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Depth of Discipline as an Influencing Factor of Engineering Identity*

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In this study, we explored the relationship between depth of discipline and engineering identity. Undergraduate engineering identity scores are of importance as engineering identity is necessary for educational persistence to graduation. We explored relationships between depth of discipline and engineering identity by surveying engineering students at higher education institutions in the United States and assessing their self-reported engineering identity and demographic variables. Findings indicate that engineering students enrolled in discipline-specific engineering degrees while also pursuing a specialization or concentration possess slightly higher engineering identity than students not pursuing a specialization or concentration. Additionally, this study found that the construct of interest, a component of engineering identity, is more related to depth of discipline. This is an interesting revelation, as the construct of interest is a required prerequisite for authoring an engineering identity.

Keywords: engineering identity; depth of discipline; breadth vs. depth; engineering retention; educational persistence; interest construct

1. 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 [1]. Compounding matters is a decline in interest in the engineering field [2] and an increase in global demand for engineers [3]. 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.

2. Background

Retaining engineering students is a complex business that involves factors ranging from financial aid to low peer expectations [4]. For the success of an engineering institution, the unit must be in the business of retention. This means innovating freshman engineering experiences [5], implementing mentoring programs [6], and offering summer bridge courses [7]. While these are sometimes effective methods of retaining students, they may not address the root-cause of attrition.

2.1 Engineering Identity

2.1.1 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 [8]. 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 [9]. As such, engineering institutions can conclude that engineering identity is essential to producing persistence in the study of engineering.

2.1.2 Composition

Three constructs comprise the formation of students' engineering identity. Those constructs, displayed in Fig. 1, include self-perceptions of: their

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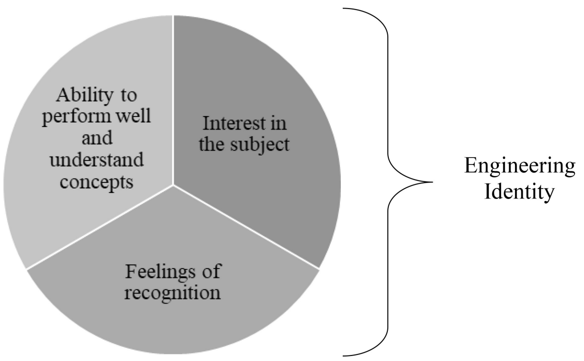

Fig. 1. Engineering Identity Composition based on Godwin [10].

ability to perform well and understand concepts, interest in the subject, and feelings of recognition [10].

Performing well and understanding concepts of engineering go beyond task-specific attainment, as measured by self-efficacy [11]. 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 [12]. Interest in engineering is a key indicator in whether or not a student is willing to identify as an engineer [10]. If interest is not present, motivation to pursue will also be lacking, and authoring an engineering identity will not commence.

2.1.3 Formation

The formation of engineering identity follows the developmental psychology development of stage theory [13]. 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 [14]. This indicates that a difference between freshman and senior level abilities to describe engineering identity is likely and should be controlled during experimentation [15].

2.1.4 Trajectories

Students identifying as engineers during their undergraduate schooling have essentially identified their career identity as well, according to Huff and associates' [16] study on engineering identity in adulthood. The interpretive phenomenological analysis investigation completed by Huff and associates [16] 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.

2.2 Educational Persistence

At the core of student decisions regarding higher education paths lies the questions of belonging and personal fit [17]. Students' sense of belonging within the engineering discipline, otherwise known as engineering identity [15], is believed to be related to educational persistence [13]. Meyers and colleagues [13] 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, and 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" [18, 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 [19] 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 [20] definition of identity, McKenzie's study inferred that identity impacts engineering educational persistence [19]. 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. Our study examines depth of discipline as a predicting factor for engineering identity.

3. Research Question

With the knowledge that engineering identity impacts persistence to remain in the engineering field [19], 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 [21]. 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 "*Is depth of discipline related to 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 [22], 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)

3.1 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.

4. Methods

4.1 Design

This study utilized a web-based 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. The web-based survey was generated using Qualtrics software [23] 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 [24]. 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 [25]. Since the communalities fall between the two, a conservative 250 samples were required.

