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Do I Think I'm an Engineer? Understanding the Impact of Engineering Identity on Retention

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Do I Think I'm an Engineer?

Understanding the Impact of Engineering Identity on Retention

Abstract

Policymakers, industry leaders, and educators have pointed to a need to graduate an increasing number of students with engineering degrees to fill anticipated job growth and maintain the nation's level of global economic competitiveness. Engineering education research has turned to affective dimensions of learning to better understand how to transform students' aspirations to engineering careers into pursuit of those pathways. One direction this research has taken is understanding engineering identity as a "key" to better understand student motivation to select engineering majors, persist to graduation, and proceed into industry. A few studies have associated engineering identity with persistence and degree completion, but none have been able to longitudinally assess whether a change in engineering identity is associated with likelihood of retention in an engineering major.

The purpose of this study was to test the relationship between engineering identity and retention in an engineering major to the fourth year. This study uses data from the Higher Education Research Institute (HERI), including 1205 students across 72 universities, collected at college entry and the end of the fourth year of college. These data are used to determine if engineering identity at the end of the fourth year of college, controlling for engineering identity at college entry, predicts a higher likelihood of being retained in an engineering major after four years of college.

Descriptive, bivariate, and multi-level logistic regression modeling were used to achieve the purpose of this study. A hierarchical generalized linear model showed that fourth-year engineering identity, net of first-year engineering identity and the other variables included in the model, significantly and positively predicted likelihood of being retained in an engineering major. Studying with other students and participating in an internship program also positively predicted retention in engineering. Women and students who in their first year felt more likely to change major were less likely to be retained, while students with a parent employed as an engineer and who at college entry were planning engineering as a career were more likely to be retained. The results not only indicate engineering identity can be important for retention in engineering, but several characteristics and experiences that relate to engineering identity are also associated with retention in engineering.

Introduction

National reports have indicated colleges and universities need to increase the number of students graduating with engineering degrees in order to meet anticipated near-term future needs[1]. Fields like engineering are critical to the nation's economic strength and competitiveness globally, and engineering expertise is needed to solve society's most pressing problems [2]. Yet only about 40% of students who aspire to an engineering degree complete one, and an even smaller percentage of those students continue into an engineering career [3].

A primary factor undergirding student persistence in an engineering major is the student's sense of engineering identity [4-6]. Identification with engineering has been referred to as a "compass" for navigating pathways into engineering careers [7]. Development of this identity is more than learning the technical skills and knowledge required to perform engineering work, it also includes aligning one's sense of self with the field of engineering. In addition, engineering identity has shown to be an important factor for broadening participation in engineering, as the identity development experience also reflects one's perceived similarity with others in the field, providing a sense of belonging or "fit" [8]. Previous research has demonstrated engineering identity also precedes persistence in engineering degree programs through degree completion [4, 6, 9], though these studies were somewhat limited in terms of their generalizability due to reliance on small, localized samples.

The purpose of this study then is to test the relationship between engineering identity and retention to the fourth year of an engineering degree using secondary analysis of a national data set. This study extends the literature on the effect of engineering identity on persistence through use of a large, longitudinal, national sample of college students. By testing whether engineering identity predicts retention in engineering, this study adds evidence to the conversation on the centrality of identity to learning, an important conversation given its potential role in broadening the participation of students from groups underrepresented in engineering.

Investigations into Engineering Identity

Because identity is central to learning [10], and persistence is a key precursor to the success of engineering graduates, the relationship between engineering identity and persistence is critical to understand how students navigate pathways into engineering [7]. The importance of this relationship is reflected in Brickhouse, Lowery, and Schultz's request for increased research on STEM identity and persistence [11]. Godwin, Potvin, Hazari, and Lock echoed this concern by pointing out that student beliefs preceding engineering identity formation point to their reasons for choosing engineering as well as choosing to leave engineering due to conflicts and alignments between their sense of self and the field of engineering [12]. Less is known about the influence of identity on persistence, especially with regard to the potential strength of engineering identity to contribute to student retention.

