ro, 2011).

Theoretical Framework

Based on previous literature, two themes emerge as foundational theories for engineering graduate school decisions: Social cognitive career theory and self-efficacy theory.

Social Cognitive Career Theory

Bandura's (1986) general social cognitive theory is the basis for SCCT. However, SCCT is more specific than Bandura's original theory, as it emphasizes how individuals act with motivation and direction in their career development (Lent et al., 1994). Within the SCCT model, major choice goals represent major career decisions, including the decision to attend graduate school. The three main factors impacting major choice goals are self-efficacy, preferences (also known as interests), and outcome expectations (Lent et al., 2008). The correlations between these factors and their impact on major choice goals are represented in Figure 3.

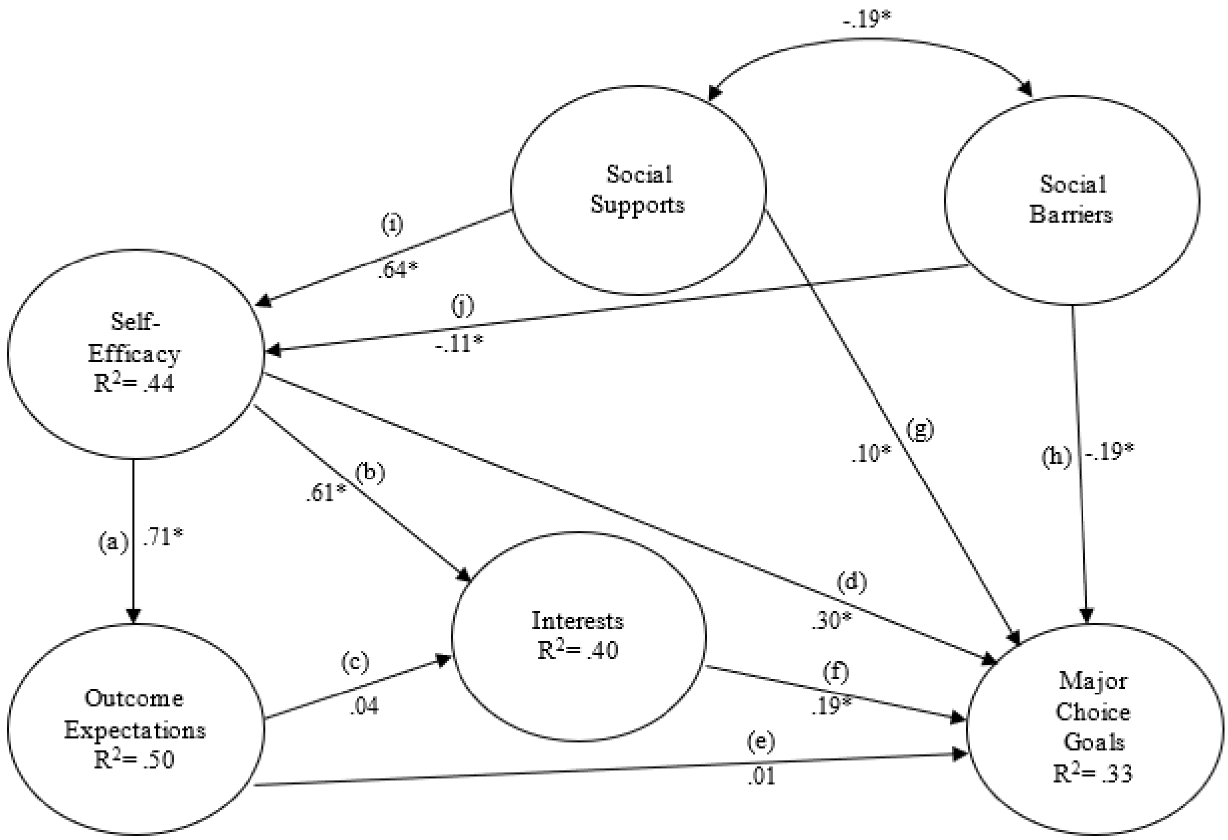


Figure 3 Social Cognitive Career Theory Structural Model * $p < .05$ (Lent et al., 2008)

As seen in the figure, each moderate to strong positive correlation (paths (a) = .71, (b) = .61, (i) = .64, and (d) = .30) involves self-efficacy, leading to the conclusion that self-efficacy is the most significant influencer of major choice goals.

Self-Efficacy

Since self-efficacy is the most potent determinant of major choice goals within SCCT, it makes practical sense to consider the concept of self-efficacy more thoroughly. Referring to an individual's beliefs in their capabilities to achieve a particular outcome (Bandura, 1986), self-efficacy can be applied in any domain (Bandura, 1997). When this construct is applied to engineering education, the construct can be more specifically coined “engineering self-efficacy” (Concannon & Barrow, 2012). Similarly, self-efficacy can be more granularly applied to knowledge spheres and skills areas. Ro (2011) reports that students with higher self-efficacy in their fundamental engineering skills are more likely to enter graduate school, while higher contextual and design self-efficacy negatively impacts graduate school plans. As such, could this mean that engineering students studying a very specific domain require additional education to feel wholly confident in their overall engineering abilities? Rather, could it mean that general engineering degrees offer opportunities for self-efficacy across a broad spectrum, which means students need additional education to increase self-efficacy in a specific domain? The following research questions aim to provide insight to these ponderings.

Research Questions

The objective of the research questions at hand is to understand which engineering disciplines seek graduate degrees, and what those graduate disciplines of study are, in relation to students' undergraduate disciplines. Formally, the research questions are:

Q1: Do engineering students with more specific undergraduate degrees seek graduate degrees?

Q2: Do engineering students with more specific undergraduate degrees seek more general graduate degrees and vice versa?

Specificity of Discipline

For this study, three levels of discipline are examined. These levels, each deemed a “specificity of discipline”, refer to the breadth of focus contained within the program of study, for both undergraduate and graduate degree programs.

1. *General engineering.* This is the broadest discipline considered. In this level of specificity, the focus is interdisciplinary, and students are expected to be able to apply knowledge of engineering to design experiments and solve problems.
2. *Traditional engineering.* This level considers the engineering disciplines of mechanical, electrical, chemical, industrial, and civil engineering, due to their long-standing acceptance as engineering majors and historical associations. Between 1966 and 2012, these five engineering disciplines were consistently awarded the most degrees per year, as indicated in the National Science Foundation's detailed statistical report, Science and Engineering Degrees: 1966–2012 (NSF, 2015). From a historical perspective, civil engineering is considered the first engineering discipline, followed by the other four disciplines around the time of the Industrial Revolution. This grouping is based upon the historical similarity and longstanding acceptance as engineering disciplines. This level of discipline is more specific than general engineering, as there is an applied focus in each discipline not found in a general engineering discipline.
3. *Specific engineering.* This level considers all engineering disciplines not considered in the "traditional engineering" or "general engineering" categories. These disciplines have been created through modification of the traditional engineering disciplines or through an identified gap in traditional engineering disciplines, and thus could be considered narrower in focus. This level includes engineering disciplines such as aerospace engineering, petroleum engineering, computer engineering, metallurgical engineering, and biomedical engineering.

Implications

By answering the research questions in this study, engineering institutions have the opportunity to benefit. By understanding which undergraduate engineering majors continue on to graduate school and what discipline graduate degrees they seek, engineering institutions can better design their undergraduate curriculum to help prepare students for graduate studies. For example, if this study finds that specific engineering majors tend to seek general graduate degrees, perhaps more general design and problem-solving skills course outcomes could be added to courses to encourage a more open-ended point of view for approaching problems.

Additionally, graduate programs could use the information found in this study to recruit potential students from undergraduate majors that tend to choose particular graduate disciplines. For instance, should it be discovered that general engineering undergraduate majors tend to gravitate toward traditional engineering graduate programs, those graduate programs could specifically recruit general engineering undergraduate students, because the probability of admitting those students is higher.

Methods

For both Q1 and Q2, quantitative research methods were used to analyze historical data.

Data Source

The National Center for Science and Engineering Statistics publishes a biennial report based on the National Survey of College Graduates, which was the sole data source for this study. Under the guidance of the National Science Foundation, the NSCG is administered by the United States Census Bureau through web surveys, mail surveys, and computer-assisted telephone interviews (NCSES, n.d.). Only survey responses between 2010 and 2019 were used in this study, as a significant survey design change occurred after the 2008 survey, making comparison with any years before the 2010 survey inconsistent with comparison to responses obtained in 2010 or later.

Procedure

Survey response data for the years 2010, 2013, 2015, 2017, and 2019 were downloaded from the Scientists and Engineering Statistical Data System data download website (https://ncsesdata.nsf.gov/datadownload/). Once downloaded, the data files were decoded and cleaned up to remove redundant participant responses, which left 194,571 records for analysis. After removing redundancy, the major response variables of interest shown in Table 11 were filtered to include only responses of interest.

Table 11 Major Responses of Interest Names and Descriptions for Decoding

NSCG data variable name	Description
GENDER	Gender
COHORT	Survey cohort
RACETHM	Race/ethnicity
Question 1 specific variables	
NBAMED/N2BAMED	Field of study of for first bachelor's degree
BSDGN	Number of bachelors or higher degrees
Question 2 specific variables	
NBAMED/N2BAMED	Field of study of for first bachelor's degree
NDGRMED/N2DGRMED	Field of study for highest degree

Participants missing responses to any of the major response variables of interest were omitted from the study. The variable “NBAMED/N2BAMED” was filtered to include only engineering bachelor’s degrees. This reduced the participant responses to 37,005.

Variables

Question 1

Research question one analyzes specificity of discipline in regards to graduate school degrees. As such, whether or not students obtain graduate degrees is the variable of interest, or dependent variable. In the NSCG data, this variable is represented as "DGRDG", which is the highest degree type that the survey participant has obtained, with the options including bachelor's, master's, doctorates, and professional degrees. The independent variable is specificity of discipline, which was evaluated at three levels – general engineering, traditional engineering, and specific engineering. Named "NBAMED" in years 2010-2017 of the survey and "N2BAMED" in the 2019 survey, when combined together yields the field of study for the participant's first bachelor's degree, this variable was categorized based on the specificity of discipline guidelines previously established in the "Research Questions" section.

Question 2

The second research question in this study focuses on participants' undergraduate degree discipline and compares it to their graduate degree discipline to see if their undergraduate and graduate disciplines align. The variable of interest is graduate degree discipline, while the independent variable is undergraduate degree discipline. Both have three levels – general engineering, traditional engineering, and specific engineering. The names of these variables, as named in the NSCG data are seen in Table 11, under the "QUESTION 2 SPECIFIC VARIABLES" section.

Demographic Variables of Interest

While underrepresented minority students (URM), a group consisting of Black, Hispanic, and Native Americans, express interest in graduate school at a rate one-and-a-half times more than non-URM students (Sheppard et al., 2010), Ro (2011) found that URM students also considered broader post-graduation options than did non-URM students. For this reason, trends between URM students and non-URM students were examined.

Engineering self-efficacy within genders has been studied extensively (Concannon & Barrow, 2012; Lent et al., 1986; Schaefers et al., 1997; Hackett et al., 1992; Concannon & Barrow, 2009) and findings repeat themselves – there is no significant difference between men and women's overall engineering self-efficacy. There is, however, evidence showing that women's general (not engineering) self-efficacy is relatively more connected with their engineering outcome expectations (Concannon & Barrow, 2012). For this reason, exploration of gender and graduate school attendance was conducted.