4.2 Survey Instrument

The survey instrument used was Godwin's [10] engineering identity survey, with demographic question additions. 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 1 shows the survey items and the construct measured by each item.

For their use in our study, the items used to

Table 1. Survey Items and Constructs based on Godwin [10]

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.

measure engineering identity constructs display validity evidence [24]. 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 [26] asserts that coefficient alphas of 0.80 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.

4.3 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.

4.4 Procedure

Participants were recruited by email correspondence from engineering deans and department heads at more than 150 engineering institutions in the United States. Contact information for 944 engineering deans and department heads was collected and those individuals were emailed, asking them to forward a solicitation email to their undergraduate 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 excluded 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.

4.5 Participants

Participants were recruited via email, with the target population being traditional undergraduate students enrolled in an engineering program in the United States. "Traditional" is defined as individuals ages 23 and under [27]. 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%).

5. Analysis

Statistical Package for Social Sciences software [28] 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 [10]. 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 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 [24,17], 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.

6. Results

6.1 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 2 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.

Overall, females reported lower engineering identity scores ($M = 5.51$, $SD = 0.76$) than males ($M = 5.69$, $SD = 0.75$). Non-URM students reported higher engineering identity scores ($M = 5.62$, $SD = 0.76$) than URM students ($M = 5.55$, $SD = 0.77$). Across class standings sophomores reported the lowest overall engineering identity scores ($M = 5.58$, $SD = 0.76$), followed by juniors ($M = 5.61$, $SD = 0.77$) and freshmen ($M = 5.61$, $SD = 0.72$), leaving seniors with the highest engineering identity scores ($M = 5.62$, $SD = 0.78$).

6.2 Inferential Statistics

Due to non-normality of data, an independent-

Table 2. 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

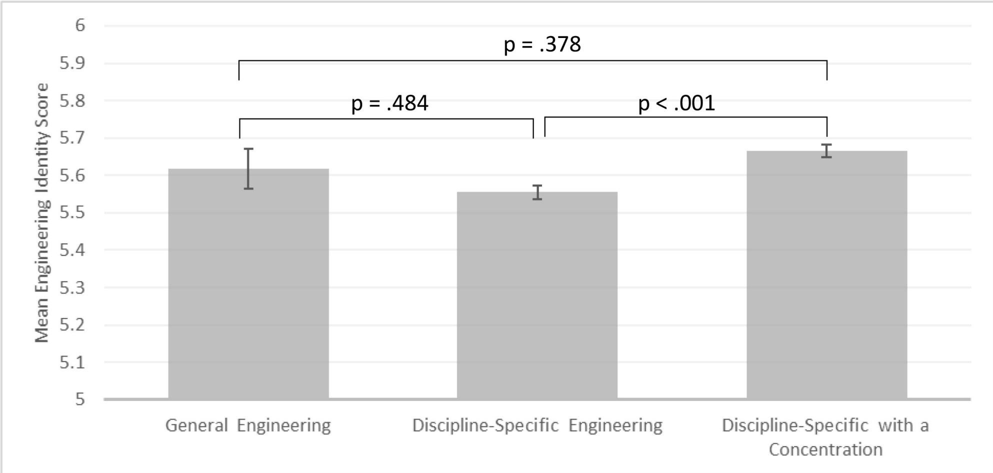

Fig. 2. Engineering Identity Mean Scores across Depths of Discipline.

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 [$H(2) = 16.61$; $p < 0.001$]. Both constructs of interest [$H(2) = 28.27$; $p < 0.001$] and performance/competence [$H(2) = 11.29$; $p = 0.004$] were shown to have significant differences between depths of discipline, while recognition did not display significant results [$H(2) = 2.36$; $p = 0.308$] at the 0.05 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 ($M = 5.55$, $SD = 0.79$) and discipline-specific with a concentration ($M = 5.67$, $SD = 0.73$) depths. Mann-Whitney results for the construct of interest showed a statistically significant difference between discipline-specific ($M = 5.99$, $SD = 0.99$) and discipline-specific with a concentration ($M = 6.14$, $SD = 0.89$) depths, and the same relationship for performance/competence exists between discipline-specific ($M = 5.32$, $SD = 0.97$) and discipline-specific with a concentration ($M = 5.44$, $SD = 0.92$) depths.