A small body of literature explores the relationship between engineering identity and persistence in engineering degree programs to demonstrate why skills and knowledge alone do not explain differences between engineering students who persist and those who leave. Pierrakos, Beam, Constantz, Johri, and Anderson interviewed small groups of engineering students who persisted and others who did not persist, and found meaningful differences between the groups in terms of the quality of their experiences [6]. Persisters had more meaningful engineering-related experiences, felt less overwhelmed by their transition to college, and were motivated by direct interactions with practicing engineers to pursue their field of study. To the researchers, these differences reflected differences in a sense of engineering identity, especially in terms of the experiences that differed between the groups. Matusovich, Streveler, and Miller performed a longitudinal qualitative study of the reasons students choose and persist in engineering degrees, finding similar results as Pierrakos et al. in terms of recognizing how the field of engineering aligns well with their sense of self [4]. These two studies posit a hypothesis that engineering identity as a latent factor may be one of the most important contributors to degree persistence.

Godwin, Potvin, Hazari, and Lock tested the effect of critical engineering agency, as indicated by math and physics identities, on incoming college students' choice of engineering as a career [12]. They found components of engineering identity [13], especially recognition and interest, promote the math and physics identities that lead to the choice of engineering as a career. Patrick, Borrego, and Prybutok then tested Godwin, Potvin, and Hazari's model of engineering identity on persistence in engineering, and found the interest dimension of the model to be a significant predictor of persistence [9]. This study was also the first to test the relationship between identity and persistence across a group of students beyond first-year students, using a cross-sectional design. The study presented in this paper helps extend the existing literature on the relationship between engineering identity and persistence by testing this relationship using a large, longitudinal sample of students.

Understanding Student Persistence

The primary conceptual framework guiding this study is Nora, Barlow, and Crisp's [14] framework for understanding student persistence beyond the first year in college. Referring to their model as a student/institution engagement model, Nora et al. respond to a literature base that heavily relies on dominant models for understanding retention and persistence: most notably, Tinto's focus on integration [15], which has been widely critiqued for a lack of relevance to the experiences of Students of Color and other minoritized students. To address this challenge, Nora et al. incorporate research conducted by Nora and others [e.g., 16, 17] to their framework to incorporate the experiences of minoritized students in deciding whether to persist in their studies or not. The model also considers the multi-level systems that affect students, e.g. institutional characteristics, the curriculum and co-curriculum, and off-campus obligations [18].

The model organizes the influence of student experiences in college on retention in temporal order, from pre-college and external factors, through commitments to a particular institution and experiences at that institution, leading to intermediate outcomes that shape final commitments to an institution and the decision to reenroll [14]. This study uses this model to conceptualize students' commitment and decision to reenroll in an engineering program. A primary motivation guiding research into engineering identity is the extent to which it reflects a commitment to engineering as a career [19]. Nora et al.'s model leads to the proposition that engineering identity is an intermediate outcome preceding the decision to reenroll, and increasing degree productivity has become an important policy goal for the field of engineering [1]. Figure 1 depicts the conceptual framework of this study.

Nora et al.'s model also identifies and organizes other factors that affect students' decisions to persist in their studies [14]. These factors also impact student persistence. Differences have been observed among students based on their background characteristics in terms of their likelihood of being retained, such as gender, underrepresented racial/ethnic minority (URM) status, socioeconomic status, and first-generation status [2]. For example, one socioeconomic factor that affects engineering identity specifically is having a parent employed as an engineer [6], while pre-college academic performance has been shown to affect retention generally and persistence in engineering specifically.

The model then parses out a student's overall experience in college into academic and social experiences [14], which mirror's Tinto's work [15]. Many experiences that engineering undergraduates have that influence engineering identity fall into the categories of academic and social, such as their choice of engineering major, participation in internship programs, undergraduate research or student organizations, as well as interaction with their faculty and peers.

