Published 13 March 2019 as early access in *IEEE Transactions on Education* DOI: 10.1109/TE.2019.2901777

Prediction of Engineering Identity in Engineering Graduate Students

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Abstract- Contribution: **This study shows that identification with engineering for engineering graduate students is positively and significantly predicted by engineering interest, competence, recognition, and interpersonal skills competence.**

Background: **Prior studies of engineering identity on undergraduates identified several factors (e.g., engineering interest, engineering recognition) as positive predictors of identification of engineering. Engineering competence, achieved by participating in design projects, is a crucial part of students' efforts to become more innovative engineers. Identity theory is used to understand undergraduates' persistence in engineering, as students with stronger engineering identification are more likely to persist. More work is needed focusing on graduate students.**

Research Questions: **Do engineering identity measurement frameworks studied for undergraduate students also apply to graduate students? Do they correlate with intention to complete the degree? What predicts the engineering identity of engineering Master's and doctoral students?**

Methodology: **Interviews informed development and adaptation of a multi-scale survey instrument. Factor analyses identified four factors that relate to graduate engineering identity: engineering interest, engineering recognition, engineering competence, and interpersonal skills competence. Three sequential multiple linear regression models were used to predict engineering graduate students' engineering identity.**

Findings: **The final regression model, which includes student characteristics and the four factors resulting from Confirmatory Factor Analysis, predicts 60% of the variance in engineering identity—substantially more than similar undergraduate engineering identity models. All four factors were significant and positive predictors of graduate students' engineering identity. The engineering recognition factor in particular needed adaptation to emphasize peers and faculty members over family, although family remained important.**

***Index Terms*—** **Factor analysis, graduate, identity, professional skills, regression, survey**

I. Introduction

The Council of Graduate Schools [1] reports that the completion rate of engineering graduate degrees within six years is below 50%, despite continuous efforts to support engineering graduate students in completing their degrees. Several researchers have proposed disciplinary identity development as a lens for understanding graduate student persistence [2], [3], [4]. In STEM fields, there is some evidence that stronger disciplinary identity is correlated with persistence in graduate programs. For example, Robnett [5] found that graduate student attrition is related to STEM disciplinary identity. Chemers, et al. [6] reported that STEM identity was a positive predictor of graduate student persistence and career choice in STEM fields.

There is also relevant literature on undergraduate engineering students' engineering identity development. Meyers, et al. [7] reported that undergraduate students who had higher identification with engineering were more likely to report they would continue their education and career in engineering-related fields. Godwin, et al. [8] found that first-year undergraduate students who identify with math and science are more likely to pursue a major in engineering. For undergraduates across all four years, engineering interest, a component of identity, was a positive and significant predictor for one year persistence in engineering programs [9].

However, engineering identity has primarily been investigated for undergraduate students [8], [9], [10], leaving a gap in the literature on graduate student engineering identity, other than for a few qualitative studies [11], [12]. This study focuses on engineering identity of engineering graduate students, specifically measuring and predicting engineering identity and understanding relationships between engineering identity and persistence in graduate students. The research questions are:

1. Do engineering identity measurement frameworks studied for undergraduate students also apply, with adaptation, to graduate students?
2. Do these adapted measures correlate with engineering graduate students' intention to complete their degree?
3. What student characteristics and components of engineering identity predict the engineering identity of

This work was supported in part by the National Science Foundation through grant numbers 1636449 and 1636404.

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engineering master's and doctoral students?

This work will enable future studies of the development of engineering identity in graduate students, the implications of engineering identity for persistence at the graduate level, and the influence of engineering identity on decisions to pursue graduate study. Additionally, it will inform engineering graduate programs about developing strong engineering identities and supporting graduate retention. Further, this study will inform how design projects activities are related to students' development of engineering skills and identities.

II. Literature review

Identity is complex, dynamic, and multi-faceted. It has been studied in engineering and STEM using a wide variety of theoretical frameworks [13]. The current study is informed by a multiple identity framework based on Gee [14], further developed by Carlone and Johnson [15], quantified by Hazari and colleagues [16], and adapted to engineering students by Godwin [17] and Patrick [10] and their colleagues.

According to Gee's [14] multiple identity theory, an individual holds or develops multiple types of identities, which connect to their performance in society. Gee's multiple identity theory was the basis for several prior studies of engineering, science and math identity. Some multiple identities that may apply to engineering graduate students include student, teacher, researcher, and engineer, in addition to identities associated with gender, race and other personal characteristics. This paper focuses on engineering identity by expanding work with undergraduates to the graduate level. According to recent investigations of undergraduate engineering students [7], [18], engineering identity plays a significant role in undergraduate students' academic motivation and persistence in their programs. The more extensive literature on undergraduate student engineering identity development can provide a foundation from which to understand engineering identity development in engineering graduate students.

