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Work in Progress: Uncovering Links between Mathematical Preparation and Engineering Persistence

Dr. Mary E. Lockhart, Texas A&M University

Mary E. "Betsy" Lockhart, Ph.D. is a Postdoctoral Research Associate at Texas A&M University. Her research focuses on what factors influence diverse students to choose and persist in STEM. Particularly, she is interested in the development and cultivation of students' STEM identities and the potential protective element these identities have in student retention. Dr. Lockhart graduated from Stephen F. Austin State University with a B.S. in Mathematics and Psychology. She then graduated from Texas A&M University with a M.S. in Mathematics and Ph.D. in Educational Psychology with a specialization in Research, Measurement and Statistics.

Noor Hakim
Vainavi Chilukuri, Texas A&M University
Jason Champagne
Dr. Karen E. Rambo-Hernandez, Texas A&M University

Karen E. Rambo-Hernandez is an associate professor at Texas A & M University in the College of Education and Human Development in the department of Teaching, Learning, and Culture. In her research, she is interested in the assessing STEM interventions on

Dr. Robin A.M. Hensel, West Virginia University

Robin A. M. Hensel, Ed.D., is a Teaching Professor in the Benjamin M. Statler College of Engineering and Mineral Resources at West Virginia University and an ASEE Fellow Member. As a mathematician and computer systems analyst, she collaborated in engineering teams to support energy research before entering higher education where she taught mathematics, statistics, computer science, and engineering courses, secured over $5.5M to support STEM education research, led program development efforts, and served in several administrative roles. She has been recognized for her teaching, advising, service, and research and as an Exemplary Faculty Member for Excellence in Diversity, Equity, and Inclusion.

Work-in-Progress: Uncovering Links between Mathematical Preparation and Engineering Persistence

Abstract

This work-in-progress research paper is at the early stages seeking to further understand the links between incoming engineering students' mathematical preparation and their actual degree attainment in engineering. The importance of mathematical achievement and preparation to engineering persistence has long been studied. This investigation seeks to further enhance this research-base. A sample of 450 incoming engineering majors were divided into three different engineering tracks by their university based upon their level of mathematics preparation: Engineering Track 1 (Calculus-ready), Engineering Track 2 (Calculus-ready with Precalculus review), and Engineering Track 3 (College Algebra-ready). Academic (e.g., GPA), demographic (e.g., gender) and psychosocial (e.g., engineering identity) variables were collected for all students upon college entrance. Satisfactory indicator variables (e.g., cumulative GPA, cumulative credit hours earned, major selection) were gathered and tracked throughout the students' collegiate tenure—including their graduating college major. Descriptive statistics, Pearson's chi-squared tests, student *t*-tests, and one-way ANOVAs were utilized in this investigation as appropriate. First, the relationship between the engineering tracks to actual degree attainment in engineering was confirmed—supporting the importance of engineering students' mathematical preparation to their degree persistence. Next, academic, demographic and psychosocial profiles of each of the engineering tracks were created and compared to investigate potential differences between the tracks. Differences in cumulative GPA and engineering major selection were noted between the tracks. Demographic consistency among the tracks was noted. In examination of the psychosocial profiles of the tracks, a social cognitive career theorist (SCCT) perspective was further utilized—investigating levels of engineering identity, engineering self-efficacy and engineering outcome expectations for each track. Notably, levels of engineering identity differed widely between the tracks. Upon closer inspection of each individual track, engineering identity again played an important role. Interestingly, students in Engineering Track 3 who attained a degree in engineering boasted the highest level of engineering identity across all subgroups within the sample. Moreover, in examining each track separately, the greatest difference in engineering identity between students who persisted to degree attainment and those who did not was also found in Engineering Track 3. Preliminary results indicate suitable rationale to further situate engineering identity within the SCCT framework and investigate its direct impact upon engineering degree attainment and potential moderating role in the relationship between mathematics preparation and engineering degree attainment. Feedback from the research community regarding the findings of this study and its future directions are desired.

Background

The National Academies Gathering Storm committee concluded several years ago that the primary driver of the future economy, security of the United States (US) as a nation, and concomitant creation of jobs would be innovation—largely derived from advances in science and, particularly, in engineering [1]. It has been estimated that close to 50% of the students who begin their education in engineering do not follow through to the completion of an engineering degree [2]-[5]. Some studies have further documented that the propensity for engineering students to attrit is particularly high during their first two years of college [2], [4]. Given engineers' critical role in the growth of the U.S.'s economy, security as a nation, and creation of jobs, this high-level of attrition is gravely concerning. A broad area of research has developed to understand why students engage and persist in engineering including the examination of influences that both cognitive and non-cognitive variables have upon engineering persistence. In this study, we examine the long-standing importance of the relationship between mathematics preparation before college entrance to undergraduate engineering persistence. Through the development of academic profiles, demographic profiles and psychosocial profiles of students on three different engineering tracks based on their entering level of mathematics proficiency, we compare these profiles to uncover various factors related to students' persistence to engineering degree attainment.

Cognitive/Academic Variables Related to Engineering Persistence

The importance of mathematical achievement and preparation to engineering persistence has been well documented. Seymour and Hewitt [6] posited over two decades ago that if students are proficient in mathematics and science at an early age, then this proficiency encourages them to choose science, technology, engineering and mathematics (STEM) undergraduate majors along with employment in STEM fields such as engineering [1]. Veenstra and colleagues [7] highlighted key differences regarding factors that predict retention and academic success between engineering majors and other majors. They found that high school academic achievement in mathematics and sciences are weighted heavily for engineering majors in comparison to other majors, along with quantitative skills, analytical thinking, and problem-solving abilities [7].

Other studies have supported the notion that mathematics preparation and various achievement indicators in high school such as SAT math scores, ACT math scores, and GPA heavily influence the likelihood of students persisting in engineering majors [8]-[14]. More specifically, and commonly noted, is the direct link between students' Calculus-readiness upon college entrance and their actual attainment of an engineering degree in college—which is well documented [9], [15].

Bowen, Hall, and Ernst [15] examined 10 years of engineering admissions data for first-year students. They concluded that engineering students who were eligible to register for Calculus upon college entrance were significantly more likely to graduate with a degree in engineering than students who were not Calculus-eligible [15]. They also noted, however, that there could be other factors acting upon this relationship that could explain more of the variability in persistence [15]. These findings were further evaluated through a follow-up investigation in which Bowen and colleagues [9] explored the impact of Calculus-readiness upon engineering persistence to degree completion along with the potential mediating effect of students' "at-risk" status. The researchers discovered that indeed Calculus-readiness upon college entrance was a significant predictor of engineering degree completion and accounted for 11% of the overall variance in persistence. They also noted that students' "at-risk" status at the end of their first year, stated as having below a 3.0 GPA, partially mediated the relationship between Calculus-readiness and engineering persistence—together accounting for 22% of the overall variance in persistence [9].