For this analysis, measures of student experience at both the individual and institutional level are included. This inclusion helps capture the ways the broader peer normative climate may influence students' decisions to persist. Elements of this climate considered in this work include the gender and racial diversity of their peers, the proportion of engineering students on a given campus, or the specific institutional focus or mission (e.g., research orientation, private control).

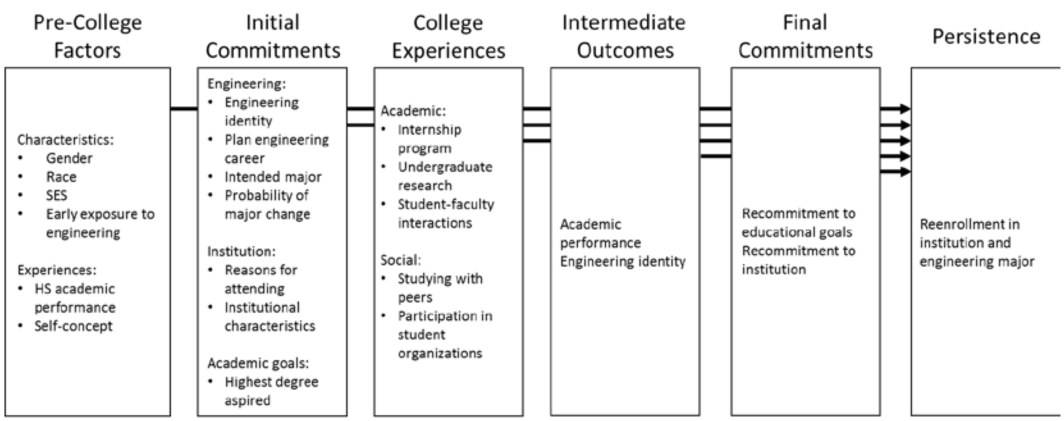

Figure 1 Conceptual Framework, modified from Nora, Barlow, & Crisp, 2005.

Methods

The purpose of this study is to test the relationship between engineering identity and four-year retention in engineering, net of other factors that may contribute to retention. The approach taken for this study is a secondary analysis of an existing survey dataset, administered nationally, that captures information on a wide range of college experiences. Secondary analysis of existing datasets benefit researchers by offering a breadth and depth of data that may have otherwise been incredibly resource-intensive to collect.

Data Source and Sample

The data for this study were taken from the 2013 College Senior Survey (CSS), an annual, national survey of college students administered at the end of their fourth year of college by the Cooperative Institutional Research Program (CIRP) at the Higher Education Research Institute

(HERI) at UCLA [20]. These responses are then matched to student responses to the Freshman Survey (TFS), administered at the very beginning of their first year of college. The TFS is the longest-running, and one of the largest, national surveys of college students, administered to provide a nationally-representative glimpse into the population of first-time, full-time college students at four-year institutions across the United States. Institution-level data from the Integrated Postsecondary Education Data System (IPEDS) was merged into this dataset to enable investigation of institution level variables. For this study, all students who indicated their intended major as engineering on the TFS constituted the sample. The sample included 1205 students at 72 universities.

Variables

A listing of the continuous variables and their descriptive statistics is provided in Appendix A, and proportions for the continuous variables are provided in Appendix B. The dependent variable is a dichotomous variable indicating if students marked engineering as their major at the end of the fourth year of college. As all students in the sample indicated engineering at the beginning of college, this variable represents whether they were retained in engineering at the end of their fourth year of college or not. Students who initially did not select engineering, but later switched majors into engineering, were not included in this analysis for two reasons. First, the number of students who switch into engineering tends to be quite small, much smaller than the number of engineering students who switch out of engineering before completing their degrees [21]. Second, inclusion of those students is beyond the scope of this study, which is focused on retention not attraction.