Participants

To be selected for participation in the NSCG, individuals must meet the following criteria (NCSES, n.d.):

1. Earned a bachelor's degree or higher prior to January 1 of the year before the survey is administered.
2. Are United States residents younger than 76 years old as of February 1 of the year the survey is administered.
3. Are not institutionalized as of February 1 of the year the survey is administered.

The structure of the 37,005 survey participants' demographic variables of interest is described by Table 12.

Table 12 Demographic Structure of Participants

Cohort year	Gender		Minority status		Total
	Male	Female	URM	Non-URM	
2010	7,130	1,339	1,305	7,164	8,469
2013	8,435	1,687	1,201	8,921	10,122
2015	4,392	926	707	4,611	5,318
2017	4,669	1,123	773	5,019	5,792
2019	5,912	1,392	1,033	6,271	7,304
Total	30,538	6,467	5,019	31,986	37,005

Analysis

Statistical Package for Social Sciences software (IBM Corporation, 2020) was utilized for significance and post hoc analysis for both research questions. Chi-square analysis of proportions was conducted, and if determined statistically significant, the crosstabulation with percentages analyzed for relationships between the dependent and independent variables. The percentages were used to evaluate the proportion of relation between graduate school decisions and specificity of discipline

Results

A total of 37,005 responses were analyzed to determine extent to which graduate school decisions related to bachelor's level specificity of discipline. Responses were categorized based on specificity of engineering degree earned by the respondent. The percentages of graduate school decision responses for each specificity of discipline are shown in Tables 13 and 14.

Table 13 Percentage of Each Discipline Specificity and if They Attended Graduate School

Graduate school attendance	Specificity of discipline			Total (N = 37,005)
	Specific engineering (N = 6,890)	Traditional engineering (N = 29,750)	General engineering (N = 365)	
Yes	45.4% $_{a}$	41.0% $_{b}$	44.4% $_{a, b}$	41.8%
No	54.6% $_{a}$	59.0% $_{b}$	55.6% $_{a, b}$	58.2%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

The traditional engineering degree specificity had the lowest percentage (41.0%) of respondents reporting graduate school attendance. The general engineering specificity followed (44.4%) and the specific engineering specificity had the highest percentage (45.4%) of respondents reporting graduate school attendance. Because the percentage of responses for "No" is the statistical complement to the percentage of responses for "Yes", only the "Yes" responses will be further evaluated for research question 1.

Table 14 Percentages of Each Discipline Specificity and the Specificity of their Graduate Degree

Graduate school specificity of discipline	Undergraduate specificity of discipline			Total (N = 15,483)
	Specific engineering (N = 3,131)	Traditional engineering (N = 12,190)	General engineering (N = 162)	
Specific engineering	44.0% $_{a}$	10.9% $_{b}$	14.2% $_{b}$	17.7%
Traditional engineering	14.1% $_{a}$	53.4% $_{b}$	22.2% $_{c}$	45.1%
General engineering	0.5% $_{a}$	0.6% $_{a}$	7.4% $_{b}$	0.6%
Non-engineering	41.4% $_{a}$	35.0% $_{b}$	56.2% $_{c}$	36.6%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

In evaluating graduate school specificity of discipline, non-engineering was added to provide an exhaustive sample space, as not all engineering undergraduates seek engineering graduate degrees. Based on percentages reported, specific engineering specificity students either remain within their specificity for graduate school or change to a non-engineering graduate program approximately the same proportion of the time (44.0% and 41.4%, respectively). Traditional specificity students remain within traditional engineering specificity for graduate school the majority of the time (53.4%), though they do change to non-engineering programs for graduate school often, as well (35.0%). General engineering specificity does not follow the same trend, as most of this specificity does not remain in the same specificity for graduate school. Only 7.4% of general engineering undergraduate students choose to study general engineering for graduate school. Most students in this grouping (56.2%) choose to attend a non-engineering graduate program.

To see a more granular picture of educational alignment in undergraduate and graduate degrees, further analysis was conducted to see if participants who attended graduate school changed *majors* between undergraduate and graduate school, even if the major change was within their specificity of discipline. Table 15 shows the proportion of each specificity that chose to attend graduate school for a different major than that of their undergraduate schooling. This crosstabulation showing proportions across specificities indicates that all specificities differ from one another, as shown by the subscript letters. General engineering specificity changes major most (92.6%), while traditional engineering specificity changes majors least (51.9%).

Table 15 Percentage of Each Discipline Specificity and if They Changed Majors between Undergraduate and Graduate School

Changed major?	Specificity of discipline: Specific engineering (N = 3,131)	Traditional engineering (N = 12,190)	General engineering (N = 162)	Total (N = 15,483)
Yes	64.9% $_a$	51.9% $_b$	92.6% $_c$	54.9%
No	35.1% $_a$	48.1% $_b$	7.4% $_c$	45.1%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

Question 1

A chi-square test of significance was used to determine if a statistically significant relationship existed between specificity of discipline and the decision to attend graduate school. The percentage of graduate school attendance differed by specificity of discipline, $\chi^2(2, N = 37{,}005) = 46.87$, $p < .001$. Post hoc analysis revealed that specific and traditional specificities statistically significantly differed from one another, but general engineering did not differ from both specific and traditional engineering specificities, as notated by the letter subscripts in Table 13.

Question 2

A chi-square test of significance was used to determine if a statistically significant relationship existed between specificity of discipline at the undergraduate level and specificity of discipline at the graduate school level. Differences in graduate school specificity are seen among undergraduate specificity levels, $\chi^2(6, N = 15{,}483) = 2575.01$, $p < .001$. As Table 14 notates with subscripts, statistically significant differences in proportions for the graduate level of specific engineering are found between specific engineering and the other two specificities. For the traditional level of graduate specificity, statistically significant differences are found between all levels of undergraduate specificity. Statistically significant differences are found at the graduate level of general engineering between general engineering specificity and both traditional and specific engineering specificities. For the non-engineering graduate school category, all undergraduate specificities show statistically significant differences.

In evaluating graduate school *major* changes across specificities, chi-square analysis shows evidence of a statistically significant relationship between changing majors and specificity of discipline, $\chi^2(2, N = 15{,}483) = 265.91, p < .001$. For both options of changing majors – "yes" and "no" – statistically significant differences were found among all three levels of specificity, as seen by the different letter subscripts across columns in Table 15.

Analysis by Gender

Of the 37,005 survey responses, a smaller percentage (17.5%) were from female respondents and a larger percentage (82.5%) were from male respondents. The two research questions were posed and analyzed while keeping gender in mind.

Question 1

Graduate school attendance proportions are different across specificities of discipline for both females, $\chi^2(2, N = 6{,}467) = 13.19, p = .001$ and males, $\chi^2(2, N = 30{,}538) = 27.68, p < .001$. Female undergraduate engineering students in specific and traditional engineering specificities attend graduate school at statistically different rates than general engineering students, as seen by the subscripts in Table 15. Approximately half (46.3%) of female engineering students attend graduate school.

Male undergraduate engineering students show the same trend as female students. Specific and traditional engineering students attend graduate school at significantly different rates from each other, but those rates are not significantly different from general engineering specificity, as seen by the subscripts in Table 15. Male engineering undergraduate students attend graduate school less than half (40.9%) of the time.

Table 16 Graduate School Attendance Percentage of Each Discipline Specificity by Gender

		Specificity of discipline			Total
		Specific engineering	Traditional engineering	General engineering	
Graduate school attendance by gender	Females	50.2% $_a$	45.0% $_b$	48.5% $_{a,b}$	46.3%
	Males	44.0% $_a$	40.2% $_b$	43.5% $_{a,b}$	40.9%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

Question 2

Graduate school specificity proportions are different across undergraduate specificities of discipline for both females, $\chi^2(6, N = 2{,}993) = 490.40$, $p < .001$ and males, $\chi^2(6, N = 12{,}490) = 2{,}087.68$, $p < .001$. Table 17 shows that the female differences in proportions do not follow the same trend as the overall sample. Significant differences are found for those attending graduate school for specific engineering between traditional engineering and both specific and general engineering specificities. For survey participants attending graduate school for traditional engineering, traditional engineering differs from both specific and general engineering. The general engineering graduate school specificity shows differences between general engineering and both specific and traditional engineering specificities. Those students attending graduate school for non-engineering graduate degrees report differences between only specific and traditional engineering specificities.

Table 17 shows that the male subgroup follows the same trend as the overall sample, across all specificities of discipline, which is expected since the overall sample consists of 82.5% males. Specific engineering differs statistically significantly from traditional and general engineering specificities at the specific engineering graduate level. At the graduate traditional engineering level, all specificities differ. General engineering specificity differs from specific and traditional specificities at the graduate general engineering level. For non-engineering graduate students, all specificities statistically significantly differ.

Table 17 Crosstabulation Results for Graduate School Specificity Alignment by Gender

Graduate specificity of discipline	Gender	Undergraduate specificity of discipline			Total
		Specific engineering	Traditional engineering	General engineering	
Specific engineering % within specificity of discipline	Female	42.9% $_a$	13.9% $_b$	28.1% $_a$	21.7%
	Male	44.4% $_a$	10.3% $_b$	10.8% $_b$	16.7%
Traditional engineering % within specificity of discipline	Female	12.1% $_a$	48.9% $_b$	21.9% $_a$	39.0%
	Male	14.8% $_a$	54.4% $_b$	22.3% $_c$	46.6%
General engineering % within specificity of discipline	Female	0.6% $_a$	0.7% $_a$	12.5% $_b$	0.8%
	Male	0.4% $_a$	0.6% $_a$	6.2% $_b$	0.6%
Non-engineering % within specificity of discipline	Female	44.4% $_a$	36.5% $_b$	37.5% $_{a,b}$	38.6%
	Male	40.4% $_a$	34.7% $_b$	60.8% $_c$	36.1%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

Analysis by Minority Status

Of the 37,005 survey responses, a smaller percentage (13.6%) were from underrepresented minority status respondents and a larger percentage (86.4%) were from non-underrepresented minority status respondents.

Question 1

Graduate school attendance proportions are different across specificities of discipline for both URM students, $\chi^2(2, N = 5{,}019) = 6.65$, $p = .036$ and non-URM students, $\chi^2(2, N = 31{,}986) = 46.59$, $p < .001$.

Students of URM status show statistically significantly differing percentages for graduate school attendance between specific and general engineering, though traditional engineering percentages do not differ from either specific or general engineering percentages. This is shown in Table 18 via letter subscripts.

Non-URM students attend graduate school at statistically significantly differing proportions across specific and traditional engineering specificities and traditional and general specificities, though not across specific and general engineering specificities, as identified in Table 18 via letter subscripts.

Table 18 Graduate School Attendance Percentage of Each Discipline Specificity by Minority Status

		Specificity of discipline			
	Minority status	Specific engineering	Traditional engineering	General engineering	Total
Attended graduate school	URM	45.2% $_{a}$	41.9% $_{a, b}$	29.2% $_{b}$	42.4%
	Non-URM	45.5% $_{a}$	40.8% $_{b}$	46.7% $_{a}$	41.8%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

Question 2

Graduate school specificity proportions are statistically different across undergraduate specificities of discipline for both URM students, $\chi^2(6, N = 1{,}778) = 192.30$, $p < .001$ and non-URM students, $\chi^2(6, N = 13{,}705) = 2{,}397.56$, $p < .001$.