Furthermore, Bowen and colleagues [9] cited that the odds of graduating with a degree in engineering for students who were Calculus-ready and not "at-risk" was 14 times higher than for students who were not Calculus-ready upon college entrance and who had below a 3.0 GPA at the end of their first year in college. This study highlights the need for different variables to be evaluated for potential influences on the relationship between mathematics preparation and engineering persistence.

Psychosocial Factors Influencing Engineering Persistence

SAT math scores, ACT math scores, high school GPA, first-year college GPA and Calculus-readiness upon college entrance are not the only variables that have been identified as influencing engineering persistence. Some scholars have undertaken a psychosocial investigative approach into uncovering non-cognitive and affective factors influencing persistence in engineering (or STEM) degree programs and careers. Students' contextual identities in STEM (e.g., engineering identity) are central to many of these investigations examining factors influencing STEM persistence [16]-[20]. In particular, several scholars have documented the significant, positive influence of students' engineering identities to their actual persistence in engineering [9], [21], [22]. Yet, what exactly is a contextual engineering identity?

The conceptualization of the contextual engineering identity can be traced back to Gee [23], who ushered identity formation theory initiated by Erickson [24] into education. Gee defined identity as a "kind of person" one is in any given context [23]. Recent studies measuring engineering identity build upon the grounded model of science identity created by Carlone & Johnson [25] that embraces Gee's definition [26]. Carlone and Johnson [25] suggested the existence of three interrelated dimensions of science identity: Competence, Performance, and Recognition. Inside the Recognition dimension of science identity resonates Gee's definition of identity—recognizing oneself as a "science kind of person" [17], [23], [25], [27], [28]. By applying this grounded theory of science identity to the field of engineering, a substantive component of a student's engineering identity has, thus, largely been recognized as being the degree to which they "view themself as an engineering kind of person" [22], [26]-[29].

Utilizing this operationalization of engineering identity, several scholars have provided evidence of support that students who do not identify with the engineering field have a greater likelihood of exiting or never entering the engineering workforce than those who do [21], [22], [30], [31]. Despite demonstrated engineering academic ability and skills, a lack of identification with engineering has been declared a primary motivating factor particularly for women who leave engineering [6], [32]. Ultimately, the successful cultivation of students' engineering identities is critical for fostering positive experiences within engineering, and directly impacts their continued pursuit of engineering majors and subsequent entrance into the engineering workforce [6], [26], [33]-[35].

Although engineering identities are, thus, important to educational and career choices engineering students make, Social Cognitive Career Theory—an effective and popular model for studying educational choices among engineering students [36]-[38]—also provides a framework with which to view student matriculation into the engineering field. It is worth noting that engineering identity has not been incorporated into the Social Cognitive Career Theory (SCCT) framework. Though the focus of this study is not to incorporate engineering identity into the SCCT framework, given the strength of both the SCCT framework and engineering identity to predict persistence into engineering, we examine both in the current study. Next, we describe SCCT in greater detail.

The SCCT theorizes that behavior is goal directed and is produced and sustained largely through an individual's evaluations of the value of achieving the goal and the expectations of reaching the goal [39]. Though various cross-sectional and longitudinal models have been depicted regarding the structuring of non-cognitive and affective variables within the SCCT that influence students' intentions to persist to degree completion or to career selection in STEM—or specifically engineering—two common paths are repeatedly unearthed. Students' engineering self-efficacy and their outcome expectations in engineering are significantly and directly related to their persistence [36], [38], [40]. Self-efficacy refers to a person's perception of their abilities to perform actions necessary to obtain specific goals relevant to their career. Foundational SCCT works have demonstrated that self-efficacy beliefs influence career-relevant choices and performance such as persisting to degree completion [41]-[43]. Outcome expectations refer to the perceived consequences of engaging in various behaviors. Self-efficacy has been found to influence outcome expectations which directly effects intentions to persist in career relevant endeavors [44].

There is mounting support for utilizing the SCCT framework in attempting to understand the academic and career selections of undergraduate STEM majors. For example, positive self-efficacy and outcome expectancies have both been found to significantly predict students' choice of STEM majors, interest in STEM careers, and perceived STEM career options [36]-[38]. Though engineering identity has not been rigorously incorporated into the SCCT framework, two studies have incorporated science identity, a similar construct to engineering identity, into an SCCT theoretical model [17],[40]. Specifically, Byars-Winston and Rogers [40] examined the relationship of self-efficacy, outcome expectations and science identity to career intentions. They found that self-efficacy and outcome expectations were directly and positively associated with research career intentions [40]. The duo also noted that science identity contributed significant, yet modest, variance to career intentions indirectly through its positive association with outcome expectations [40].

This study seeks to build upon past research and contribute to the knowledge base regarding how a student's engineering identity, engineering self-efficacy and outcome expectations in engineering are related to engineering persistence—specifically for students exhibiting different levels of mathematics preparation upon college entrance. To our knowledge, no prior study has examined how these variables differ in relation to students' levels of mathematics proficiency. Thus, much knowledge is left to be gained.

Present Study

The current study is a part of a larger, grant-funded study focused on cultivating Inclusive Professional Engineering Identities within engineering majors. Participants in the study were from a large, R1 university and were all first-year students planning to major in engineering or computer science. The university divided the students into three different engineering tracks for their first year, representative of their level of mathematics preparation upon college entrance based upon their mathematics achievement and coursework in high school. Students on Engineering Track 1 were deemed to be Calculus-ready and prepared to enter a Calculus course. Students on Engineering Track 2 were Calculus-ready with Precalculus review and, thus, not truly prepared for a Calculus course but were eligible for Precalculus. Students on Engineering

Track 3 were College Algebra-ready and, thus, not able to register for any mathematics course above College Algebra—including Precalculus and Calculus. The primary goal of the present study is to investigate the relationship between levels of mathematics preparation of engineering students upon college entrance to their persistence to engineering degree attainment, and the variables that impact this relationship. "Persisters" in this study are defined as those students who persist to engineering degree completion while "switchers" are defined as those students who switch out of engineering altogether at some point during their collegiate tenure. The specific research questions (RQ) and sub-question (SQ) addressed in this study include:

- RQ1: Is there a relationship between the three engineering tracks representing different levels of mathematics preparation upon college entrance to persistence to degree attainment in engineering?
- RQ2: What are the academic profiles of each track?
    - SQ2.1: For each individual track, how do average GPAs compare between engineering "persisters" before graduation and "switchers" before exiting engineering?
    - SQ2.2: Is the engineering track students are placed into related to the type of engineering degree students attained?
- RQ3: What are the demographic profiles of each engineering track?
    - SQ3.1: Do the demographic profiles differ between tracks?
    - SQ3.2: Within each individual track, are there differences in demographics that are related to engineering persistence?
- RQ4: What are the psychosocial profiles of each engineering track?
    - SQ4.1: Do the psychosocial profiles differ between tracks?
    - SQ4.2: Within each individual track, are there differences in initial levels of psychosocial variables that are related to engineering persistence?
    - SQ4.3: For each individual track, how do changes in average levels of psychosocial variables from the beginning to the end of students' first semester compare for engineering "persisters" versus "switchers?"

Methods

Participants and Procedures

Participants for this study were all enrolled in an introductory engineering class over one semester. The study was reviewed and approved by the Institutional Review Board (IRB# 1905584259) and participant consent was obtained through the online survey platform.

Demographic and psychosocial variables were measured initially, T1, for each student upon college entrance in the fall semester of 2018. Psychosocial variables were measured three other times during students' first semester—the final measurement, T4, occurring at the end of the fall semester of 2018. Student satisfactory indicator variables (e.g., cumulative GPA, cumulative credit hours earned, college major) were gathered in the fall semester each year for four years—ending in the fall semester of 2021. Information was gathered and evaluated from a total of 466 student participants. To maintain the integrity of the data and accuracy of the analyses, sixteen participants were removed from the analytic sample due to their selection of a "computer science" major in 2021. Given that some universities house computer science departments within engineering colleges/schools and other universities do not, we could not adequately determine if a computer science major should be classified as an engineering degree.

Information from the remaining 450 students was investigated. Demographic information for the total analytic sample is as follows: 76% self-identified as men, 95% White, 50% were on Engineering Track 1, 30% were on Engineering Track 2, and 20% were on Engineering Track 3.

Measures

Engineering Self-Efficacy. Students' confidence in their ability to complete necessary steps for obtaining their engineering degree was measured using a three-item instrument developed by Lent and colleagues [45]. The items were rated on a 5-point Likert scale (1-no confidence to 5-complete confidence) where participants indicated their level of confidence in their ability to complete each step necessary to obtain their engineering degree. Engineering self-efficacy scale scores were derived as the average of all items. Prior research evidence has shown that this measure of self-efficacy is directly related to social cognitive outcomes, including performance attainment and persistence intentions [36], [45]. Good internal reliability for the three items was obtained with Cronbach's $\alpha = .90$.

Outcome Expectations for Engineering. Students' outcome expectations for Engineering were assessed by asking participants to indicate the extent to which they agreed with statements such as, "Graduating with a BS degree in engineering will likely allow me to do work that I would find satisfying." This measure contained three items adapted from Lent and colleagues' [45] instrument and rated on a scale from 1 (strongly disagree) to 7 (strongly agree). Scale scores were derived as the average of all items. Previous research efforts have shown that this measure of outcome expectations is directly related to social cognitive outcomes, including persistence intentions [36], [45]. Good internal reliability for the three items was obtained with Cronbach's $\alpha = .90$.

Engineering Identity. The Identity as a Scientist instrument developed by Chemers and colleagues (2010) was adopted and modified specifically for engineering to reflect a student's self-identification as an engineer. Participants' engineering identity was measured using three of Chemers and colleagues' [46] original six identity items. Items were rated on a scale 7-point Likert scale (1-strongly disagree to 7-strongly agree). Participants indicated their level of agreement with the statements such as, "I have come to think of myself as an engineer." Thus, a higher average scale score indicated a greater degree of self-identification as an engineer. Good internal reliability for the three items was obtained with Cronbach's $\alpha = .89$.

Data Analytic Strategy

Math Preparation. To determine if the level of mathematics preparation represented by the three engineering tracks was related to engineering degree attainment, a variable representing students' degree attainment was created. Students who graduated in 2020 with a degree in engineering, or who were on track to graduate in 2021 with a degree in engineering were coded as "engineering degree". Students who switched to another major outside of engineering between 2018 and 2021 were coded as "switch out of engineering". Next, decisions had to be made about students whose data was missing, or there was not enough data to determine if they had completed a degree in engineering or switched to a different major. Given that reasons for the missing data were unknown (e.g., student could have transferred, dropped-out, or information simply not gathered) it was decided to divide these students into two groups for initial analysis purposes based upon their last "satisfactory indicators" gathered. Students in the engineering program needed a cumulative 2.25 GPA to continue in good standing. Thus, students whose data went missing but they had a cumulative GPA at or above a 2.25 at their final time point were categorized as “missing data-good standing”. However, students whose data went missing but they had a cumulative GPA below a 2.25 at their final time point were categorized as “missing data-poor standing”.

The frequency of students within each of the four engineering degree attainment categories explained above was calculated for each track and then compared across the tracks. A formal Pearson’s chi-squared test at the standard $\alpha = .05$ significance level was used to determine if relationships between degree attainment in engineering and level of mathematics preparation was statistically significant.

Academic Profiles. To build academic profiles of each engineering track, average GPAs of persisting students and students who switched out of engineering were calculated and compared. GPA was calculated based upon persisting students’ final documented cumulative GPA before graduation, or as the final cumulative GPA of switchers before they switched out of engineering. Next, the frequency of students’ graduating major was compared across the three tracks to determine if a relationship existed between levels of mathematics preparation and the type of engineering major selected. As necessary, formal Pearson’s chi-squared test at the standard $\alpha = .05$ significance level was used to determine if relationships amongst variables were statistically significant. Students with missing data for their degree attainment were not analyzed within each track as the reasons for the missing data were too broad and unknown to adequately model these students (e.g., dropped out, transfer, etc.).

Demographic Profiles. To create demographic profiles of each engineering track, percentages of gender and students being of an ethnicity typically underrepresented in engineering, URM, were calculated. Bar charts were used to compare these variables across tracks. Percentages of each demographic variable within each track that attained an engineering degree, referred to as “persisters” were then compared to those who switched to a different major, referred to as “switchers”, to determine if there was a relationship between demographic variables to degree attainment within each track. Students with missing data for their degree attainment were not analyzed within each track. As needed, formal Pearson’s chi-squared test at the standard $\alpha = .05$ significance level was used to determine if relationships amongst variables were statistically significant.