A visual examination of the data in Fig. 2 shows the statistically significant differences confirmed by the post hoc tests for engineering identity scores.

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 ($M = 5.99$, $SD = 0.99$) and discipline-specific with a concentration ($M = 6.14$, $SD = 0.89$) depths. Fig. 3 shows these differences via a bar chart.

6.3 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.

6.3.1 Gender

Kruskal-Wallis testing based on gender indicates a significant relationship for females [$H(2) = 17.56$; $p < 0.001$] between engineering identity and depth of discipline. The relationship for males [$H(2) = 6.96$; $p = 0.031$] also shows significance. Post hoc testing indicates a statistically significant difference in engineering identity score between both general engineering ($M = 5.38$, $SD = 0.74$) and discipline-specific with a concentration ($M = 5.59$, $SD = 0.74$) depths and discipline-specific ($M = 5.45$, $SD = 0.77$) and discipline-specific with a concentration ($M = 5.59$, $SD = 0.74$) depths for females while males show a statistically significant difference in engineering identity scores between only discipline-specific ($M = 5.63$, $SD = 0.79$) and discipline-specific with a concentration ($M = 5.73$, $SD = 0.72$) depths. Visual inspection of a bar chart with standard error (Fig. 4) 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.

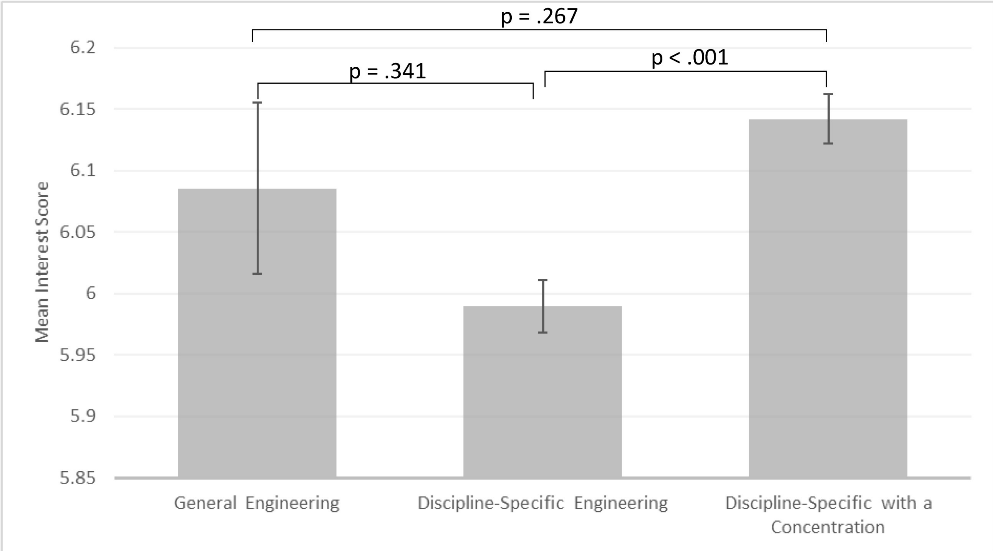

Fig. 3. Interest Mean Scores across Depths of Discipline. Note: The vertical axis of this chart is slightly longer than all other bar charts in this section, extending to 6.2 rather than 6.

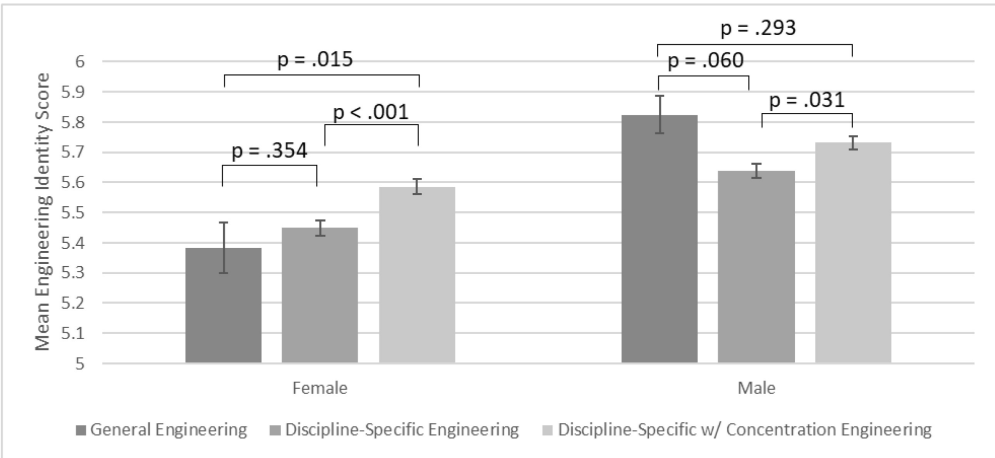

Fig. 4. Engineering Identity Mean Scores across Genders.