URM students attending graduate school in specific engineering differ in proportions between specific engineering and both traditional and general engineering undergraduate specificities. Traditional engineering specificity proportions differ from both specific and general engineering specificities at the traditional engineering graduate level for URM students. URM students choosing general engineering for graduate school specificity proportions differ between general engineering and both specific and traditional engineering undergraduate specificities. At the non-engineering graduate level for URM students, specific and traditional undergraduate specificities do not statistically significantly differ from each other, but general engineering specificity differs from the other two specificities. These relationships are identified by letter subscripts in Table 19.

Non-URM participants show the same differences in proportions as the overall sample, as seen in Table 19. Specific engineering differs statistically significantly from traditional and general engineering specificities at the specific engineering graduate level. At the graduate traditional engineering level, all specificities differ. General engineering specificity differs from specific and traditional specificities at the graduate general engineering level. For non-engineering graduate students, all specificities statistically significantly differ.

Table 19 Crosstabulation Results for Graduate School Specificity Alignment by Minority Status

Graduate specificity of discipline	Minority status	Undergraduate specificity of discipline			Total
		Specific engineering	Traditional engineering	General engineering	
Specific engineering % within specificity of discipline	URM	38.3% $_a$	11.8% $_b$	16.7% $_b$	17.0%
	Non-URM	44.7% $_a$	10.8% $_b$	13.8% $_b$	17.7%
Traditional engineering % within specificity of discipline	URM	14.4% $_a$	42.4% $_b$	4.2% $_a$	36.4%
	Non-URM	14.1% $_a$	54.9% $_b$	25.4% $_c$	46.3%
General engineering % within specificity of discipline	URM	0.3% $_a$	0.6% $_a$	4.2% $_b$	0.6%
	Non-URM	0.5% $_a$	0.6% $_a$	8.0% $_b$	0.6%
Non-engineering % within specificity of discipline	URM	47.0% $_a$	45.3% $_a$	75.0% $_b$	46.0%
	Non-URM	40.7% $_a$	33.7% $_b$	52.9% $_c$	35.3%

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

Discussion

Question 1

Since specific engineering and traditional engineering graduate school attendance proportions statistically differ from one another, but general engineering does not differ from either specific or traditional specificities, this shows that obtaining a general engineering specificity does not influence graduate school attendance more or less than obtaining a specific or traditional specificity. However, the statistically significant difference between specific (45.4%) and traditional (41.0%) specificities indicates that those undergraduate students who obtain a specific undergraduate degree are more likely, though only slightly, to attend graduate school. Relating these results to Bandura's (1997) self-efficacy theory, these findings could indicate that students in the traditional specificity feel more confident in their content domain, and are thus ready to apply it in a career, whereas specific specificities may feel slightly less confident in their content domain and require supplemental instruction in graduate schooling. However, the small difference in graduate school attendance could be due to the more narrowly-defined nature of the specific specificity undergraduate degree limiting employment options or due to personality traits inherent in students that seek a more specific undergraduate degree that also drive them to seek additional knowledge beyond undergraduate level before concluding their studies. The reason for the almost 4.5% difference between the two specificities is unknown, but the difference remains.

The finding that less than half of each specificity attend graduate school and specific engineering graduates attend slightly more often than traditional engineering graduates may indicate that undergraduate engineering students, especially those in the traditional specificity, feel that an engineering bachelor's degree is sufficient to carry them successfully into the engineering career field. This decision to enter the workforce after only a bachelor's degree would correlate with higher levels of contextual and design self-efficacy, according to Ro (2011), as she found that students with higher contextual and design self-efficacy are less likely to attend graduate school.

If engineering institutions wish to increase their graduate school enrollment, the traditional engineering specificity would be the most advantageous group to recruit more graduate students from. Not only is the traditional engineering specificity larger in size and has a larger pool to recruit from, it also reports less graduate school attendance, which also increases the gain potential from this group.

Somewhat at odds with Ro's (2011) findings that majoring in civil, electrical, or "other" engineering programs increase odds of attending graduate school, this study's findings indicate that majoring in a specific engineering program, as Ro labeled "other" in her study, does increase graduate school attendance the most, while civil or electrical engineering undergraduates, which were both part of the traditional engineering specificity in this study, were slightly less likely to attend graduate school. Ro's findings, however, were in comparison to mechanical engineering as the control group, which means that her findings are all relative to mechanical engineering, whereas the results of this research are stand-alone. Ro (2011) also reported that students with higher self-efficacy in their fundamental engineering skills are more likely to enter graduate school. Relating Ro's findings to the current results, it seems specific engineering students possess higher levels of self-efficacy in their fundamental engineering skills, since they decide to attend graduate school most frequently of the specificities.

Question 2

This study found that specific and traditional engineering students prefer to align their undergraduate and graduate specificities of discipline, while general engineering students most often choose an alternate specificity for graduate school. This means that specific and traditional specificities choose to supplement their undergraduate domain depth rather than complementing it with breadth, while general engineering specificity chooses the opposite – breadth over depth. However, general engineering specificity students most often choose to obtain a graduate degree in a non-engineering discipline, leading to the assumption that those students are not preparing themselves for a career in engineering. Since more than half (56.2%) of general engineering students choose a non-engineering graduate degree path, it seems possible that general engineering students may not possess high engineering self-efficacy and thus, choose to leave the field. However, general engineering is not the only specificity with a high percentage of its students attending graduate school for non-engineering degrees. Specific engineering students attend graduate school in non-engineering graduate programs 41.4% of the time, and traditional engineering students follow at 35.0%. This indicates that if breadth of knowledge is the student's goal, they seek breadth across all knowledge-base, not just across the engineering knowledge-base.

From the finding that 36.6% of the overall study sample chose a non-engineering graduate degree, it seems that in order to retain engineering students in engineering graduate programs, academic advising interventions may be necessary during the undergraduate years. Introductions to the programs of study available in engineering after graduation, undergraduate research opportunities within engineering, and exposure to current engineering graduate students and their research may assist in peaking interest in engineering graduate programs.

More granularly speaking, students were found to change their *majors* between undergraduate and graduate school the majority of the time (54.9%), with general engineering leading at 92.6%, specific engineering following at 64.9% and traditional engineering having the least amount of major changes at 51.9%. With the large majority of students in specific and general specificities not aligning their undergraduate and graduate school majors, this could indicate either a change in interests or desire to complement their undergraduate studies rather than supplement them with depth in the same major. Traditional specificity students leave their majors least, indicating that they more often prefer to supplement their undergraduate content domain.

Engineering institutions should be aware that the majority of their graduate students are entering from different undergraduate majors and do at least two things with this information:

1. Curate their graduate engineering programs to be flexible, so other majors entering the program can transfer and engage smoothly.
2. Integrate materials and curriculum to assist undergraduate students in becoming more resilient students, so that the transition to another major in graduate school is not a hurdle that cannot be overcome.

Gender

Females attend graduate school more frequently than males at a proportion of 46.3% compared to 40.9% for males. This aligns with Concannon and Barrow's (2012) finding that women's self-efficacy is relatively more connected with their engineering outcome expectations, and thus graduate school decisions. Because women's self-efficacy is more connected with their decision to attend graduate school, undergraduate women in engineering who possess more self-efficacy in their field decide favorably for graduate school attendance. Viewing this through the lens of Social Cognitive Career Theory, females who possess more self-efficacy have increased outcome expectations, and are thus more likely to reach the major choice goal, which is attending graduate school, in the case of this study. Thus, females who show more self-efficacy during their undergraduate engineering career should be recruited for graduate school programs, as they are more likely to attend.

When considering gender and graduate school choices, both male and female proportions for attending graduate school follow the same trend of specific engineering specificity of discipline students attending graduate school most, followed by general engineering, and lastly traditional engineering specificity. Though males and females show the same patterns in proportions of attendance, what specificities the genders choose in graduate school differs across undergraduate specificities.

Male specific engineering undergraduates choose to align their graduate specificity most (44.4%). If they do not choose a specific specificity in graduate school, then they likely choose a non-engineering discipline (40.4%). Female specific engineering undergraduate students, on the other hand, show the exact opposite results. They choose non-engineering graduate programs most (44.4%), followed by specific disciplines (42.9%). These proportions are all relatively close, encompassed in the 40-45th percentile, but indicate that both genders either remain in their specificity or transition to a discipline that has a completely different content domain. The reason for this change to non-engineering may be due to the narrowness of a specific engineering undergraduate degree limiting employment opportunities after graduation, meaning that breadth of discipline in a graduate program would be helpful for employment opportunities.

Traditional engineering undergraduates seek to align their undergraduate and graduate degrees most often, for both males (54.4%) and females (48.9%). Non-engineering graduate degrees are the second most sought-after for both genders in traditional engineering undergraduate specificities. This, again, implies that most traditional engineering specificity students seek to supplement their undergraduate knowledge-base with depth rather than seeking complementary breadth, but if breadth is desired, then traditional engineering students tend to seek knowledge breadth not related to engineering.

Both male and female students obtaining their undergraduate degree in the general engineering specificity report leaving engineering to obtain graduate degrees in non-engineering related disciplines (60.8% and 37.5%, respectively). The second most chosen graduate-level specificity for males is traditional engineering, while females choose specific engineering specificity.

Females in both specific engineering and general engineering undergraduate specificities show the same pattern of choosing non-engineering graduate degrees most, followed by specific engineering degrees, indicating that females on either end of the specificity spectrum make similar decisions toward non-traditional engineering graduate programs. This could be influenced by traditional engineering's longstanding history as being male-dominated, whereas newer engineering disciplines, including general engineering and some of the specific engineering disciplines have shown an increase in female students over the years, thus appearing to be a more hospitable environment for females. Alternately, the large proportion of females drawn to non-engineering disciplines could be due to changes in interest. While the reasons are unknown, engineering institutions - especially academic advisors - should be aware of the tendency for females in specific and general engineering specificities to stray from engineering for graduate school, and act in order to retain those females in the engineering field for graduate school.

Minority Status

Minority and majority students both attend graduate school approximately 42% of the time. While Sheppard and colleagues (2010) indicate that URM students express interest in graduate school at a rate one-and-a-half times more than non-URM students, this study shows that they do not act upon this expression, as URM and non-URM students attend graduate school approximately the same proportion of time. General engineering specificity URM students attend graduate school least (29.2%) out of the three specificity levels, but for non-URM students, the general engineering specificity attends graduate school the most (46.7%). This is an interesting find, as it indicates a difference in thought process or expectation is present between URM and non-URM students that influences one demographic group to choose to attend graduate school most while the other group chooses to attend graduate school least. This reason is unidentified in this study, though Social Cognitive Career Theory implies that varying levels of interest or self-efficacy coupled with social supports and social barriers in the two demographic groups are the likely culprits.

Non-engineering is a dominant graduate school specificity for both URM and non-URM students. URM students choose non-engineering disciplines most, no matter their undergraduate specificity of discipline. The second most attended graduate program for URM students in the specific engineering specificity is specific engineering, thus aligning undergraduate and graduate disciplines. Traditional engineering URM students choose traditional engineering as their graduate program most, after general engineering, thus aligning their degree specificities as well. General engineering URM students do not, however, align their degree specificities, as the second most attended graduate program for this group is specific engineering, which mirrors the specific engineering pattern. Non-URM specificities align their undergraduate and graduate degrees, for the most part. Both specific and traditional engineering specificities choose to match their undergraduate and graduate specificities, followed by choosing non-engineering disciplines. Non-URM general engineering undergraduate specificity students choose non-engineering disciplines most, followed by traditional engineering specificity graduate degrees.