Psychosocial Profiles. Averages and other descriptive statistics for each SCCT variable in consideration were calculated for each track. Averages were then compared for each variable across the three tracks. If substantial variations in averages were noted between the tracks, a oneway ANOVA (Analysis of Variance) was used to determine if the variations were statistically significant at the standard $\alpha = .05$ significance level.

Next, averages on the different SCCT variables within each individual track were examined in relation to actual engineering degree attainment. Again, students with missing data for their degree attainment were not analyzed within each track. If substantial variations in initial averages between “persisters” and “switchers” were noted within the tracks on any psychosocial variable, a oneway ANOVA or t-test was used to determine if the differences were statistically significant at the standard $\alpha = .05$ significance level. Next, average changes in students’ measured psychosocial variables over the course of their first semester were calculated and compared between engineering “persisters” and “switchers” for each track.

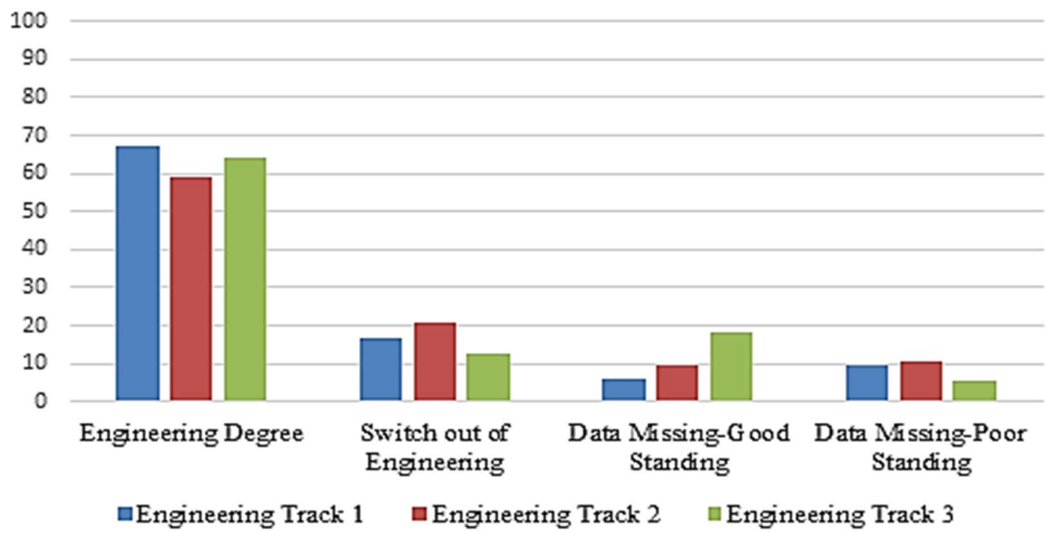
STATA 17.1 [47] was used for all analyses.

Results

Math Preparation

To address *RQ1: Is there a relationship between the three engineering tracks representing different levels of mathematics preparation upon college entrance to actual degree attainment in engineering?* the frequency of students within each of the four engineering degree attainment categories for each track was calculated. Related percentages can be found in Figure 1.

Figure 1. Percentage of students attaining engineering degrees per engineering track



A relationship between degree attainment and engineering track appeared feasible given that students with the highest level of mathematics preparation (i.e., Engineering Track 1) had the greatest percentage of students graduating with a degree in engineering and the lowest percentage of students for almost all other categories. Interestingly, however, Engineering Track 2 demonstrated the lowest percentage of students graduating with a degree in engineering and the highest percentage of students switching out of engineering. Though the relationship between mathematics preparation and persistence was not entirely as expected (i.e., where track 1 would have the most "persisters" and fewest "non-persisters" and track 3 would have the least "persisters" and most "non-persisters") a Pearson's chi-squared test revealed that there was indeed a statistically significant relationship between these variables $(p = .03)$. Track 3, thus, presented an interesting case for investigation as greater percentages of these students appeared to persist than was expected.

Academic Profiles

To begin investigating *RQ2: What are the academic profiles of each track?* and *SQ2.1: For each individual track, how do average GPAs compare between engineering "persisters" before graduation and "switchers" before exiting engineering?* average GPA's of "persisters" and "switchers" within each track were calculated. Table 1 provides the results of these calculations. Clearly, "persisters" demonstrated higher GPAs than "switchers" across all of the tracks. GPAs also tended to be related to math preparation as students with greater levels of mathematics preparation demonstrated higher GPAs than those with lower levels of math preparation for both “persisters” and “switchers.” Interestingly, the greatest differences in GPA appeared in Engineering Track 1 and Engineering Track 3—those with the highest and lowest levels of mathematics preparation. “Persisters” in Engineering Track 1 showed an average of .70 GPA points higher than “switchers,” while those in Engineering Track 3 documented average GPAs that were .69 points higher than switchers. For both of these tracks, GPA differs substantially between “persisters” and “switchers.”

Table 1. Average GPAs’ of “persisters” and “switchers” per track

	Engineering Track 1	**Engineering Track 2**	**Engineering Track 3**
Persisters’ GPA	3.49	3.18	2.96
Switchers’ GPA	2.79	2.74	2.29

Next, we sought to investigate *SQ2.2: Is the engineering track students are placed into related to the type of engineering degree students attained?* Appendix A provides a full table with count data related to degree selection per each track. As is consistent with the literature, students selecting a major outside of engineering was the most populous category for each track—containing 20% of track 1 students, 26% of track 2 students, and 16% of track 3 students. The next most common major selections for track 1 included: Mechanical Engineering (15%), Aerospace Engineering (15%), and Industrial Engineering (14%). The other most common major selections for track 2 included: Industrial Engineering (13%), Civil Engineering (12%), and Petroleum and Natural Gas Engineering (9%) along with Aerospace Engineering (9%). Track 3’s other most commonly selected majors included: Petroleum and Natural Gas Engineering (16%), and Industrial Engineering (15%) along with Mechanical Engineering (15%).

Pearson’s chi-squared test produced significant results ($p < .001$) yielding that there is indeed a relationship between engineering track and major selection, rejecting the null hypothesis that major and track were completely unrelated. This is most clearly seen in Aerospace Engineering where eight more students than expected for track 1 selected the major while five fewer students than expected from track 3 selected the major. Biomedical Engineering was similar where nine more students than expected from track 1 declared the major compared to three less students than expected in track 3. On an opposite note, seven more students than expected from track 3 declared a Petroleum and Natural Gas Engineering major while 10 less students than expected declared this major for track 1. Indeed, differences in major selection were observed across the tracks.