The main independent variable of interest in this study is engineering identity. Engineering identity was computed using exploratory factor analysis with three items from the CSS indicating the importance to students of becoming an authority in their chosen field (factor loading = 0.68), being recognized for contributions to their field (0.71), and making theoretical contributions to science (0.48). These items have been used in previous studies using CIRP data to measure science and STEM identity [22], and are theoretically grounded in Carlone and Johnson's [23] model of science identity (competence, recognition, and performance), which also undergirds models of engineering identity in the field [e.g., 13]. These items do exclude the component, "interest," but interest had been incorporated by Cass et al. and Godwin et al. to account for the heterogenous nature of their samples [13, 24]. Our sample includes solely engineering students, thus negating the need for this variable. Factor scores were calculated through a summation of these variables, weighted by factor loading. Eigenvalues revealed a single factor structure, and all three items loaded onto the factor at the generally accepted level of 0.40 or higher, with a Chronbach's alpha of 0.69. Although the reliability is below the 0.70 threshold most commonly used, given the size of the sample, and that the computation for reliability depends on the number of variables included in the analysis—using fewer variables somewhat artificially depresses the calculation of the Chronbach's alpha [25-27]—the Chronbach's alpha is adequate. See Table 1 for detail on the engineering identity factor.

Table 1. Engineering identity factor components, loadings, and reliabilities

Element of Identity	First Year Engineering identity (TFS) (α=0.6788)	Fourth Year Engineering identity (CSS) (α=0.6888)
Becoming an authority in my field	0.6480	0.6799
Being recognized by others for contributions to my field	0.6983	0.7114
Making a theoretical contribution to science	0.4836	0.4808

Other independent variables of interest were a set of college experiences hypothesized to predict either leadership or engineering identity. These included three dichotomous variables indicating whether students participated in internship programs, clubs and organizations, and undergraduate research programs. Two variables captured the frequency by which students studied with other students and worked on professors' research projects, on a three-point scale from "not at all" to "frequently". The last college experience variable is a CIRP construct score for student-faculty interactions that included nine items such as the frequency during college faculty provided encouragement to pursue graduate study, a letter of recommendation, and help in achieving professional goals [for technical information on CIRP constructs, see 28, 29].

Several other variables were included in the model to control for confounding factors and help parse out the unique variance shared between the primary independent variable and the dependent variable. First, a pre-test of engineering identity was computed from items on the TFS that matched those from the CSS used to compute engineering identity. Inclusion of a pre-test allows the results for engineering identity to be interpreted as change in engineering identity over four years of college. Students' sex, status as an underrepresented racial or ethnic minority (URM; African American, Latinx, or American Indian), family income, and first-generation status were all included as a set of student characteristics possibly related to retention in engineering. The final variable in this set indicated whether either of a student's parents were employed as an engineer.

The next set of variables measured pre-college academic preparation, self-concept, and career intentions. These items were high school grade point average and standardized test scores (SAT score or ACT equivalent). Students' academic and social self-concept, as measured by CIRP constructs (see earlier citation for more information), were included, as were indicators of their future plans at college entry. One of these was whether students planned to pursue engineering as a career after college; the other was how likely they were to change major during college (on a four-point scale from very unlikely to very likely). A third was the highest degree to which students aspired during their lives. Students' intended major was included to test differences among engineering fields, as was the importance of getting a better job as a reason for them to attend college (measured on a three-point scale from not important to very important), assuming this reason might explain why they were motivated to select engineering.

The final set of variables included a set of institution-level measures collected by both CIRP and IPEDS. These tested for potential institutional differences affecting retention in engineering programs. From CIRP, the type of institution attended (research university or four-year college), institutional control (public or private), and institutional selectivity (average SAT scores among first-year class) was included. From IPEDS, the percentages of women and URM students among engineering students, the overall full-time enrollment at each institution, and the proportion of students at each institution in engineering were included.

Analysis

Before analysis, the dataset was inspected for potential assumption violations and to determine the extent to which missing data might be a problem. Several variables were transformed to improve normality or for better interpretability. For example, income was recoded to reduce the number of categories to simplify the analysis. Percentage of women among engineering students was scaled so an increase of one unit represented an increase of 10 percentage points. Enrollment was transformed using a natural logarithm due to a right-skewed distribution. Variable transformations are indicated with the variable name in the table of descriptive statistics.