6.3.2 Class Standing

When viewed across class standings, only junior-standing showed significance [$H(2) = 8.17$; $p = 0.017$, while freshman [$H(2) = 4.40$; $p = 0.111$], sophomore [$H(2) = 5.68$; $p = 0.059$], and senior [$H(2) = 2.88$; $p = 0.237$] 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 ($M = 5.54$, $SD = 0.80$) and discipline-specific with a concentration ($M = 5.69$, $SD = 0.74$) depths of discipline. Visual inspection of Fig. 5 manifests this finding. Discipline-specific with a concentration showed a higher engineering identity score mean than discipline-specific for junior class-standing respondents.

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 3.

With no statistically significant differences between class standings for each depth of discipline, post hoc analysis was not completed, though Fig. 6 shows trends between the depths across class standings.

6.3.3 Minority Status

When depth of discipline was analyzed across minority status, a significant relationship between

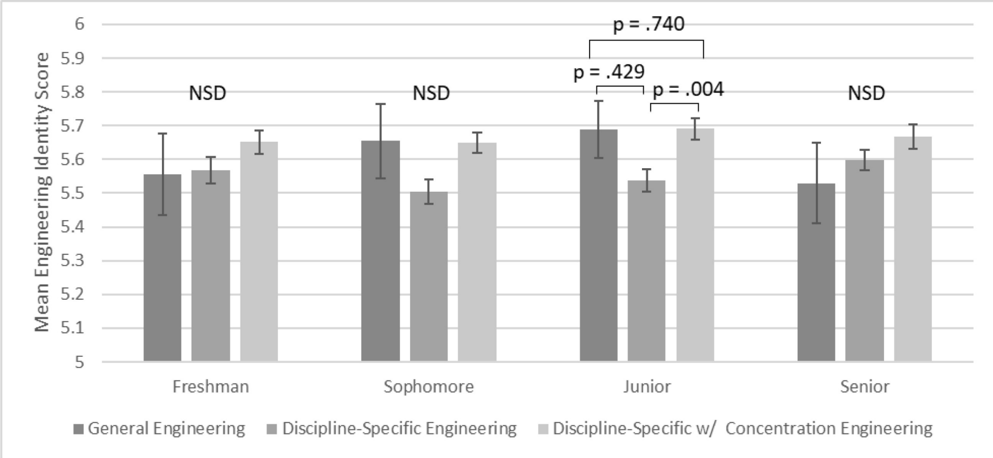

Fig. 5. Engineering Identity Mean Scores across Class Standing.

Table 3. 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	0.763
Discipline-specific	6.43	4	0.169
Discipline-specific with a concentration	2.27	4	0.687

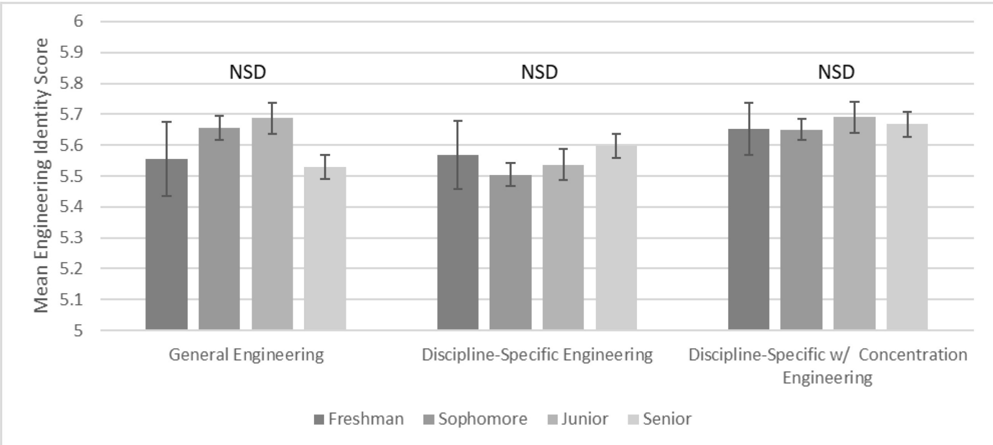

Fig. 6. Engineering Identity Scores Grouped by Depth of Discipline and Viewed across Class Standings.