Previous investigation of undergraduate engineering identity showed that researchers have adapted math and science identity development to understand the disciplinary characteristics of engineering identity [9]. Further, investigation of science identity showed that science identity can be explained by performance/competence, recognition, and interest factors, and these factors were predictors of persistence and career choice in STEM fields [8], [15], [16]. Engineering education researchers have adapted these three academic (as opposed to professional) factors to develop engineering identity measures for undergraduates [9], [10], [17]. The performance/competence factor refers to students' belief in their ability to perform engineering tasks in engineering classes and understand engineering concepts and materials in their programs. The interest factor reflects students' desire to learn more engineering concepts and to design and participate in engineering activities as well as their motivations for pursuing engineering careers as a part of their engineering interests. The recognition factor refers to being recognized by others (e.g., engineering professors, friends, and family) as an engineer.

All three of these factors are positive and significant predictors in regression models of engineering identity. Patrick et al. [9], explained 27% of the variance in engineering identity of undergraduates using this framework. Using these factors, Choe et al. [19] explained 8.4% of the variance in engineering identity of undergraduate students. In both cases, engineering interest was the strongest positive predictor, followed by engineering recognition by others and engineering performance/competence.

Finally, Tonso [20] explained that individuals develop their engineering identity through a complex process that is associated with individuals thinking about themselves *as* engineers, thinking *like* an engineer, and *performing* as an engineer. In addition, engineering identity can be fostered by activities related to a particular professional engineering role [21]. Therefore, identification with engineering is different from identification with math and science, since it is related not only to discipline but also to profession [22], whereas identification to math and science is mainly disciplinary. Through the addition of factors that capture affinity toward professional aspects of engineering practice, Choe et al. [19] were able to explain 17.7% of the variance in engineering identity of undergraduates. Professional skills in engineering—such as decision making, leadership, working as a team, negotiation, and effective communication—are vital for engineers in the workplace [23], which is why they have been emphasized in undergraduate engineering curricula [24], and are an important consideration for engineering graduate students [25].

Although Master's and doctoral students' engineering identity is likely to differ from that of undergraduates, a majority of engineering graduate students hold Bachelor's degrees in engineering and developed their engineering identity during their undergraduate engineering education, so the undergraduate engineering identity scale is a suitable basis for developing an engineering identity scale for graduate students.

III. Methods

A. Overview

This paper describes six phases of instrument development and validation. For the pilot study, a total of 115 engineering graduate students completed a survey in Spring 2017. This pilot data was used to conduct the first exploratory factor analysis (EFA) for possible factor structure. In Spring 2018, 320 graduate students completed the revised survey. A second round of EFA was conducted on a randomly split data sample to examine the factor structure of engineering identity. A confirmatory factor analysis (CFA) was conducted on the holdout sub-sample from Spring 2018. Finally, a sequential multiple linear regression was conducted to predict engineering identity with the four independent variables that resulted from the CFA. This research was approved by the Institutional Review Board (IRB) governing the researchers and participants.

B. Demographic Information Items

In all versions of the survey, participants were asked their gender, nationality, engineering discipline, type of program (i.e., Master's or doctoral), prior engineering degrees (e.g., Bachelor's or Master's degree), engineering work experience prior to graduate study, and internship experience during graduate study.

C. Dependent Variable Items

In all versions of the survey, participants responded to engineering identity items using a five-point Likert scale. A total of five items were investigated as measures of engineering identity [26]. After EFA of five items, four remained (Cronbach's Alpha of 0.83); these were used to create the mean composite score of engineering identity used in the current study. An example is "*I consider myself an engineer*."

D. Instrument Development for Independent Variables

1) Identifying and Describing Behaviors that Underlie the Factor

Since previous instruments had been validated for undergraduates, several individuals were interviewed as informants to confirm key graduate experiences that relate to engineering identities. The interviewees included mechanical engineering graduate students, faculty members, postdoctoral fellows, and Ph.D. engineers in engineering corporations. All interviewees were affiliated with the same institution where survey data were collected. Sample interview questions were "*What makes you a better engineer?*", "*Do you consider yourself an engineer?*", and "*Is the meaning of engineering different now compared to when you were an undergraduate?*"

2) Development of Initial Instrument

In this phase, the authors borrowed, adapted, and generated items to address the study's framework of engineering interest, engineering competence, engineering recognition from others, and interpersonal skills competence. All versions of the survey used a five-point Likert scale for responses. The survey stem questions for measuring interest or recognition were "*To what extend do you agree or disagree with the following statements?*" The stem questions for quantifying competence were "*How competent are you with the following tasks*?" Five expert reviewers provided feedback on the initial 65 items. Three were engineering faculty members, and the other two were engineers working in industry. Individual reviewers provided feedback on each item to evaluate whether these were appropriate descriptors of engineering identity as defined, and to provide alternative suggestions where needed. Finally, they provided feedback on the overall instrument, including additional items to be incorporated.