In terms of missing data, most variables were missing data on 5% or fewer of cases, while some variables, like standardized test scores, were missing for a much higher percentage. However, when considering the full data set in terms of the proportion of cases with complete data, only about 46% of cases were complete. To use the full information available to efficiently estimate model parameters, missing values were imputed using a multiple imputation process. Multiple imputation is a method for estimating missing values that overcomes the limitations of many other widely used imputation procedures [30]. Foremost among these limitations, the use of single imputation procedures increases the likelihood of a Type 1 statistical error by estimating standard errors too low. Multiple imputation overcomes this limitation by incorporating random error into the estimation process and estimating several values for missing data by creating multiple datasets. The variability among estimated values is used to adjust standard errors upward to compensate for the downward bias in standard errors from single imputation procedures and reduce the likelihood of Type 1 error [30]. For this study, Stata version 12 was used to run a procedure using a series of chained regression equations to predict missing values, using equations appropriate for the level of measurement of the imputed variables (multiple regression for continuous variables, logistic regression for dichotomous, etc.). The procedure then draws random values from a normal distribution (mean of 0, standard deviation of 1) and adds these values to the imputed estimates to incorporate random error [31]. These datasets were analyzed separately, and results pooled into a single model.

Descriptive statistics were computed for all variables and are displayed in Appendices A and B. The analysis technique used to address the purpose of this study was hierarchical generalized linear modeling (HGLM) with robust standard errors. The model is provided in Table 2 below. HGLM was used for two reasons [32]. First, HGLM is a multilevel multivariate regression procedure, which is appropriate for data that are “nested” in structure—in this case, student-level data is nested within institutions. Nested data violate the assumption of independence for OLS and logistic regression because of intraclass correlation among cases within groups. Second, HGLM is a form of multilevel logistic regression and used when the dependent variable is dichotomous in level of measurement, such as retention in engineering. To ease interpretation of results, delta-p values were computed for significant model coefficients. Delta-p values are an estimate of the change in likelihood of the outcome variable given a one-unit change in the associated independent variable [33]. Delta-p values can be an easier way to understand significant results than logits or odds ratios and are included in a separate column in Table 2.

Results

Two-thirds of engineering aspirants (66.9%) were still in an engineering major by the end of their fourth year of college. Comparing those who were retained to those who were not, engineering identity at the fourth year of college differed significantly, $t(1137) = 2.4782$, $p = 0.013$. Students who were retained scored on average 4.89 ($SD = 1.26$) on the engineering identity scale; student who were not retained scored on average 4.69 ($SD = 1.42$).

Although this difference is descriptively small, it is statistically significant. For this reason, the multilevel multivariate model was used to parse out many confounding factors that might explain this difference. A null (empty) model was run first to examine variance at level two, and then a single HGLM was run to test the hypothesized model. Variance at level two in the null model was significant: var = 1.74, SE = 0.307; 95% CI [1.24, 2.46]. In the full model, variance at level two also appears significant: var = 0.24, SE = 0.149; 95% CI [0.068, 0.813]. The full model accounted for about 86% of the variance at level two. (Variance at level one is heteroskedastic due to the dichotomous nature of the outcome variable.)

The hierarchical generalized linear model (HGLM) demonstrated that fourth-year engineering identity, net of first-year engineering identity and all other predictors in the model, is a significant predictor of four-year retention in engineering. A one-point increase in fourth-year engineering identity as measured on the scale is associated with a 4% increase in the likelihood of persisting in engineering. As the analysis includes a pretest for first-year engineering identity, the relationship between fourth-year engineering identity and retention could be interpreted as the effect of change in engineering identity on likelihood of being retained.