engineering identity and depth of discipline was not found for underrepresented minority students [$H(2) = 1.83$; $p = 0.400$] but was found for non-URM students [$H(2) = 16.28$; $p < 0.001$]. Post hoc analysis indicated that engineering identity scores for non-URM students differed statistically significantly between discipline-specific ($M = 5.56$, $SD = 0.78$) and discipline-specific with a concentration ($M = 5.67$, $SD = 0.74$) depths of discipline. Fig. 7 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.

6.4 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. Differing letters in Table 4 – a, b, and c – in each depth of engineering category column indicate that the column proportions were found to differ significantly from each other at the 0.05 level for the measured variable. The same letter present in each column represents the opposite – no statistically significant difference between the depths of discipline. Columns should be compared across columns, but not between rows. As seen in

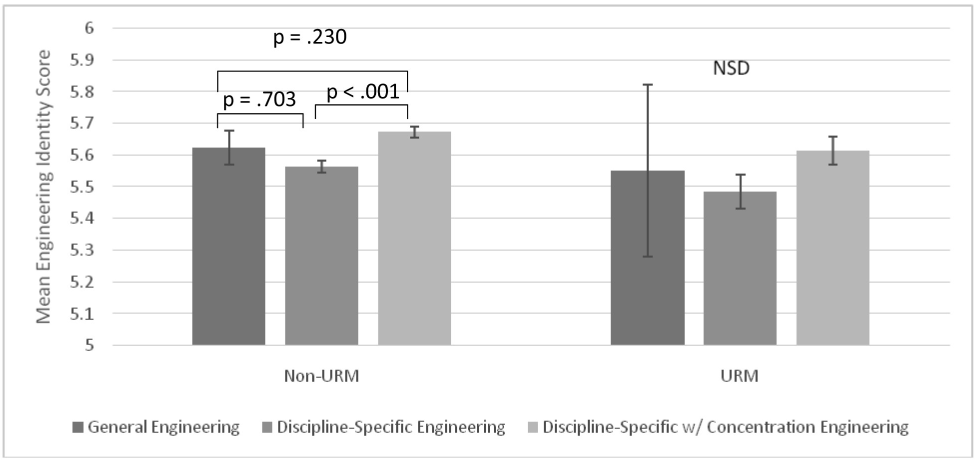

Fig. 7. Engineering Identity Mean Scores across Minority Status.

Table 4. 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 Depth of Discipline whose column proportions do not differ significantly from each other at the 0.05 level.

Table 4, 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.

7. 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. [9]. 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 = 0.73) than for students pursuing a discipline-specific engineering degree with no concentration (M = 5.55, SD = 0.79). This indicates that depth of discipline is related to 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 [9]. 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 restructure 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 = 0.98) and discipline-specific with a concentration (M = 6.14, SD = 0.89) 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 [10] 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 related to depth of discipline, the construct of interest is more related, and interest is a prerequisite for engineering identity formation, according to Godwin [10]. 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 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 = 0.76) than males (M = 5.69, SD = 0.75), as seen previously by Godwin and Lee [24], 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 [24]. 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 [24] 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 [13]. 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 relation of depth of discipline to 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 Fig. 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 [24] and Rainey and colleagues [17], minorities reported lower overall engineering identity scores (M = 5.55, SD = 0.77) than non-URM students (M = 5.62, SD = 0.76), 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 related to 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 = 0.98) and discipline-specific with a concentration (M = 6.14, SD = 0.89) 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 [10] 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 related to depth of discipline, the construct of interest is related, and interest is a prerequisite for engineering identity formation, according to Godwin [10]. 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.

7.1 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.

7.2 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.

8. 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 [10] 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.

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