3) Initial Item Reduction

The pilot version of the survey was administered in Spring 2017 to 115 mechanical engineering graduate students at one large public research university. An EFA was conducted to identify a possible factor structure from the initial survey items and to determine how well items were dominantly weighted to specific factors. Cross-loaded and weakly loaded items were eliminated. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is recommended when the ratio between variables and sample size are less than 1:5 [27], [28]. The KMO value was 0.79, which is above the recommended minimum of 0.60. The other assumption test conducted was Bartlett's test of sphericity. The value was ($X^2(210) = 1179.32$, $p < .0001$), less than the .05 threshold p value to verify homogeneity of item variances [29]. These two tests ensured that the survey scales were appropriate to conduct EFA. Principal axis factoring (PAF) extraction and oblique (non-orthogonal) rotation were used in the EFA.

An initial set of 48 items was reduced to 27 items after the item factoring and elimination process [30]. Preliminary analysis of survey development results was presented in a conference paper [31]. These pilot EFA results indicated that the engineering competence, engineering interest, and interpersonal skills competence items factored as expected, with four item each, and Cronbach's alphas ranging from 0.67 to 0.88. During this round of EFA, the engineering recognition factor did not emerge as would be expected based on prior studies of undergraduates.

4) Adding Items and Expanding Engineering Disciplines

Prior to full data collection in Spring 2018, seven items were added to capture recognition and boost internal consistency values for other factors. Although previous interviews indicated that engineering recognition from others was an important part of engineering identity, the initial item reduction process did not yield an engineering recognition factor. The authors suspected this was because undergraduate measures of engineering recognition rely heavily on family and friends, so several items were added that reflect recognition by individuals from academia and industry. Sample items are "*other students in my program see me as an engineer*," "*my advisor expects me to continue my career as an engineer*," and "*industry researchers value my work*."

Additional interviews were conducted with electrical/computer and civil/environmental engineering graduate students to verify that they had a similar interpretation of survey items. In addition, interviewees were asked whether these items captured their engineering graduate experiences. Six graduate engineering students, one Master's and two doctoral students from each discipline, participated in these interviews. The interviews confirmed that the first set of survey items was properly worded for their disciplines and communicated the meaning of the survey items as intended.

5) Exploratory Factor Analysis (EFA)

An exploratory factor analysis was again used to check if the newly added items reflected initially hypothesized factors, and to conduct another around of item reductions. The final set of items was administered via an online survey to electrical/computer, civil/environmental, and mechanical engineering graduate students along with dependent variable and demographic items. The surveys were distributed by the graduate coordinators via one email survey invitation and three additional reminders. Respondents were entered into a raffle for one of six $50 gift cards.

With a response rate of 26%, 320 engineering graduate students completed the survey. Among participants, 131 were domestic, 156 international, and 33 did not state citizenship status. Seventy-six respondents identified as women, 244 as men. One hundred eighty-three respondents were in doctoral programs, 71 were in non-thesis Master's programs, and 66 were in thesis Master's programs. In terms of engineering discipline, 135 were electrical/computer engineering students, 105 were civil/environmental engineering students, and 80 were mechanical engineering students.

A sub-sample (n = 120) was used to conduct an EFA on the 34 items to measure engineering identity factors. Due to the small sample size, the same procedures as for the first EFA were used in this EFA. KMO value (0.86) and Bartlett's test of sphericity ($X^2(210) = 1630.10$, $p < .0001$) satisfied cut-off values to conduct the EFA. PAF extraction and oblique rotation were used.

6) Confirmatory Factor Analysis (CFA)

A CFA was conducted on the items resulting from the previous procedure using a holdout sub-sample from the final set (n = 200), i.e., the responses not used for EFA. A CFA with at least 200 samples is a threshold for "low risk of drawing the wrong conclusion" [32]. Thus, this study split the final data unevenly for the EFA and CFA. In addition, this CFA data set satisfied the minimum ratio between observations and variables (5:1) to conduct CFA [33]. Several indices were calculated to examine the goodness of the model fit. Cronbach's alpha was calculated for internal consistency in the final items for each factor.

E. Correlations and Regression Analysis

Pearson correlations were calculated to investigate relationships between intention to complete the graduate degree, the dependent variable of engineering identity, and the independent variables that influence engineering identity.