Limitations

Though the analyzed sample was large (37,005), the number of responses in the general engineering category was relatively small (365). The number of general engineering specificity responses totaled only about 0.99 percent of the respondents. Thus, conclusions made about the general engineering specificity should be done so with caution, as the small sample size may not appropriately reflect the population.

Additionally, this study was unable to measure the amount of time between undergraduate completion and the start of graduate school, meaning that some study participants may have entered the career field and completed multiple life events before deciding to enroll in graduate school, which may have influenced their specificity and major choices.

Future Work

This study attempted to identify relationships between specificity of discipline and graduate school decisions. However, reasons for why students chose to attend graduate school and why they decided upon certain graduate school majors could not be extracted from the survey data. Future work recommendations include capturing the reasons why students attended graduate school and chose their graduate school majors to make additional valid connections.

Conclusion

This study included analyzing historical data from the National Survey of College Graduates published by the National Center for Science and Engineering Statistics. Survey responses from years 2010, 2013, 2015, 2017, and 2019 were combined for a total of 37,005 usable responses.

The purpose of the study was to identify relationships between specificity of discipline and graduate school decisions for engineering students.

Analysis utilized chi-square tests of significance as well as crosstabulations to compare proportions of responses. This study concluded that while general engineering specificity does not influence graduate school attendance more or less than obtaining a specific or traditional specificity, undergraduate engineering students who obtain a specific undergraduate degree are more likely, though only slightly, to attend graduate school. Of students who do continue to graduate studies, this study found that specific and traditional specificities were most likely to attend graduate school in the same specificity as their undergraduate degree. If these groups did not choose to align their undergraduate and graduate specificities, then they were most likely to choose a non-engineering graduate discipline. General engineering specificity students were most likely to leave engineering and choose a non-engineering discipline for their graduate studies or attend graduate school in a traditional engineering specificity. All engineering specificities were found to be more likely to change their major between their undergraduate and graduate programs, which gives engineering institutions insight to how they should design both their undergraduate and graduate programs, knowing that the majority of their graduate students will be entering from different undergraduate majors.

Notable differences in male and female graduate school attendance were seen, as well as a notable similarity in graduate school attendance between URM and non-URM students. Reasons for theses differences cannot be claimed, but the differences remain.

CHAPTER IV

STUDY 3: DEPTH OF DISCIPLINE AS AN INFLUENCING FACTOR OF ENGINEERING IDENTITY

Introduction

As the national demand for engineering professionals continues to grow, the retention rate of engineering students continues to be of importance. According to the 2020 United States National Science Board and National Science Foundation report on labor force, the need for engineers in the United States is estimated to increase from approximately 1.7 million engineers in 2016 to 1.9 million engineers in 2026 (National Science Board & National Science Foundation, 2019). Compounding matters is a decline in interest in the engineering field (National Center for Education Statistics, 2014). To fill the gap between increased demand and limited supply, engineering institutions have two options – recruit more students into engineering or retain more of their engineering students to graduation. Between the two options exists a relationship worth noting; if engineering institutions cannot retain the students they have recruited, then expending resources for recruiting is not productive. Thus, this study focuses on the retention of engineering students.

Background

Retaining engineering students is a complex business that involves factors ranging from financial aid to low peer expectations (Hargrove & Burge, 2002). For the success of an engineering institution, the unit must be in the business of retention. This means innovating freshman engineering experiences (Peuker & Glinski Schauss, 2015), implementing mentoring programs (Poor & Brown, 2013), and offering summer bridge courses (Cançado et al., 2018). While these are sometimes effective methods of retaining students, they may not address the root-cause of attrition.

Engineering Identity

Importance

When an individual claims an identity, they strive to act in accordance with others claiming that identity, as described in the theory of symbolic interactionism (Burke & Stets, 2009). This suggests that individuals who identify as engineers will act upon the communally accepted behaviors of the engineering profession. Commitment to identity moderates role performance such that a high commitment to engineering identity would produce consistent lines of activity found within the engineering profession (Burke & Reitzes, 1991). As such, engineering institutions can conclude that engineering identity is essential to producing persistence in the study of engineering.

Composition

Three constructs comprise the formation of students' engineering identity. Those constructs, displayed in Figure 4, include self-perceptions of: their ability to perform well and understand concepts, interest in the subject, and feelings of recognition (Godwin, 2016).

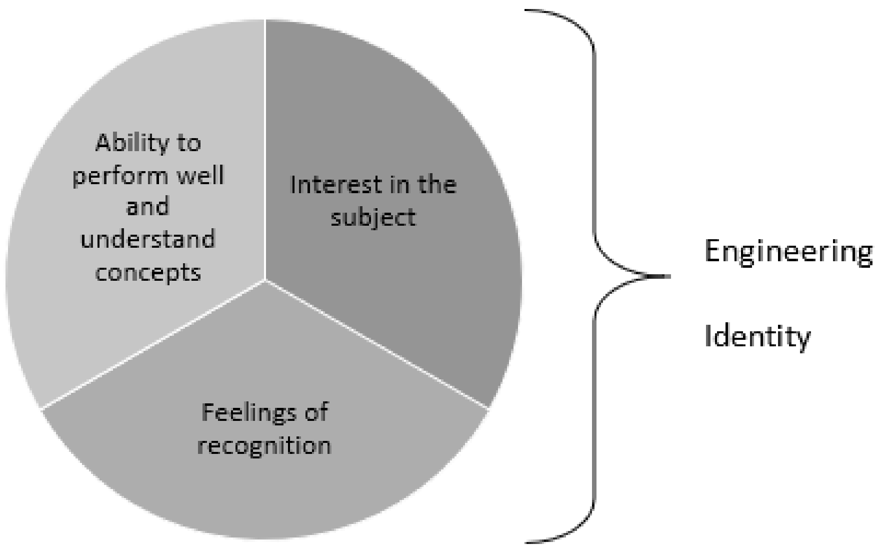


Figure 4 Engineering Identity Composition based on Godwin (2016)

Performing well and understanding concepts of engineering go beyond task-specific attainment, as measured by self-efficacy (Bandura, 1997). Students must look beyond their ability to simply perform practices of their discipline and be able to visualize themselves as an individual who can authentically participate in the areas of their discipline (Marsh et al., 2004). Interest in engineering is a key indicator in whether or not a student is willing to identify as an engineer (Godwin, 2016). If interest is not present, motivation to pursue will also be lacking, and authoring an engineering identity will not commence.

Formation

The formation of engineering identity follows the developmental psychology development of stage theory (Meyers et al., 2012). Under the guidance of this theory, passage from one stage to the next is gradual, individuals progress through the stages at different rates, and the progression through stages is accomplished by a universal sequence of achievements (Lerner, 2001). This indicates that a difference between freshman and senior level abilities to describe engineering identity is likely and should be controlled during experimentation (Tonso, 2007).

Trajectories

Students identifying as engineers during their undergraduate schooling have essentially identified their career identity as well, according to Huff and associates' (2019) study on engineering identity in adulthood. The interpretive phenomenological analysis investigation completed by Huff et al. (2019) highlights how early-career engineers experience a perceived early arrival to adulthood, with little exploration of alternative career trajectory possibilities. This realization could imply that a strong development of engineering identity during undergraduate school solidifies commitment to an engineering career after college, and thus educational persistence to achieve said career.

Educational Persistence

At the core of student decisions regarding higher education paths lie the questions of belonging and personal fit (Rainey, et al., 2018). Students' sense of belonging within the engineering discipline, otherwise known as engineering identity (Tonso, 2007), is believed to be related to educational persistence (Meyers et al., 2012). Meyers and colleagues (2012) hypothesized that students having plans to remain in engineering school and pursue an engineering career are more likely to identify as engineers during their undergraduate education. The research team administered a web-based survey to a medium-sized, private midwestern institution and yielded a 64% response rate. The results indicated that their hypothesis is supported, and that planning on continuing in engineering school and pursuing an engineering career are the most significant factors relating to student self-identification as an engineer. However, causality cannot be claimed and the reverse statement ("strong engineering identity leads to educational and professional persistence") was not examined in this study. This finding does highlight the importance of career goal formation during undergraduate engineering education as part of engineering identity development.

Matusovich, Streveler, & Miller found in their 2010 qualitative, longitudinal study that engineering students were motivated to persist in engineering when they perceived their degree to be "consistent with sense of self" (Matusovich, et al., 2010, p. 294). This indicates that when students feel as though their engineering identity and personal identity align, educational persistence in engineering is more probable.

McKenzie's (2016) more recent work further explores engineering identity, academic self-confidence, self-efficacy, and educational persistence. This mixed-methodology experiment included a web-based survey of 37 participants from two northeastern engineering schools, and a follow-up interview with six qualified participants selected from the sample. The findings of McKenzie's study indicate relationships exists between student academic self-confidence and engineering identity, and between engineering self-efficacy and educational persistence. This means that engineering identity can meaningfully be predicted by academic self-confidence and educational persistence can meaningfully be predicted by engineering self-efficacy. Though not directly calculated, using Arnett's (2000) definition of identity, McKenzie's study inferred that identity impacts engineering educational persistence (McKenzie, 2016).

While the findings from previous studies do not explicitly state that engineering identity is a factor for predicting educational persistence (though the reverse has been proven), engineering identity has been recognized as an important enough construct that researchers are studying its predicting factors. This study examines depth of discipline as a predicting factor for engineering identity.

Research Question

With the knowledge that engineering identity impacts persistence to remain in the engineering field (McKenzie, 2016), questions remain about how to best increase engineering identity. For this study, the question is not "what new initiative can an institution employ to enhance student engineering identity?". Instead, the question at hand is "should a restructuring of engineering disciplines at the institutional level occur to best encourage engineering identity naturally, without additional initiatives?". This particular question is of importance because studies indicate that engineering identity is a challenge for students to form due to the diverse areas and industries that engineers serve. Because of the breadth of the discipline of engineering, articulating a distinct identity becomes difficult (Downey & Lucena, 2004). It seems possible that engineering institutions could benefit from narrowing their focuses of study so that identity formation can more easily transpire through differentiated attributes, rather than broad generalizations. To test this hypothesis the formalized research question **"Does depth of discipline impact engineering identity?"** is pursued. In other words, do engineering students who pursue more specialized or more generalized engineering studies show stronger commitment to their engineering identity? Differentiating engineering students through labelling them by degree programs has proven to increase engineering identity and commitment to engineering (Stevens et al., 2008), but how narrow of a focus should these degree programs offer to take advantage of such an increase?

For this study, three levels of discipline focus are examined. These levels, each deemed a "depth of discipline", refer to the breadth of focus contained within the program of study. The depths included are defined as:

1. *General engineering.* This is the broadest level considered. In this level of depth, the focus is interdisciplinary, and students are expected to be able to apply knowledge of engineering to design experiments and solve problems.
2. *Discipline-specific engineering.* This is the most common level of depth, and includes those engineering disciplines that focus on a more specific area of engineering, while exposing students to all sub-disciplines the discipline has to offer. Most commonly, these disciplines are identified at engineering institutions as majors. (Ex: civil engineering)
3. *Discipline-specific engineering with a concentration or emphasis.* This is the most narrowly focused level of depth. In this level, students not only classify with a major, but also with a specialty within the major. (Ex: civil engineering with a concentration in environmental and water resource engineering)

Implications

The results of this study will help academic institutions understand the risks of attrition associated with each depth of discipline, if a relationship between engineering identity and depth of discipline is found. Depending on the strength and direction of the relationship, engineering programs may consider adding more general engineering degrees and/or concentrations and specialization options to provide degree options where students can achieve increased engineering identity, and thus increased persistence in engineering.