Demographic Profiles

Next, to address *RQ3: What are the demographic profiles of each engineering track?* frequencies of gender and URM status of each track were calculated. Related percentages of each can be found in Figure 2 and Figure 3.

Figure 2. Percentages of men and women per engineering track

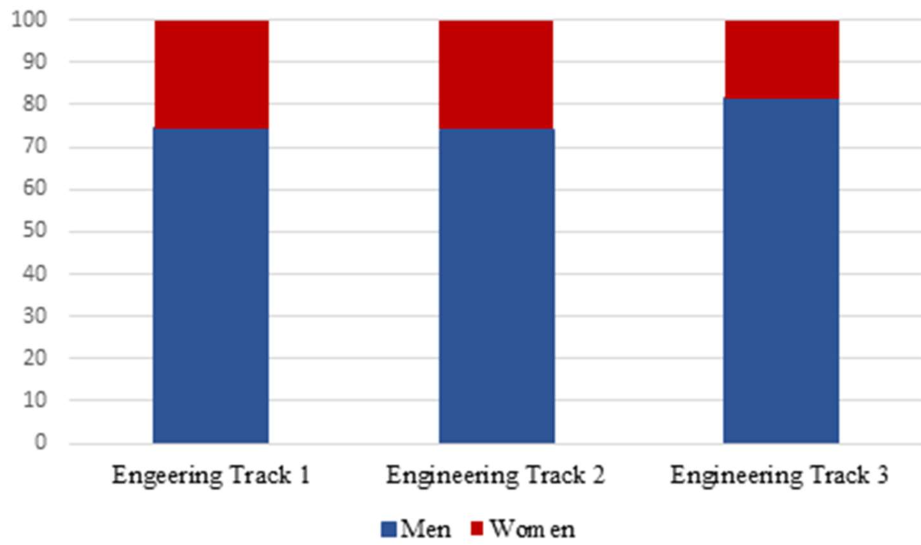
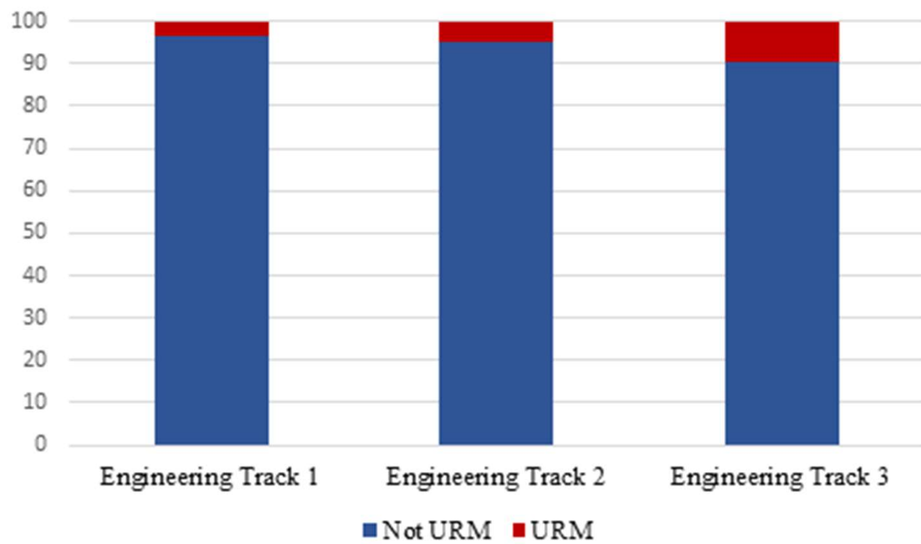


Figure 3. Percentages of URMs per engineering track



To address *SQ3.1: Do the demographic profiles differ between tracks?* figures 2 and 3 were examined. The demographic profiles appeared to be fairly consistent across the tracks with only a slightly greater percentage of men and URMs in track 3. Given this result, there did not appear to be a relationship between the demographic variables and the engineering tracks. Thus, no formal testing was conducted.

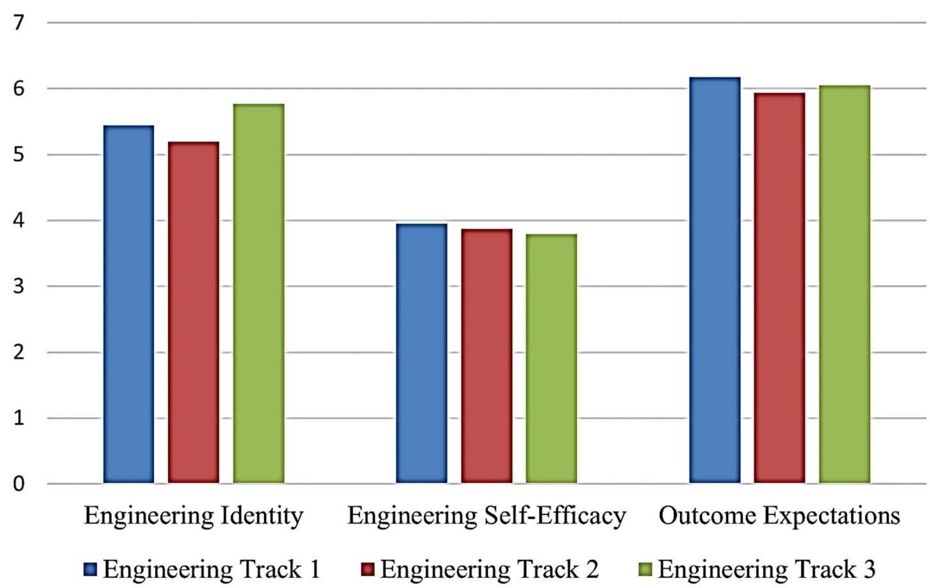
Next, to address *SQ3.2: Within each individual track, are there differences in demographics that are related to engineering persistence?* each individual track was analyzed independently. A chart depicting the related percentage of gender within each track who graduated with a degree in engineering or switched to a different major can be found in Appendix B. Though percentages within each track of men and women persisting or switching is fairly consistent for track 2 and track 3, this is not the case for track 1. Engineering Track 1 showed somewhat disproportionate amounts of women attaining a degree in engineering compared to switching. Approximately 30% of "persisters" in Engineering Track 1 were women compared to 16% of “switchers”. This difference in representation between women “persisters” and women “switchers” was substantially larger than what was observed for the other tracks though the total percentage of women on each track was consistent. Thus, a Pearson chi-squared test was conducted and revealed no statistically significant relationship between gender and engineering persistence to degree attainment for Engineering Track 1 ($p = .08$).