In other words, those students whose scores reflected a strengthened engineering identity were more likely to persist in their engineering programs. This finding seems especially important given the coefficient for first-year engineering identity is not a significant predictor of retention in engineering. One could interpret this finding as suggesting positive change in engineering identity increases one's likelihood of being retained, but at the same time this finding could mean students who have remained in engineering for four years identify more strongly than those who left. Either way, the relationship between the measure used for engineering identity in this study and engineering retention offers support for the validity of this measure for engineering identity.

Table 2. HGLM predicting retention in engineering (n=1271)

	Coef.	Std. Err.	Sig.	Delta-p
Constant	-6.137	2.864	*	
Student-level variables				
CSS engineering identity factor score	0.188	0.071	**	4.02%
Background characteristics				
TFS engineering identity factor score	0.078	0.078		
Female	-0.392	0.192	*	-8.91%
Underrepresented racial/ethnic minority student	-0.076	0.261		
Either parent employed in engineering	0.612	0.231	**	12.52%
Low income (ref: middle income)	0.392	0.415		
Low-middle income	0.036	0.326		
Middle-high income	0.099	0.220		
High income	-0.182	0.253		
First-generation student	0.131	0.256		
Pre-college experiences				
High school GPA	0.090	0.108		
SAT score or ACT equivalent (scaled by 100)	0.179	0.094		
TFS academic self-concept construct score	-0.103	0.151		
TFS social self-concept construct score	-0.203	0.114		
Likelihood, change major field	-0.671	0.112	***	-16.07%
Planned engineering career at college entry	0.764	0.198	***	4.47%
Importance, reason attended: to be able to get a better job	0.401	0.222		
Initial intended major				
Aeronautical or Astronautical Engineering (ref: Mechanical Engineering)	0.425	0.446		
Civil Engineering	-0.010	0.252		
Chemical Engineering	-0.112	0.263		
Computer Engineering	-0.632	0.290	*	-14.74%
Electrical or Electronics Engineering	0.421	0.344		
Industrial Engineering	-1.009	0.802		
Other Engineering	-0.582	0.273	*	-13.49%
Highest degree aspired at college entry				
Less than bachelor's degree (ref: bachelors)	0.280	1.524		
Master's degree	0.185	0.226		
Doctoral degree	0.223	0.268		
Medical degree	-0.182	0.394		
Law degree	-0.569	0.504		
College experiences				
Participated in an internship program	0.650	0.175	***	14.80%
Participated in student clubs/groups	-0.019	0.221		
Participated in an undergraduate research program	0.249	0.230		
Frequency, studied with other students	0.943	0.144	***	16.93%
Frequency, worked on professor's research project	0.111	0.156		
CSS faculty interaction construct score	-0.089	0.115		
Institutional characteristics				
Percent women in engineering (per 10%)	0.280	0.227		
Percent URM students in engineering (log, 10%)	-0.065	0.215		
Full time equivalent enrollment (log)	0.353	0.231		
Percent engineering majors among undergraduates (log, scaled by 10)	0.439	0.248		
Average SAT score of first-year class (scaled by 100)	-0.160	0.129		
Four-year college (ref: four-year university)	0.359	0.326		
Control: private (ref: public)	-0.023	0.492		

Note : * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; variable transformations indicated in parentheses

Four other precollege characteristics and expectations also significantly predicted retention in engineering. Men are more likely to be retained in engineering than women (by about 8.9%), reflecting a disparity that engineering programs continue to address through efforts toward increasing gender diversity. Having a parent who is employed as an engineer positively predicts retention in engineering (12.5%), which aligns with the literature on engineering identity formation. Commitment to engineering is important; students who plan to switch majors are less likely to persist (-16.1% per one-point increase in self-reported likelihood of switching), while students who plan a career in engineering are more likely to persist (4.5%). Using students in mechanical engineering as the baseline, since they are the largest component of both the sample and national engineering, retention differences were also found by major. These differences included significant decreases in probability of retention for students in computer engineering (-14.7%), or who indicated “other engineering” as their major (-13.5%). The coefficients for other groups were not significant, even though differences were observed.