Methods

Design

This study utilized qualitative research methods through administering a survey that aimed to collect data regarding engineering identity in relation to depth of discipline, after approval to conduct the survey from the Institutional Review Board (IRB). The web-based survey was generated using Qualtrics software (Qualtrics, Provo, UT) and distributed via email. The survey was to remain open until at least 250 usable responses were obtained. This sample size is sufficient because three factors are present and their communalities ranged between 0.50 and 0.88 (Godwin & Lee, 2017). Had the communalities been slightly higher at 0.60, 100 samples would have been sufficient and had the communalities been lower than 0.50, 300 samples would have been needed (Bandalos, 2018). Since the communalities fall between the two, a conservative 250 samples were required.

Survey Instrument

The survey instrument used was Godwin's (2016) engineering identity survey, with demographic question additions, as seen in Appendix A. The survey contains 11 items that measure three constructs – students' perceptions of their *interest* in engineering, feelings of *recognition* by others as an engineer, and beliefs about their *performance/competence* in engineering. Participants responded to items with an anchored scale from 1 – "Strongly Disagree" to 7 – "Strongly Agree". Table 20 shows the survey items and the construct measured by each item.

Table 20 Survey Items and Constructs based on Godwin (2016)

Construct	Item
Recognition	My parents see me as an engineer.
	My instructors see me as an engineer.
	My peers see me as an engineer.
Interest	I am interested in learning more about engineering.
	I enjoy learning engineering.
	I find fulfillment in doing engineering.
Performance/competence	I am confident that I can understand engineering in class.
	I am confident that I can understand engineering outside of class.
	I can do well on exams in engineering.
	I understand concepts I have studied in engineering.
	Others ask me for help in this subject.

For their use in this study, the items used to measure engineering identity constructs display validity evidence (Godwin and Lee, 2017). Within the population of undergraduate engineering students and for the purpose of measuring interest in engineering, feelings of recognition by others as an engineer, and beliefs about their performance/competence in engineering, the material within the tool covers the intended content domain, supported by engineering theory. Reliability has also been established, as Cronbach's alpha values for interest, recognition, and performance/competence constructs were 0.93, 0.90, and 0.90, respectively. Nunnally (1978) asserts that coefficient alphas of .80 and higher are sufficient. Thus, the tool is valid and reliable, and may be used for the purpose of this study.

Demographic information collected includes current degree major, degree concentration (if applicable), community college transfer status, gender, ethnicity, age, and classification. Current degree major and concentration are both components of the independent variable – depth of discipline. Community college transfer status allowed for removal of any participant indicating they attended community or junior college preceding their senior college work. Age was collected to ensure students are of traditional student status. Gender, ethnicity, and classification are factors that may provide additional insights.

Variables

The variable of interest, or dependent variable, is engineering identity. The independent variable is depth of discipline, which will be held at three levels – general engineering, discipline-specific engineering, and discipline-specific engineering with a concentration/specialty.

Procedure

Participants were recruited by email correspondence from engineering deans and department heads. Contact information for 944 engineering deans and department heads was collected and those individuals were emailed, asking them to forward the solicitation email seen in Appendix B to their engineering students. Along with a link to the survey, participation solicitation correspondence included:

1. A description of the study and its purpose
2. An IRB approval number
3. A description of how the survey results will be used
4. Confidentiality assurance
5. An estimate of the approximate time required to complete the survey

The survey remained open approximately three weeks, and upon survey closure 6,053 responses were recorded. After removing incomplete responses and responses not meeting the inclusion criteria, 4,183 responses remained. Responses removed from the analysis were those from community college transfer students, participants falling outside of the targeted 18-23 age range, students not enrolled in undergraduate engineering schools located in the United States, and those students answering “prefer not to say” or “other” to demographic variable questions of interest.

Participants

Participants were recruited via email, with the target population being traditional undergraduate engineering students. “Traditional” is defined as individuals ages 23 and under (Spitzer, 2000). Transfer students were excluded from the analysis due to the potential of belonging to multiple depths of discipline, since community colleges do not offer discipline-specific associate’s degrees. Both students admitted directly to an engineering discipline and those admitted to a general engineering program first were considered.

The 4,183 student respondents can be described demographically as 45.1% female and 54.9% male. Minority status is reserved for participants claiming African American, Hispanic, or Native American ethnicity. This group is collectively called the underrepresented minorities. All other ethnicities are considered non-URM, or not classified as a minority ethnicity. URM students composed 12.3% of the participant makeup, while non-URM composed 87.7%. The breakdown of responses by class standing is as follows: 793 freshmen (19.0%), 1,020 sophomores (24.4%), 1,141 juniors (27.2%), 1,229 seniors (29.4%).

Analysis

Statistical Package for Social Sciences software (IBM Corporation, 2020) was used for analysis. The survey item results were used to identify any existing relationships between depth of discipline and engineering identity. Each item in the engineering identity survey was scored on an anchored scale of one to seven, with four being neutral. Because Godwin used an anchored scale rather than a Likert scale in her engineering identity survey, the assumption of the scale providing continuous numerical results is valid (Godwin, 2016). An overall engineering identity score was computed by calculating the mean of all item scores for questions 1-11 on the engineering identity survey. This overall score was analyzed against depth of discipline data collected in the demographic portion of the survey.

Because the mean engineering identity score is a continuous variable, descriptive statistics and analysis of variance (ANOVA) techniques were used.

After analyzing the overall engineering identity score versus depth of degree, the data was further analyzed three additional times - each time controlling for different demographic data. The three demographic markers to be held constant were classification, gender, and ethnicity. Based on findings from previous engineering identity studies (Godwin and Lee, 2017; Rainey et al., 2018), it is expected that females, minorities, and lower classification students will have lower levels of engineering identity, regardless of their depth of discipline.

Further, the responses were divided by construct – recognition, interest, and performance/competence – to identify any relationships between the constructs and depth of discipline

Results

Descriptive Statistics

Overall, the average self-reported engineering identity score for the surveyed sample was 5.61. A score of four would be considered neutral, while a score between one and three would be considered a "negative identity" and a score between five and seven would be considered a "positive identity". Table 21 shows all sample sizes, means, and standard deviations for different data breakdowns. The overall engineering identity score descriptive statistics were reported for each depth of discipline, as well as an overall score. Similarly, the three construct scores' descriptive statistics were reported across each depth of discipline, as well as overall.

Table 21 Survey Score Descriptive Statistics

Variable	N	Mean	Std deviation
Engineering identity score			
Overall	4,198	5.61	0.76
General	164	5.62	0.69
Discipline-specific	2,108	5.55	0.79
Discipline-specific + concentration	1,926	5.67	0.73
Recognition score			
Overall	4,198	5.53	0.98
General	164	5.51	0.99
Discipline-specific	2,108	5.50	1.00
Discipline-specific + concentration	1,926	5.57	0.95
Interest score			
Overall	4,198	6.06	0.94
General	164	6.09	0.89
Discipline-specific	2,108	5.99	0.98
Discipline-specific + concentration	1,926	6.14	0.89
Performance/competence score			
Overall	4,198	5.38	0.95
General	1,634	5.40	0.87
Discipline-specific	2,108	5.32	0.97
Discipline-specific + concentration	1,926	5.44	0.92

Overall, females reported lower engineering identity scores (M = 5.51, SD = .76) than males (M = 5.69, SD = .75). Non-URM students reported higher engineering identity scores (M = 5.62, SD = .76) than URM students (M = 5.55, SD = .77). Across class standings sophomores reported the lowest overall engineering identity scores (M = 5.58, SD = .76), followed by juniors (M = 5.61, SD = .77) and freshmen (M = 5.61, SD = .72), leaving seniors with the highest engineering identity scores (M = 5.62, SD = .78).

Inferential Statistics

Due to non-normality of data, an independent-sample Kruskal-Wallis test was conducted to compare the effect of depth of discipline on engineering identity and its constructs. Kruskal-Wallis test results for engineering identity indicate that there was a statistically significant difference in engineering identity between depths of discipline [$H(2) = 16.61$; $p < .001$]. Both constructs of interest [$H(2) = 28.27$; $p < .001$] and performance/competence [$H(2) = 11.29$; $p = .004$] were shown to have significant differences between depths of discipline, while recognition did not display significant results [$H(2) = 2.36$; $p = .308$] at the .05 alpha level.

Because statistically significant relationships were found, post hoc testing was required. The Mann-Whitney test for between-group comparisons with Bonferroni correction was utilized. This test showed that engineering identity differed statistically significantly between discipline-specific (M = 5.55, SD = .79) and discipline-specific with a concentration (M = 5.67, SD = .73) depths. Mann-Whitney results for the construct of interest showed a statistically significant difference between discipline-specific (M = 5.99, SD = .99) and discipline-specific with a concentration (M = 6.14, SD = .89) depths, and the same relationship for performance/competence exists between discipline-specific (*M* = 5.32, *SD* = .97) and discipline-specific with a concentration (*M* = 5.44, *SD* = .92) depths.

A visual examination of the data in Figure 5 shows the statistically significant differences confirmed by the post hoc tests for engineering identity scores.

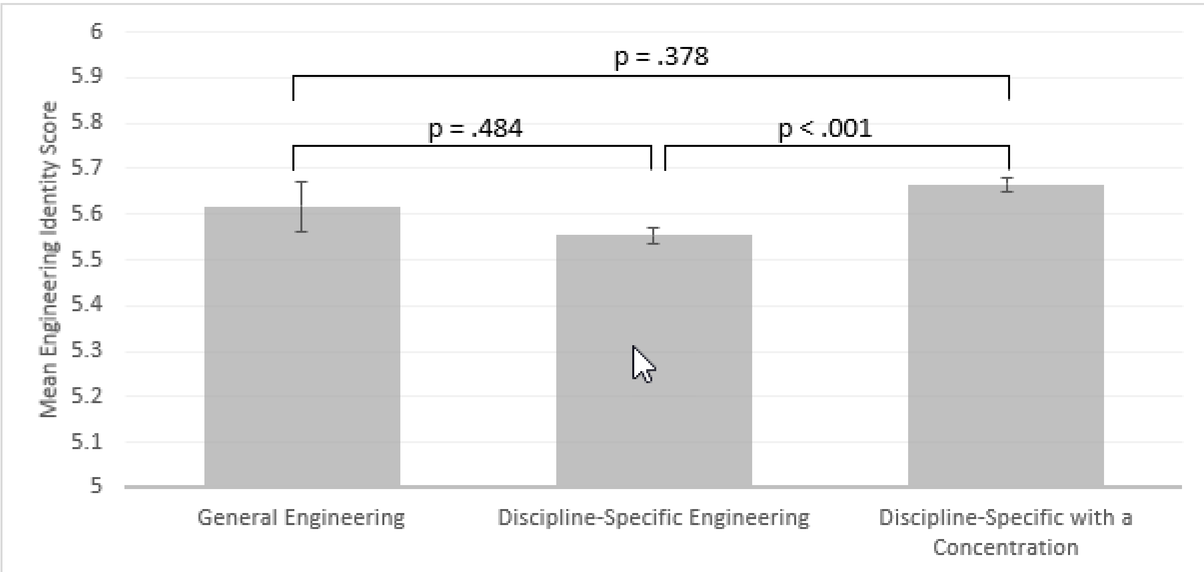


Figure 5 Bar Chart of Engineering Identity Mean Scores across Depths of Discipline

The construct of interest was further analyzed, due to possessing the largest mean score difference of all reported scores. Post hoc Mann-Whitney results for the construct of interest showed a statistically significant difference between discipline-specific (*M* = 5.99, *SD* = .99) and discipline-specific with a concentration (*M* = 6.14, *SD* = .89) depths. Figure 6 shows these differences via a bar chart.