The same strategy was employed for URM status. A chart depicting the related percentage of URMs within each track who graduated with a degree in engineering or switched to a different major can be found in Appendix C. The percentages of URMs appeared consistent between engineering degree attainment categories within each track. No formal testing was conducted.

Psychosocial Profiles

To begin investigating *RQ4: What are the psychosocial profiles of each engineering track?* and *SQ4.1: Do the psychosocial profiles differ between tracks?* scale scores for engineering identity, engineering self-efficacy and engineering outcome expectations measured at T1 were compared across the three tracks. A complete table of descriptive statistics can be found in Appendix D. Initial levels of psychosocial variable means for each track are visualized in Figure 4.

Figure 4. Initial psychosocial variable means for the engineering tracks



Relatively small differences in means are observed for engineering self-efficacy and outcome expectations across the tracks, so no formal statistical testing was pursued. Engineering identity, however, presents contrasting results. Interestingly, Engineering Track 3 (green) boasts the highest engineering identity by a substantial margin. Formal testing was pursued to determine if engineering identity differed significantly among the tracks. A squared transformation was used for identity scores given its non-normal distribution across the tracks. A oneway ANOVA with a Welch F-test was then applied and yielded that a non-statistically significant difference in identity scale scores between the tracks existed ($F(2, 227.61) = 2.84, p = .06$). Though formal testing produced insignificant results, the trend in the data suggested that tracks 2 and 3 differed substantially in their levels of engineering identity with track 2 posting the lowest scores and track 3 the highest.

Next, to investigate *SQ4.2: Within each individual track, are there differences in initial levels of psychosocial variables that are related to engineering persistence?* each track was individually examined to determine if initial averages of any psychosocial variables differed between students who attained an engineering degree and those who switched to a different major. Figure 5 provides a visual example of these differences within the three tracks.

Figure 5. Initial mean levels of psychosocial variables between engineering degree attainers and switchers per each track

Notably, outcome expectations (blue) in engineering between engineering degree attainers and "switchers" appears to differ substantially within both tracks 1 and 3. Engineering identity (green) also seems to differ substantially between "persisters" and "switchers" within each track, but most widely in track 3. Also of interest, engineering identity was higher for Engineering Track 3 students who persisted in engineering than for any other subgroup examined. Self-efficacy demonstrated only minor variations within the tracks between "persisters" and "switchers."

A series of six t-tests were utilized to examine if differences in identity or outcome expectations were statistically significant between "persisters" and "switchers" within each of the three tracks. The squared transformation of identity scores was again utilized due to non-normality. A Bonferroni corrected significance level of .008 was, thus, adopted to control for type-1 error rates. Utilizing this criterion, only engineering identity differed significantly between "persisters" and "switchers" within track 3 $(t(65) = 2.88, p = .005)$. With $Hedge's\ g = .95$, this was a large effect. Though the trend in the data suggested engineering identity also differed by a fair amount between "persisters" and "switchers" in track 2, this difference was not statistically significant $(t(106) = 1.70, p = .09)$. With $Hedge's\ g = .37$, this effect for track 2 was a small effect.

Lastly, to examine *SQ4.3: For each individual track, how do changes in average levels of psychosocial variables from the beginning to the end of students' first semester compare for* *engineering "persisters" versus "switchers?"* measured psychosocial variables were observed for each group at both timepoints. These results are presented in Table 2. Though "persisters" and "switchers" for each track began the semester fairly similarly on each measured variable (except for engineering identity in track 3), clear differences were observed by the end of their first semester. By four months into the semester, "switchers" showed substantial declines in outcome expectations in engineering and engineering self-efficacy while "persisters" tended to remain fairly stable—perhaps demonstrating a slight increase or decline, but no substantial changes. In general, by the end of students' first semester, "switchers" were already demonstrating substantial declines in psychosocial variables related to engineering persistence, though they may not switch out of engineering for several more semesters. Engineering identity appeared to remain somewhat stable for both groups across the semester—primarily demonstrating small gains or losses over time in comparison to the other constructs. "Switchers" in track 2 showed the greatest decline in engineering identity over time, dropping from an average of 4.84 to 4.28. This group in particular demonstrated substantial losses in all psychosocial variables over time. The other groups remained fairly stable in their engineering identity. Noting the lack of variation in students' engineering identities across their first semester, this finding highlights the importance of the cultivation of this identity prior to college entrance, or shortly thereafter.

Table 2. Measured psychosocial variables for "Persisters" and "Switchers" on each track at beginning and end of first semester

		Engineering Track 1		Engineering Track 2		Engineering Track 3	
		Persisters	Switchers	Persisters	Switchers	Persisters	Switchers
Outcome Expectations	T1	6.18	6.04	5.91	5.82	6.21	5.52
	T4	6.04	5.27	5.79	5.32	6.07	5.67
Self-Efficacy	T1	3.99	3.83	3.86	3.89	3.74	3.55
	T4	4.06	3.47	3.8	3.09	3.82	3.33
Identity	T1	5.55	5.14	5.37	4.84	5.88	4.97
	T4	5.33	4.89	5.49	4.28	5.62	4.62

Discussion

The primary purpose of this work-in-progress study was to investigate the relationship between levels of mathematics preparation of engineering students upon college entrance to their persistence to engineering degree attainment, and the variables that influence this relationship. To accomplish this feat, academic, demographic and psychosocial profiles were created for each of three engineering tracks that corresponded to students' levels of mathematical preparation. The primary findings of this study are discussed below.

First, our study confirmed that there was indeed a relationship between mathematics preparation and engineering persistence—just not entirely as expected. Track 3 presented an interesting case for investigation as greater percentages of these students appeared to persist in engineering compared to track 2 and fewer of them left engineering compared to track 2. Though this was not the relationship that we expected to uncover, it further substantiates the findings by Bowen and colleagues [9], [15] that there indeed appeared to be other variables impacting engineering persistence besides just mathematics preparation. This result also provides further credibility to the need for developing various profiles for these tracks to further enable researchers to explore the variables impacting the relationship between mathematics preparation and engineering persistence and the manner in which they impact it.