Two experiences in college significantly predicted retention in engineering. Participation in an internship or cooperative education program was one of the strongest predictors of retention in engineering (14.8%), and the frequency a student studied with other students was the strongest predictor in the model (16.9% per one-point increase in frequency). Both results suggest that engagement with peers and industry partners is critical in students’ decision-making to commit to their plans to pursue an engineering degree. No institution-level predictors were significant in the model, suggesting retention in engineering may not vary as much between universities as it does within universities in terms of the opportunities students take advantage of during their undergraduate years.

Limitations

Several limitations need to be noted in terms of generalizing from these findings to the overall population of engineering undergraduates. First, these data were taken from first-time, full-time students at four-year colleges and universities; readers are cautioned regarding generalizing to more nontraditional populations or community college students. Second, this study is a secondary analysis of an existing dataset collected for other purposes. In other words, there may be other factors and experiences that relate to engineering identity and persistence that were not available for modeling. A review of the literature indicated this study’s model did not omit any potentially significant variables, and the dataset itself included items previously used to study science identity. Existing datasets can make important contributions to research when it can be demonstrated an existing dataset can answer research questions other than those for which the data were collected. A dataset similar in scope and magnitude would be resource-intensive and possibly unwieldy to collect to address the specific purpose of this study. Third, the analysis used for this study is correlative in nature—the results should not be interpreted as causal relationships between the independent and dependent variables. That said, the literature can be used to support causal interpretations of the study results, but the reader is cautioned to be judicious in doing so. Finally, survey data are self-reported which can be subject to some social desirability bias in the manner in which participants respond, but self-reported responses have been generally shown to be reliable when the items measure generally benign phenomena [34].

Implications

This study examined the relationship between engineering identity and four-year retention in engineering in a longitudinal, national sample of engineering students. The results showed that engineering identity, measured in the fourth year, was a significant predictor of retention in engineering, net of students' scores on engineering identity at the start of college, and several other factors. This finding aligns with previous work that suggested engineering identity might be a precursor to committing to and persisting in engineering [4, 6, 12], and extends those results by demonstrating students who persist in engineering may not necessarily differ from their peers in terms of initial engineering identity but do by the fourth year of college. Although this analysis is unable to conclude that change in engineering identity caused persistence in engineering, or that persisting in engineering enhances engineering identity, it does help establish the relationship between the two phenomena. As Godwin et al. argued, engineering identity provides insight into students' beliefs about engineering, and specifically the alignment between the field of engineering and their sense of self-concept [12].

The results of this study also point to experiences in college that support the retention of students in engineering. Participating in an internship and studying with peers both significantly predicted a higher likelihood of being retained in engineering after four years of college. These experiences also align with understandings of engineering as a community of practice [35, 36]; internships offer authentic engagement with the practice of engineering and studying with peers provide an opportunity to develop a sense of belonging within an engineering program. While many engineering programs already sustain strong relationships with industry that serve students through the availability of internships, they may consider how they can promote more interactions among students. This is especially valuable with regard to study groups and otherwise engaging course material outside the classroom, like the availability of study space to students in academic buildings.

Two differences in retention were observed among engineering majors; computer engineering students and other engineering students were less likely to persist in engineering than their peers in mechanical engineering. Although the data for this study are not granular enough to point to any specific differences between engineering fields to identify precisely why these differences were observed, engineering deans may consider how they are able to aggregate and disaggregate data to determine how differences among programs may differentially affect student retention. Colleges of engineering already disaggregate data to examine whether students from groups underrepresented in engineering face inequitable outcomes, and this study showed women continue to leave engineering for other fields at higher rates than men. Much of the work on engineering identity has specifically examined how women's experiences in engineering contribute to a sense of (mis)alignment with the field [8, 12]. The negative coefficient for women in this study also suggests colleges of engineering have more work to do to promote women's sense of belonging in the field.