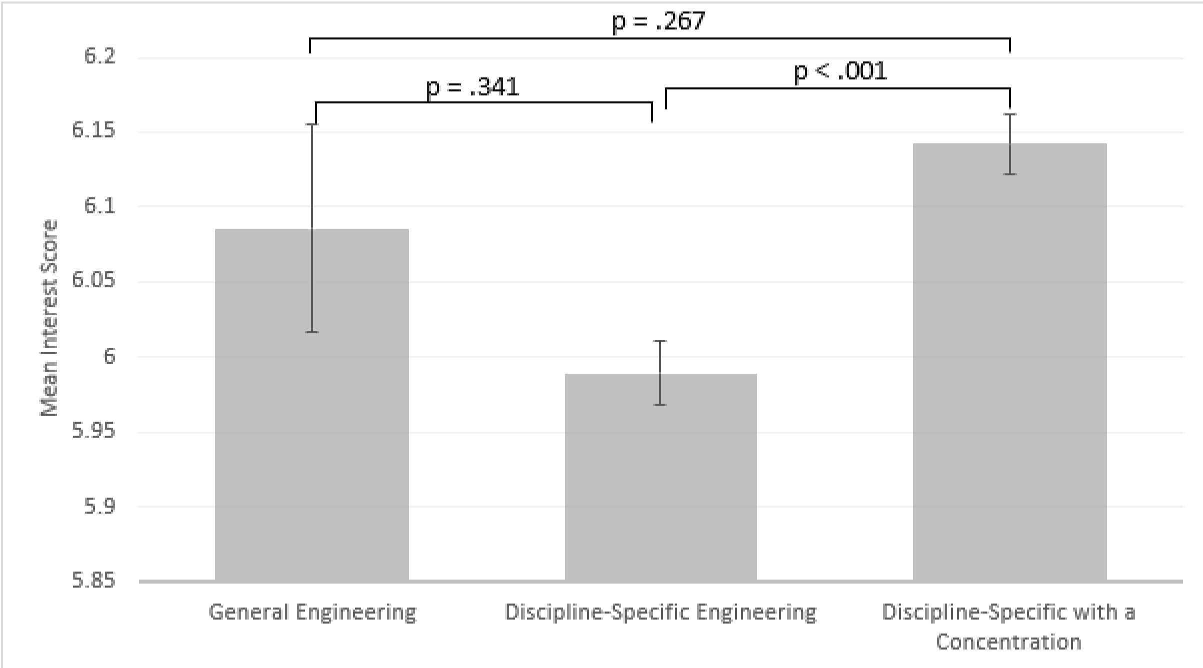


Figure 6 Bar Chart of Interest Mean Scores across Depths of Discipline

Note: The vertical axis of this chart is slightly longer than all other bar charts in this section, extending to 6.2 rather than 6

Additional Analysis

Though depth of discipline for overall engineering identity was the main focus of this study, additional analysis on demographic data shows additional insight on the effects of engineering identity due to depth of discipline through the lens of other demographic variables.

Gender

Kruskal-Wallis testing based on gender indicates a significant relationship for females [$H(2) = 17.56$; $p < .001$] between engineering identity and depth of discipline. The relationship for males [$H(2) = 6.96$; $p = .031$] also shows significance. Post hoc testing indicates a statistically significant difference in engineering identity score between both general engineering ($M = 5.38$, *SD* = .74) and discipline-specific with a concentration (*M* = 5.59, *SD* = .74) depths and discipline-specific (*M* = 5.45, *SD* = .77) and discipline-specific with a concentration (*M* = 5.59, *SD* = .74) depths for females while males show a statistically significant difference in engineering identity scores between only discipline-specific (*M* = 5.63, *SD* = .79) and discipline-specific with a concentration (*M* = 5.73, *SD* = .72) depths. Visual inspection of a bar chart with standard error (Figure 7) confirms these differences. For females, the average engineering identity for students in a discipline-specific with a concentration depth is higher than both the general engineering and discipline-specific levels. For males, the discipline-specific with a concentration depth has a higher engineering identity score mean than the discipline-specific depth.

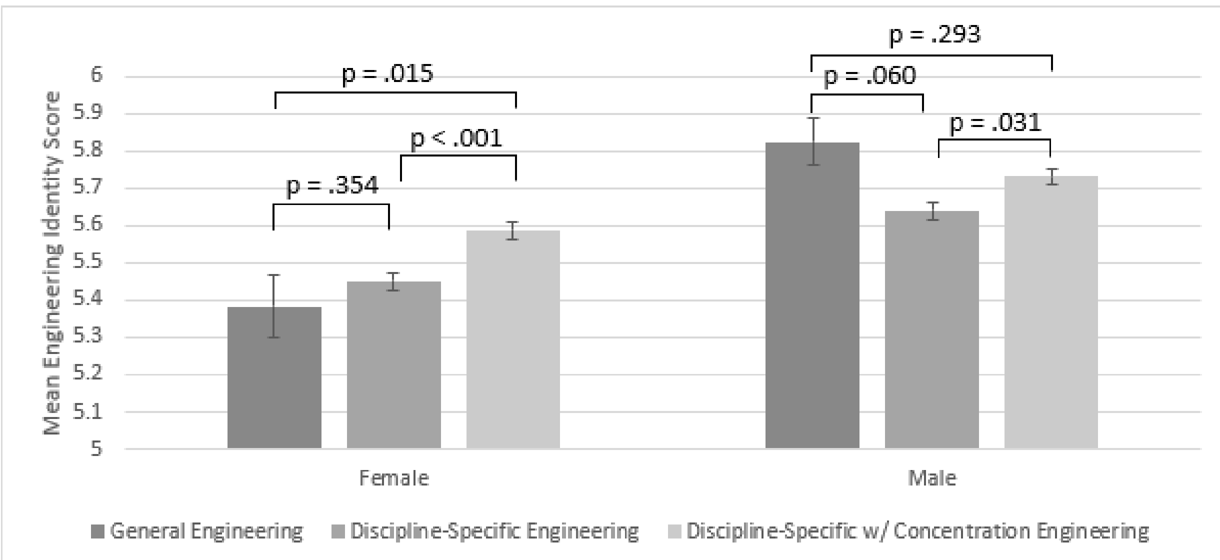


Figure 7 Bar Chart of Engineering Identity Mean Scores across Genders

Class Standing

When viewed across class standings, only junior-standing showed significance [$H(2) = 8.17$; $p = .017$], while freshman [$H(2) = 4.40$; $p = .111$], sophomore [$H(2) = 5.68$; $p = .059$], and senior [$H(2) = 2.88$; $p = .237$] level standings showed no significance. Since significance was discovered for junior class standing, post hoc Mann-Whitney testing for between-group comparisons with Bonferroni correction was used on this class. Post hoc testing identified a statistically significant difference in engineering identity means between discipline-specific ($M = 5.54$, $SD = .80$) and discipline-specific with a concentration ($M = 5.69$, $SD = .74$) depths of discipline. Visual inspection of Figure 8 manifests this finding. Discipline-specific with a concentration showed a higher engineering identity score mean than discipline-specific for junior class-standing respondents.

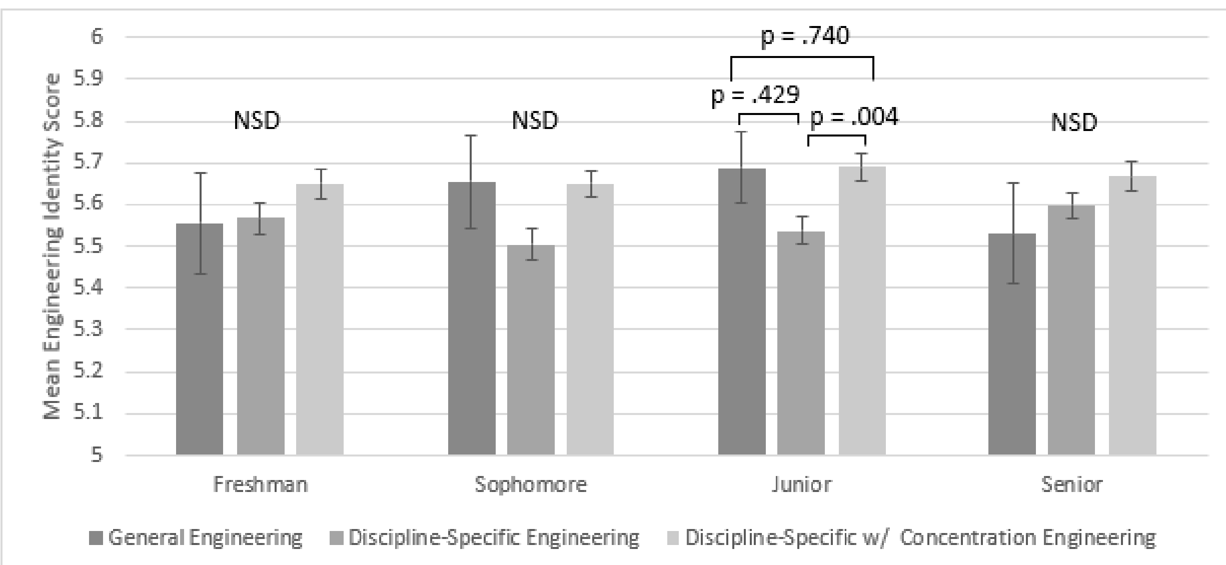


Figure 8 Bar Chart of Engineering Identity Mean Scores across Class Standing

Further analysis of depths of discipline within each class standing found that when grouped by depth of discipline, engineering identity scores do not differ statistically significantly across class standings, as indicated by the large p-values in Table 22.

Table 22 Significance Test Results for Engineering Identity Scores across Class Standing when Grouped by Depth of Discipline

Depth of discipline	Kruskal-Wallis value	df	Asymptotic significance (2-sided)
General	1.16	3	.763
Discipline-specific	6.43	4	.169
Discipline-specific with a concentration	2.27	4	.687

With no statistically significant differences between class standings for each depth of discipline, post hoc analysis was not completed, though Figure 9 shows trends between the depths across class standings.