Our investigation regarding academic profiles showed that GPAs tended to be related to math preparation as students with greater levels of mathematics preparation demonstrated higher GPAs than those with lower levels of preparation for both "persisters" and "switchers." This finding is in conjunction with previous literature emphasizing the predictive nature of students' GPAs to degree persistence in engineering or other STEM fields [2], [9]. Interestingly, the greatest differences in GPA for "persisters" and "switchers" appeared in Engineering Track 1 and Engineering Track 3—those with the highest and lowest levels of mathematics preparation. Moreover, engineering major selection also tended to be somewhat linked to mathematics preparation as the more math-intensive and academically rigorous majors such as aerospace and biomedical engineering were comprised of greater numbers of students from track 1 than expected. One explanation for this finding relates to the biomedical engineering entrance requirements at this university. Before being admitted to the biomedical engineering major, students must complete a series of prerequisite courses. Due to the number prerequisites involved, only track 1 students can complete all requirements within the first year (without summer school). Depending on specific scores on math placement instruments, some track 2 students can complete the prerequisites during the summer semester of their first and second year. It is not possible for track 3 students to complete the biomedical engineering admission requirements within their first year.

Gender and URM status appeared consistent across the tracks and within the tracks. This signified that being a member of a typically underrepresented group in engineering (i.e., women, Blacks, Hispanics) was not related to students' level of mathematics preparation, nor the likelihood of them persisting in engineering given their level of mathematics preparation. Given that several studies have highlighted the high percentages of women who attrit out of engineering (e.g., [6], [32]} it is important to note that in this study we examined attrition of women and men in relation to mathematics preparation. When mathematics preparation was carefully considered, no differences between the attrition of men and women in engineering were observed—defining attrition as switching out of engineering. The only slight exception to this was found in track 1 where a trend in the data suggested that women persisted at a higher rate to degree completion than switched, though this result was not statistically significant. More study is warranted.

Through the investigation into the psychosocial profiles of each track, no difference in initial levels of self-efficacy or outcome expectations between the tracks was noted. However, a trend in the data suggested a difference in initial identity scale scores existed between the tracks where track 3 boasted the highest average initial engineering identity scores. Though this result was not statistically significant (p = .06), the trend is noteworthy and warrants future study. Students who entered the engineering program being the least mathematically prepared appeared to identify themselves as being an engineer at greater levels than students who were Calculus or Precalculus-ready. This trend became even more interesting when we compared "persisters" and "switchers" within each track. Engineering identity was higher for Engineering Track 3 students who persisted in engineering than for any other subgroup examined.in this study. Moreover, the greatest difference observed in engineering identity between "persisters" and "switchers" was also in track 3. It appeared that students entering engineering programs who were the least prepared mathematically but strongly identified themselves as engineers potentially received an added protective element from this identity that helped them persist through their struggles.

Hamlet [48] discovered something similar for women in engineering. Hamlet [48] posited that women wrestle with their sense of belonging and identity in engineering as they learn to navigate white-men dominant norms that are common within the engineering culture. However, it is this wresting that is believed to potentially provide an added protective component to women's engineering identities as their struggles with acclimating into the culture lead them to more deeply internalizing their fit within engineering [48]. Again, not only did track 3 students enter engineering the least mathematically prepared, but they also boasted the lowest GPAs throughout their college tenure—two variables fighting against their likelihood to acclimate into the engineering culture and persist to degree completion. Clearly, academic achievement alone was not the driving force behind these students being retained in engineering. There is reason to suspect that engineering identity has the potential to moderate the relationship between mathematics preparation and engineering persistence, or even from academic achievement to engineering persistence—altering the strength and direction that low mathematical preparation has on engineering persistence.

Engineering identity was found to be fairly stable for students across their first semester except for track 2 students who portrayed the lowest levels of engineering identity initially and declined substantially over the semester. This is in-line with previous research studies that have documented the seemingly unchangeable nature of the similar construct of science identity over students' first year or two in college [49], [50]. Robinson and colleagues [50] highlighted the exception to this stability for science identity through a person-centered study by discovering that though two of their science identity classes (or groups) remained stable in their science identity, their lowest group showed a significant declination over time—similar to what is portrayed with track 2. Noting the importance of engineering identity and its seemingly stable nature across one semester for many students and unstable nature for some students, it is imperative that efforts to successfully cultivate a stronger identity within students be targeted and occur early in ones' engineering pursuit.

Outcome expectations in engineering and engineering self-efficacy both showed significant changes across the semester between "persisters" and "switchers." Though engineering "persisters" and "switchers" tended to start at similar levels on these psychosocial variables, "switchers" showed clear decline in their levels of outcome expectations in engineering and engineering self-efficacy after four months. In general, by the end of students' first semester, students who eventually switched out of engineering were already demonstrating substantial declines in these psychosocial variables even though they may not switch out of engineering for several more semesters. By identifying students who demonstrate declines in their outcome expectations in engineering and engineering self-efficacy early in their collegiate career, interventions can be targeted directly towards these students along with more thorough studies regarding the variable(s) leading to this decline. These targeted interventions may help to reduce the attrition within engineering programs.

Implications for Future Research

From the beginning of this study, results were not as expected with the lowest mathematically prepared students persisting more to degree completion than those with moderate preparation. Through the examination of several demographic and psychosocial variables that have been documented to impact persistence within the SCCT framework, engineering identity rose to the forefront in importance. This study has given reason to continue to explore engineering identity within the SCCT framework for its potential power to moderate the relationship between mathematics preparation and engineering persistence. Future studies can build upon these results. Future studies can also work to identify students showing decline in outcome expectations in engineering and engineering self-efficacy over the beginning of their collegiate tenure and further investigate the reason(s) leading to these declines. This endeavor is important as these students are likely to attrit. By uncovering the variable(s) impacting this declination, researchers, scholars and practitioners can work to create targeted and effective interventions.

Limitations

Though this study is a work-in-progress and the sample size was adequate for exploration of variables, the study lacks in generalizability. Only one cohort of students from one university was investigated. Future studies can continue to build upon these findings by examining these results in comparison to studies with greater numbers of cohorts from a diverse range of universities. Furthermore, reasons for missing data regarding students' degree selection were not obtained for this study. Thus, we could not incorporate into our analysis the students who left engineering, but whose data was missing—potentially a large and important group to the study of engineering retention.