That said, initial commitments to engineering, also reflective of interest in engineering, do contribute to retaining students in engineering. Having a parent employed as an engineer and planning to pursue a career as an engineer both positively predicted retention in engineering after four years of college. Both of these factors have also been established as contributors to engineering identity in the literature [6, 12], reflecting how important prior experience with and knowledge of the field is for shaping students' decisions to enter and commit to the field. These factors may also represent anticipatory socialization into engineering [37], which can influence whether and how novices enter a community of practice. The interrelationships of many of the findings in this study warrant future work using structural equation modeling to decipher direct and indirect effects to determine how all these factors may shape the diversity of pathways into engineering careers.

Conclusion

National reports have called for an increase in the number of students graduating with engineering degrees from colleges and universities in the United States and research has posited that attention to engineering identity may be critical for students to navigate pathways into the field. This study tested the relationship between engineering identity and retention to determine the efficacy of this proposition in terms of meeting this policy aim. Results demonstrated that engineering identity in the fourth-year of college, net of engineering identity at college entry, significantly affects retention in engineering. Given previous research that has shown engineering identity may also help broaden participation in engineering by students from groups underrepresented in the field, this study lends further support to a focus on engineering identity as an important outcome of engineering formation that may help undergraduate engineering programs better contribute to a diverse, dynamic engineering workforce that helps resolve some of society's most pressing concerns.

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Appendix A

Descriptive statistics for continuous variables.

	Mean	St. Dev.	Min	Max
Student-level variables				
CSS engineering identity factor score	4.790	1.505	0.72	8.45
TFS engineering identity factor score	4.670	1.280	1.83	7.32
High school GPA	7.312	0.949	3.00	8.00
SAT score or ACT equivalent (scaled by 100)	13.259	1.634	7.30	16.00
TFS academic self-concept construct score	5.585	0.838	3.25	7.00
TFS social self-concept construct score	5.069	0.908	1.98	7.04
Frequency, studied with other students	2.592	0.610	1.00	3.00
Frequency, worked on professor's research project	1.596	0.786	1.00	3.00
CSS faculty interaction construct score	4.984	0.898	2.73	7.69
Likelihood, change major field	2.501	0.810	1.00	4.00
Importance, reason attended: to be able to get a better job	2.866	0.406	1.00	3.00
Institution-level variables				
Percent women in engineering (per 10%)	2.448	0.602	0.00	10.00
Percent URM students in engineering (log, 10%)	-0.260	0.650	-1.93	2.24
Full time equivalent enrollment (log)	8.777	0.731	6.19	10.36
Percent engineering majors among undergraduates (log, scaled by 10)	0.412	0.521	-6.94	1.81
Average SAT score of first-year class (scaled by 100)	12.959	1.433	8.70	15.00

Appendix B

Sample profile for categorical variables

	Proportion
Student-level variables	
Retained in engineering	66.93%
Women	27.69%
Underrepresented racial/ethnic minority	15.09%
Either parent employed as engineer	17.74%
First-generation student	18.23%
Planned engineering career at college entry	78.66%
Family income	
Low income (<$25,000)	6.68%
Middle-low income ($25,000-$49,999)	9.68%
Middle income ($50,000-$99,999)	31.50%
Middle-high income ($100,000-$199,999)	32.65%
High income ($200,000 or higher)	19.49%
Intended major	
Aeronautical or Astronautical Engineering	4.96%
Civil Engineering	17.55%
Chemical Engineering	17.47%
Computer Engineering	9.99%
Electrical or Electronic Engineering	8.97%
Industrial Engineering	1.18%
Mechanical Engineering	26.12%
Other Engineering	13.77%
Highest degree aspired at college entry	
Less than a bachelor's	0.44%
Bachelor's degree	17.75%
Master's degree	52.54%
Doctoral degree (Ph.D., Ed.D.)	21.91%
Medical degree (M.D., D.O., D.D.S., D.V.M.)	4.78%
Law degree (J.D.)	2.59%
College experiences	
Participated in an internship program	66.88%
Participated in student clubs/groups	82.58%
Participated in an undergraduate research program	37.08%
Institution-level variables	
Four-year college (ref: research university)	51.85%
Control: private (ref: public)	85.37%