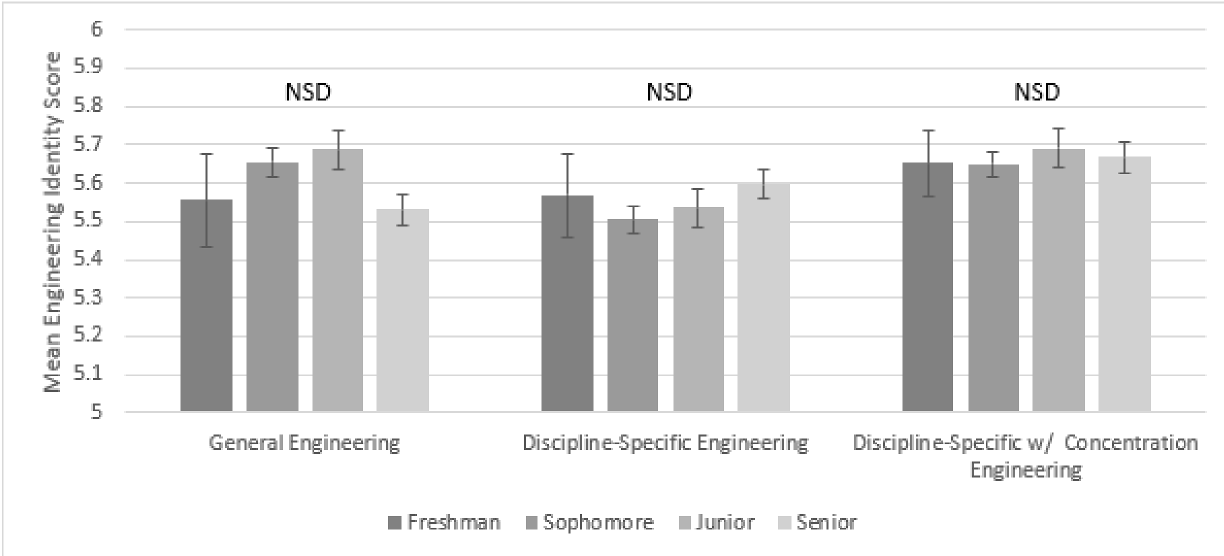


Figure 9 Bar Chart of Engineering Identity Scores Grouped by Depth of Discipline and Viewed across Class Standings

Minority Status

When depth of discipline was analyzed across minority status, a significant relationship between engineering identity and depth of discipline was not found for underrepresented minority students [$H(2) = 1.83$; $p = .400$] but was found for non-URM students [$H(2) = 16.28$; $p < .001$]. Post hoc analysis indicated that engineering identity scores for non-URM students differed statistically significantly between discipline-specific ($M = 5.56$, $SD = .78$) and discipline-specific with a concentration ($M = 5.67$, $SD = .74$) depths of discipline. Figure 10 visualizes the difference in engineering identity means. Non-URM students in a discipline-specific with a concentration depth have a higher mean engineering identity score than those non-URM students in a discipline-specific depth.

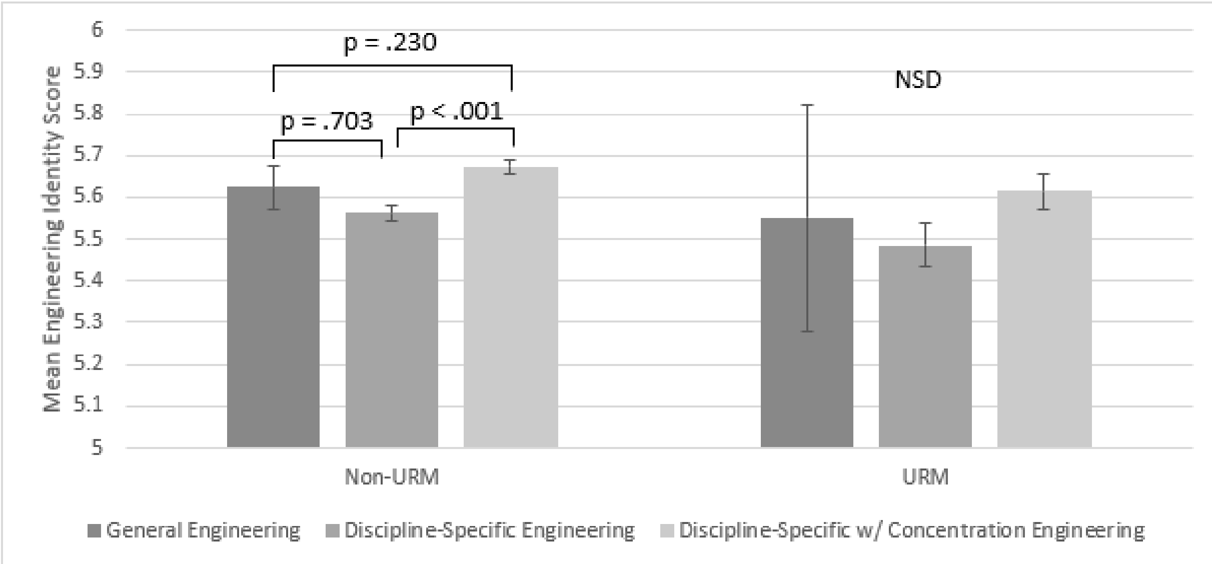


Figure 10 Bar Chart of Engineering Identity Mean Scores across Minority Status

Summary of Results

To summarize the statistically significant findings, a compact letter display was constructed for overall engineering identity and overall constructs, as well as engineering identity across multiple demographic variables. As seen in Table 23, overall recognition, freshman engineering identity, sophomore engineering identity, senior engineering identity, and URM engineering identity had no statistically significant relationship between engineering identity and depth of discipline.

Table 23 Compact Letter Display of Statistical Significance

Variable	General engineering	Discipline-specific engineering	Discipline-specific with a concentration
Engineering identity score, overall	ab	a	b
Recognition score, overall	a	a	a
Interest score, overall	ab	a	b
Performance/competence score, overall	ab	a	b
Engineering identity, females	a	a	b
Engineering identity, males	ab	a	b
Engineering identity, freshman standing	a	a	a
Engineering identity, sophomore standing	a	a	a
Engineering identity, junior standing	ab	a	b
Engineering identity, senior standing	a	a	a
Engineering identity, URM	a	a	a
Engineering identity, non-URM	ab	a	b

Note: Each subscript letter denotes a subset of Specificity of Discipline whose column proportions do not differ significantly from each other at the .05 level.

Discussion

Based on the mean engineering identity score of each depth of discipline, it seems that all depths show positive engineering identity, with scores above the "neutral" score of four. This is a positive finding for engineering institutions, as it shows that no matter the depth level, students enrolled in engineering programs generally identify as engineers, which is necessary for persisting to graduation. (Burke & Reites, 1991). This study found that engineering identity scores are higher for students in discipline-specific engineering majors who are also pursuing a concentration within that major (*M* = 5.66, *SD* = .73) than for students pursuing a discipline-specific engineering degree with no concentration (*M* = 5.55, *SD* = .79). This indicates that depth of discipline does impact engineering identity. However, this relationship does not extend across all depths of discipline, as statistical significance was not found for the general engineering depth at the overall engineering identity level. The higher engineering identity for students choosing a deeper depth of discipline should produce increased persistence in the study of engineering due to more commitment to the engineering identity (Burke & Reites, 1991). However, it is worth noting that the magnitude of engineering identity mean score increase between the two significant depths is just over a tenth of a point out of seven available points. While the difference is statistically significant, it is likely not enough to prompt engineering institutions to re-structure their discipline schemes to include more depth. Engineering administrators should look to engineering identity scores as an indicator of educational persistence to graduation, and strive to increase engineering identity within their student populations. Re-structuring engineering degree programs to include more depth of discipline will lead to a small engineering identity gain, but institutions would need to evaluate whether the cost to do so is worth the gain.

From evaluating the engineering identity constructs of recognition, interest, and performance/competence and finding that statistically significant differences in score means exist for both interest and performance/competence between the discipline-specific and discipline-specific with concentration depths, this may be an area of interest for further evaluation by engineering institutions. The largest mean score difference observed in the entire study was between discipline-specific (M = 5.99, SD = .98) and discipline-specific with a concentration (M = 6.14, SD = .89) for the construct of interest. This may indicate that more specific curriculum aligns with student interests better than broad curriculum. This finding is of importance, as Godwin (2016) claims that interest in engineering is a key indicator in whether or not a student is willing to identify as an engineer. If interest is lacking, then authoring an engineering identity will not commence. This finding suggests that while engineering identity may not be tremendously impacted by depth of discipline, the construct of interest is more impacted, and interest is a prerequisite for engineering identity formation, according to Godwin (2016). With this finding comes a recommendation to engineering institutions to evaluate the broader depths of discipline for ways to increase interest, or consider offering voluntary concentration options for the broader engineering depths, to increase the foundational construct of interest.

Interestingly, the same trend of discipline-specific having a statistically significantly lower mean than discipline-specific with a concentration depth is seen for many of the tested demographic subgroups – males, females, non-URM students, and junior-class-standing students. In all cases where statistical significance was determined, the difference in means found was between discipline-specific with a concentration and discipline-specific, with the concentration depth always possessing the higher mean. The only analysis including a statistically significant difference for general engineering was for the female sub-sample.

Female engineering identity is particularly susceptible to the impact of depth of discipline. Of all demographic variables studied, females were the only group to report that general engineering statistically significantly differed from any of the other depths. In the case of the female engineering identity, a difference in means was identified between both general engineering and discipline-specific engineering and discipline-specific engineering with a concentration, with the concentration depth having the higher mean. This means that obtaining a discipline-specific major with a concentration produces a higher engineering identity score than *both* discipline-specific and general engineering depths in females. Thus, a more specific depth of discipline should be of focus for academic advisors assisting female students in major selection, as choosing a general engineering or discipline-specific engineering degree produces lower engineering identity scores than those engineering disciplines offering concentrations. Since females possess a lower engineering identity score (*M* = 5.51, *SD* = .76) than males (*M* = 5.69, *SD* = .75), as seen previously by Godwin and Lee (2017), all platforms for improving engineering identity for females should be utilized, including guidance to incorporate a concentration of specialization into their discipline-specific major while in engineering school, if at all possible.

Class standing has already proved to be an influencing factor in engineering identity (Godwin & Lee, 2017). This study found that sophomores possess the lowest engineering identity scores of all class standings, followed by freshmen and juniors, and then by seniors - which aligns with Godwin and Lee's (2017) work indicating a dip in identity during the second year of engineering school, referred to as the "sophomore slump". While no statistically significant differences in engineering identity across depths of discipline was found in this study for sophomores, this study's results confirm Godwin's findings that sophomore students' engineering identity dips below the other classes, which suggests that this class of students is at risk for higher attrition levels, since there exists a positive relationship between engineering identity and engineering persistence (Meyers et al., 2012). Engineering institutions should take notice of this decrease in engineering identity at the sophomore level and implement proactive steps to counteract the "sophomore slump". Sophomore year is generally when coursework focuses on math and science, and less on engineering, which could be a reason for the lower engineering identity scores, since students may feel "removed" from the major they selected while attempting to satisfy prerequisites. Most engineering programs offer an introduction-type class freshman year, but sophomore year poses more of a challenge, as coursework becomes more difficult, and students have no engagement with their departments, since their introduction classes are over and other major-specific courses do not begin until junior year. A remedy to this may be to increase departmental engagement with students through creation of a sophomore level introduction class, induction into an engineering society or extracurricular group, pairing students with an upper-classman engineering mentor, or scheduling more advising sessions with engineering faculty. Junior class standing showed statistically significant differences between discipline-specific and discipline-specific with a concentration depths, which could be because junior year is when students are finally immersed in mostly major-specific coursework. This is the year that differences in engineering identity based on depth were really expected, as it is the first-year students spend more time in their major-related classes, and less in university core classes. With that in mind, the junior class is the class that exhibits the true impact of depth of discipline on engineering identity. However, this difference did not extend to the senior class, indicating that depth is important junior year, but other factors become more influential to engineering identity as students progress into senior year. Though a trend is visible in Figure 8 that seems to indicate that seniors have increased engineering identity scores in more specific depths of discipline their senior year, this cannot be claimed, as the difference is not statistically significant.