Conclusion

Engineers play a critical role in the growth of the U.S.'s economy, security as a nation, and creation of jobs. Thus, the high-level of attrition in engineering degree programs and fields is concerning. A broad area of research has developed to understand why students engage and persist in engineering including the examination of influences that both cognitive and non-cognitive variables have upon engineering persistence. In this study, we examined the long-standing importance of the relationship between mathematics preparation before college entrance to undergraduate engineering persistence. Through the development academic profiles, demographic profiles and psychosocial profiles of students in three different engineering tracks based on their entering level of mathematics proficiency, we uncovered the novel findings that students who were the least prepared mathematically and persisted in engineering boasted the highest levels of engineering identity of any subgroup within our sample. This study provides reason for researchers to continue to investigate the potential power of engineering identity to moderate the relationship between mathematics preparation and engineering persistence. Uncovering this finding and learning to cultivate students' engineering identities could indeed be a future key to reducing attrition in engineering.

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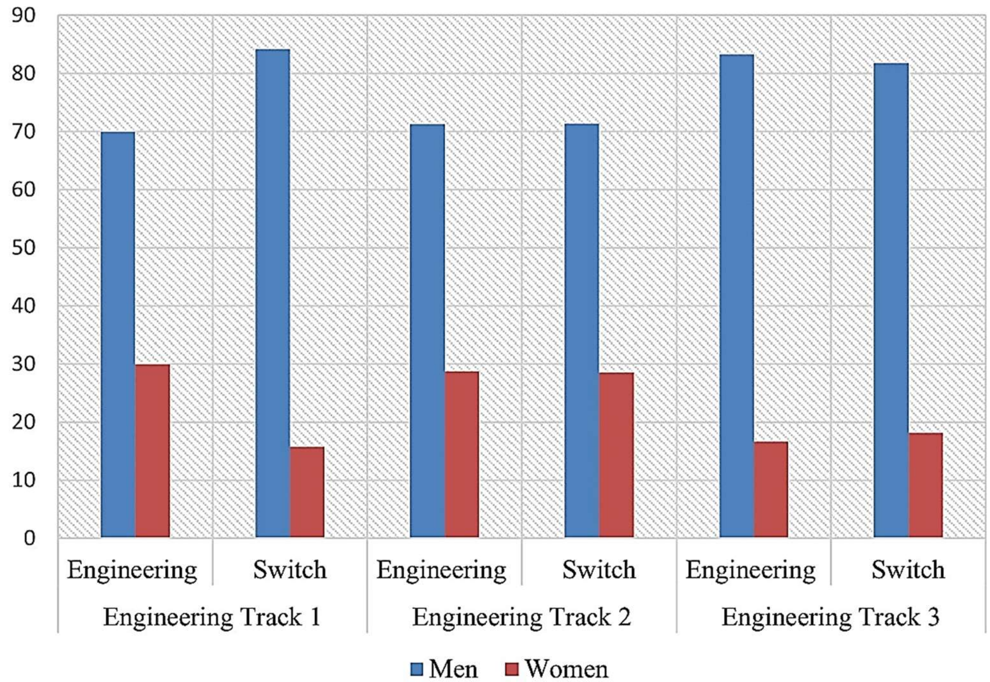
Appendix A

Count Data Related to Degree Selection per each Track

	Engineering Track 1	**Engineering Track 2**	**Engineering Track 3**	***Total***
Aerospace	29	10	2	***41***
Biomedical	24	4	2	***30***
Biometric Systems	1	2	0	***3***
Chemical	12	6	7	***25***
Civil	12	13	6	***31***
Computer	11	4	3	***18***
Electrical	3	3	5	***11***
Industrial	26	14	10	***50***
Mechanical	29	9	10	***48***
Mining	4	5	1	***10***
Petroleum and Natural Gas	1	10	11	***22***
Switch	38	28	11	***77***
Total	***190***	***108***	***68***	***366***

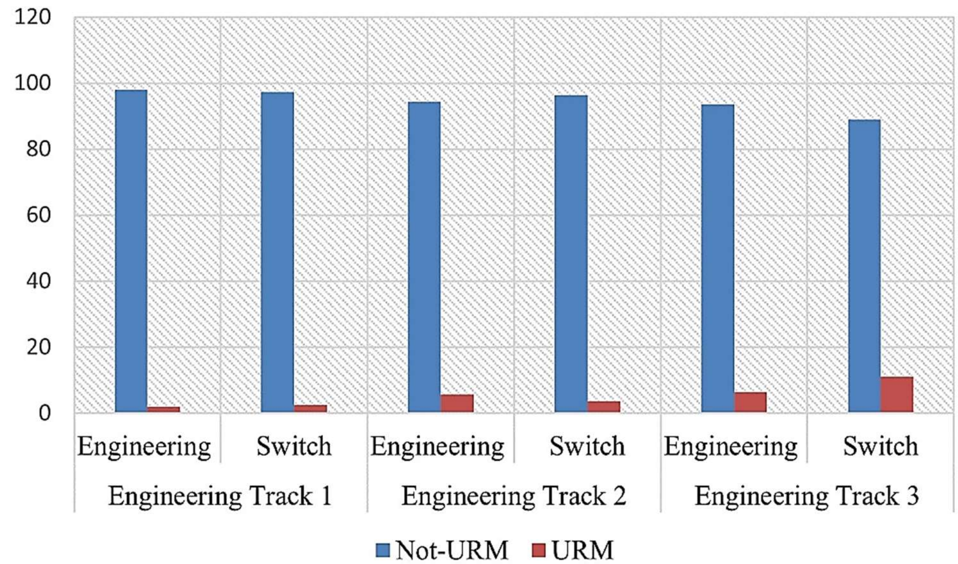
Appendix B

Percentages of Men and Women who Attained an Engineering Degree or Switched Majors per each Engineering Track



Appendix C

Percentages of URMs who Attain an Engineering Degree or Switch Majors per each Engineering Track



Appendix D

Initial Psychosocial Variable Descriptive Statistics per Engineering Track

	Mean	Standard Deviation	Skewness	Kurtosis
		Engineering Track 1		
Identity	5.44	1.44	-.78	2.90
Self-Efficacy	3.95	.73	-.22	3.00
Outcome Expectations	6.18	.87	-1.84	9.20
		Engineering Track 2		
Identity	5.20	1.57	-.89	3.42
Self-Efficacy	3.87	.77	-.40	2.86
Outcome Expectations	5.94	.95	-1.00	3.63
		Engineering Track 3		
Identity	5.77	1.13	-.86	3.27
Self-Efficacy	3.79	.76	-.22	2.62
Outcome Expectations	6.05	.93	-1.23	4.48