As seen in earlier studies conducted by Godwin and Lee (2017) and Rainey and colleagues (2018), minorities reported lower overall engineering identity scores (M = 5.55, SD = .77) than non-URM students (M = 5.62, SD = .76), regardless of depth of discipline. Non-URM students report the same significant differences between discipline-specific and discipline-specific with a concentration as the overall engineering identity, which is not unexpected since the majority of the total sample (N = 4,198) is composed of the non-URM sub-sample (N = 3,679).

Underrepresented minority students showed no statistically significant differences between depths of discipline, which implies that their engineering identity is not impacted by depth of discipline. This finding rules out depth of discipline for the reduction in mean engineering identity score, and should be a catalyst for searching for the variables that do impact URM engineering identity scores.

The construct of interest is one of the three constructs to comprise engineering identity. While not the variable of interest, it was found to have the largest difference in mean scores among all scores reported – overall engineering identity, interest, recognition, and performance/competence. The difference between discipline-specific (M = 5.99, SD = .98) and discipline-specific with a concentration (M = 6.14, SD = .89) is a finding of interest because it may indicate that more specific curriculum (specific engineering grouping) aligns with student interests better than broad curriculum (general engineering grouping). This finding is of importance, as Godwin (2016) claims that interest in engineering is a key indicator in whether or not a student is willing to identify as an engineer. If interest is lacking, then authoring an engineering identity will not commence. This finding suggests that while engineering identity may not be tremendously impacted by depth of discipline, the construct of interest is impacted, and interest is a prerequisite for engineering identity formation, according to Godwin (2016). With this finding comes a recommendation to engineering institutions to evaluate the broader depths of discipline for ways to increase interest, or consider adding depth to those programs through voluntary concentration or specialization options.

Limitations

It should be noted that of 4,183 analyzed responses only 165, or 3.9% of the sample, belonged to the general engineering category. This small sample size is not detrimental, but conclusions should be made with caution, as this small sample may not accurately represent the population. Additionally, this was a cross-sectional study and not a longitudinal study. This type of study does not account for variations over time that students may report in their engineering identity.

Future Work

A longitudinal study that follows the same students throughout their engineering education career would eliminate some variation, as it would give insight into how students' engineering identities change over time, instead of assuming independent samples from each class standing. Evaluating individual majors for relationships between engineering identity and depth of discipline may also prove insightful, as some majors offer with and without concentration options. Do majors who offer voluntary concentration options differ in engineering identity at the concentration and non-concentration level? Analyzing depth of discipline within majors may provide a different perspective.

Conclusion

This study included a survey of the nation's current undergraduate engineering students to measure the levels of engineering identity possessed by the respondents via Godwin's (2016) engineering identity survey and identify any relationships between engineering identity and depth of discipline. The survey results were analyzed via Kruskal-Wallis testing, due to the data being identified as non-normal. This test identified statistical significance between engineering identity and depth of discipline, which was further explored by post hoc Mann-Whitney testing to identify statistically significant mean differences between depths. Analysis showed that while discipline-specific students pursuing a concentration do self-report statistically significantly higher engineering identity scores than discipline-specific students not pursuing a concentration, the increase is likely not large enough to prompt action by engineering institutions. General engineering displayed no statistically significant relationships with engineering identity, except among female engineering students. Overall, depth of discipline was not found to be a main contributing factor to differences in engineering identity.

The construct of interest was found to be reported higher for students in a discipline-specific with a concentration depth than discipline-specific depth. Though not the variable of interest, this is an interesting finding, as interest is a prerequisite for engineering identity building. To increase interest, engineering institutions should consider more depth of discipline or other means to increase interest.

CHAPTER V

CONCLUSION

Would structuring engineering institutions to offer more specific engineering majors and curriculum positively impact engineering students? Findings supporting this question exist in this dissertation, but not with resounding evidence.

The first study considered the effects of providing more specific engineering disciplines on occupational alignment after graduation. Through analysis of historical data, a relationship was discovered, though not a linear relationship, as expected. Traditional engineering graduates are the most occupationally aligned specificity, followed closely by specific engineering and lastly - general engineering. Findings from this study indicate that either industry more often bases job creation on traditional engineering curriculum or that traditional engineering curriculum provides graduates with what is needed to function well in industry jobs more than the other two specificities. Additionally, a positive relationship between occupational alignment and job satisfaction was discovered, though the relationship did not necessarily show differences in job satisfaction between depths.

Studying the impacts of graduate school decisions through the lens of specificity of degree was the focus of the second study. Using historical data from the NSCG and chi-square analysis, two related questions were evaluated - Do engineering students with more specific undergraduate degrees seek graduate degrees and do engineering students with more specific undergraduate degrees seek more general graduate degrees and vice versa? The answer to both questions is "yes", though with varying levels of support. While specific engineering majors make the decision to attend graduate school more frequently than traditional engineering students, they only do so 4.4% more of the time. The more interesting finding from this study is that when engineering students make the decision to attend graduate school, most times they change their major between undergraduate and graduate schooling. These findings support a recommendation to engineering institutions to incorporate curriculum that aids undergraduate students in adapting to any discipline of graduate program, as well as integrating flexibility in graduate programs because of the understanding that more than half of students do not attend graduate school for the same major as their undergraduate program.

The final study studied students that were still undergraduates at the time of the survey. Using Godwin's (2016) engineering identity survey as a basis, this study aimed to measure the impact of depth of discipline on engineering identity. Findings support that engineering identity does differ between discipline-specific engineering depth and discipline-specific with a concentration. Though the difference was less than a tenth of a point, it is statistically significant, thus indicating that students with a deeper depth of discipline possess higher engineering identity. Female engineering identities are more impacted by depth of discipline, and this should be noted by all academic advisors who assist in major selection among female students. For underrepresented minorities, no impact was found from depth of discipline on engineering identity, thus other variables that may be the contributing factors to lower engineering identity scores for URM students should be explored. Interestingly, the largest difference in means between any depths of discipline was found between discipline-specific (*M* = 5.99, *SD* = .99) and discipline-specific with a concentration (*M* = 6.14, *SD* = .89) depths of discipline for the *construct of interest*. As interest is a prerequisite for engineering identity formation, this may be where engineering institutions should place their focus.

As mentioned previously, the evidence from these studies does suggest that more depth and specificity of discipline has a positive impact on the focus of each study, though as a whole, the evidence does not point toward one dominant depth or specificity. We are able, however, to identify the weakest link – general engineering. General engineering was considered across all three studies, though low samples sizes were reported in each study, and in each study general engineering either yielded no significant differences between the other discipline levels or was lowest. Again, these results must be digested with caution because of low sample sizes, but general engineering level is not aiding in the creation of occupationally aligned engineers in the field, more graduate school students, or higher engineering identity in our engineering students. For this reason, is general engineering a program worth offering to students? This is a decision for engineering institutions to make, but the evidence in these studies seem to lead to the conclusion that general engineering degrees are not best for retaining our engineering students, both educationally and professionally.

On the other hand, offering concentrations was found to be beneficial for engineering students to gain interest in their field of study and increase their engineering identity. As identified in Lent and colleagues' (2008) SCCT, interest is a main factor in major choice goals, and thus is an influencing factor for engineering students choosing to work or study in the engineering field after their undergraduate education. This information could be used to support the creation of concentration programs within discipline-specific engineering programs for the benefit of engineering students, engineering education institutions, and industries seeking to employ engineering graduates.

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APPENDIX A

ENGINEERING IDENTITY SURVEY

(Adapted from Godwin, 2016)

Informed Consent Form for Participation in Research for Exempt Research*

Title of Research Study: Depth of Discipline as an Influencing Factor of Engineering Identity

Researcher(s): Jenna Johnson, Dr. Lesley Strawderman, Dr. Jean Mohammadi-Aragh, Dr. Reuben Burch, and Dr. Jennifer Easley, Department of Industrial and Systems Engineering, Mississippi State University.

Procedures: If you agree to participate, your participation will be for approximately 5 minutes. You will be given a survey that will ask you to rate how strongly you agree or disagree to 11 statements regarding your perception of yourself as an engineering student. You will then be asked to provide 9 pieces of demographic information.

Questions: If you have any questions about this research project, please feel free to contact Jenna Johnson at jlo124@msstate.edu or Dr. Lesley Strawderman at strawderman@ise.msstate.edu.

Voluntary Participation: Please understand that your participation is voluntary, and your responses will be anonymous. **Your** refusal to participate will involve no penalty or loss **of benefits to which you are otherwise entitled. You** may discontinue your participation **at any time without penalty or loss of benefits.**

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

Thank you for agreeing to participate in our research. This research is for residents of the United States over the age of 18; if you are not a resident of the United States and/or under the age of 18, please do not complete this survey.

If you decide to participate, your completion of the research procedures indicates your consent. Please keep this form for your records.

*The MSU HRPP has granted an exemption for this research. Therefore, a formal review of this consent document was not required.

Research Participant Satisfaction Survey

In an effort to ensure ongoing protections of human subjects participating in research, the MSU HRPP would like for research participants to complete this anonymous survey to let us know about your experience. Your opinion is important, and your responses will help us evaluate the process for participation in research studies. ***https://www.surveymonkey.com/r/M5M95YF***

On a scale from 1 – "strongly disagree" to 7 – "strongly agree", please circle a number to indicate to what extent you agree or disagree with the following statements:

1. My parents see me as an engineer.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

2. My instructors see me as an engineer.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

3. My peers see me as an engineer.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

4. I am interested in learning more about engineering.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**

1	2	3	4	5	6	7

5. I enjoy learning engineering.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

6. I find fulfillment in doing engineering.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

7. I am confident that I can understand engineering in class.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

8. I am confident that I can understand engineering outside of class.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**

1	2	3	4	5	6	7

9. I can do well on exams in engineering.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

10. I understand concepts I have studied in engineering.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

11. Others ask me for help in this subject.

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1	2	3	4	5	6	7

Please fill in your answer for the following:

Current Degree Major:

____

(Ex: Civil Engineering)

Concentration/Specialization, if any:

____

(Ex: Environmental and Water Resources Concentration)

Current Overall GPA: ___________

Age: _________

Please circle your answer for the following:

Did you transfer to this university from a community or junior college?

Yes No

Gender: Male Female Other: ___________

Ethnicity: Caucasian African-American Latino or Hispanic Asian

Native American Other/Unknown I prefer not to answer

Class Standing: Freshman Sophomore Junior Senior 5^{th} Year Senior

APPENDIX B

SOLICITATION EMAIL TO TARGETED PARTICIPANTS

Hello, Engineering Undergraduate!

My name is Jenna Johnson, and I am an Industrial and Systems Engineering doctoral student at Mississippi State University (MSU). I am conducting an academic survey to collect data from participants regarding engineering identity.

Participants must be ages 18 to 23, and enrolled as an undergraduate student in an engineering program in the United States.

If you agree to participate, the survey should take less than 5 minutes to complete. Participation is completely voluntary, and your answers will be anonymous. A copy of the survey is attached for your reference. After completing the survey, you will have the option of entering your email address on a separate webform if you would like to be entered into a random drawing for one of fifteen $25 Amazon gift cards. This drawing is simply an opportunity for me to thank you for your time, but this webform is not tied to your survey response in any way.

This study has been reviewed by Mississippi State University's HRPP/IRB and has been granted an Exemption Determination. This research is supervised by Dr. Lesley Strawderman and has been approved by MSU's Institutional Review Board (Protocol ID: IRB-21-046).

Please click the hyperlink below to complete the survey. Thank you so much for your time!

Survey - Depth of Discipline as an Influencing Factor of Engineering Identity

Best Regards,

Jenna Johnson