Three multiple linear regression models were run to understand which student characteristics and identity factors were significant in predicting engineering identity of engineering graduate students. Prior to regression analysis, several assumptions were tested. Normality, linearity, and homoscedasticity were confirmed as assumptions via quantile-quantile and scatter plots. Additionally, the variance inflation factors (VIF) for each independent variable, a measure of how much each coefficient variance is inflated, were less than two. This indicates that there were no multicollinearity issues in the regression models [34].

Three sequential regression models to predict engineering identity were run. In Model 1, the seven student characteristics were entered: gender, nationality, engineering discipline, current degree program, obtained engineering Bachelor's degree, engineering work experience prior to graduate study, and internship experience during graduate study. In Model 2, three factors used in several other studies of engineering identity were added: engineering interest, engineering competence, and engineering recognition. Then interpersonal skills competence was added in Model 3.

All control variables were dummy-coded; the reference group does not appear in the regression table. For gender, male was the reference group. For nationality, US citizens were the reference group when compared to international students. For engineering discipline, electrical/computer engineering was the reference group for civil/environmental and mechanical engineering. For current degree program, Ph.D. students were the reference group when compared to Master's without thesis and Master's with thesis. For engineering Bachelor's degree obtained, students without were the reference group for

TABLE I
EFA AND CFA RESULTS FOR SURVEY MEASURES OF ENGINEERING IDENTITY

Factor	Survey Items	EFA Factor Loading	CFA Factor Loading
Engineering interest (α = 0.91)	I like doing engineering	0.81	0.80
	I am interested in learning more about engineering	0.76	0.80
	In general, I find working on engineering projects interesting	0.76	0.78
	I enjoy engineering activities as part of my work week	0.76	0.84
	I think engineering is fun	0.76	0.66
	I am interested in my engineering work	0.73	0.81
	I feel good when I am doing engineering[1]	0.55	-
Engineering competence (α = 0.88)	Creating prototypes to test an idea	0.96	0.81
	Designing a system, a part/component of a system, or a process based on realistic constraints	0.77	0.76
	Improving a design to make it more efficient (faster, better, cheaper)	0.73	0.69
	Designing and conducting experiments to test an idea or learn more about a system	0.63	0.81
	Identifying technical solutions that are as simple as possible	0.60	0.75
Engineering recognition (α = 0.88)	Other students in my program see me as an engineer	0.90	0.80
	My friends see me as an engineer	0.77	0.63
	My family sees me as an engineer	0.74	0.78
	My peers view me as an engineer	0.70	0.79
	My advisor sees me as an engineer	0.66	0.83
	My advisor expects me to continue my career as an engineer[1]	0.55	-
Interpersonal skills competence (α = 0.79)	Communicating verbally, for example in discussion with others	0.85	0.78
	Presenting my professional work to others	0.78	0.80
	Communicating my ideas in writing	0.52	0.70

Note: 1: Eliminated item for the CFA procedure;
Cronbach's Alpha values stay same after eliminating item for CFA.
Most items are drawn from the work of Choe et al [ref 31]

comparison with students with an engineering Bachelor's degree. For work experience in engineering prior to graduate study, the students with no work experience were the reference group compared to students with work experience. For internship experience during graduate study, the students with no internship experience were the reference group compared to students with internship experience.

For the pilot and current studies, there are no missing values after eliminating participants who did not answer their characteristic information. The multiple linear regression used 287 samples for all three models. The range of sample sizes for Pearson correlations was from 291 to 320.

IV. Results

A. Dependent Variable – Engineering Identity

Cronbach's alpha was 0.83 for the four items comprising the engineering identity dependent variable, which is well within the acceptable range of internal consistency [35].

B. Independent Variables Instrument Development

1) Exploratory Factor Analyses

After following EFA item reduction procedures [36] and content validity checks, the initial 34 items were reduced to 21 items, which loaded onto four factors. All items that had either less than 0.40 loading onto one factor or significant cross-loadings across factors (higher than 0.32 on more than two factors) were removed [30]. The four-factor solution was selected considering both the scree plot and the eigenvalue test. Table I shows the label, survey items, and EFA item factor loadings for each of the four factors. The four factors were identified and labeled in reference to the initial hypothesis of engineering identity and the items that composed each factor. Each factor is composed of at least three items. All four factors are well above the acceptable range of the Cronbach's alpha values (0.70) shown in Table. I. This result is aligned with the EFA result of Perkins et al. [37] that the engineering identity of doctoral students comprises recognition, interest, and competence/performance.

2) Confirmatory Factor Analysis

A CFA was conducted for two purposes: to confirm the structure of the scale based on the results of the EFA and to confirm the authors' theorized engineering identity factors. The four-factor solution was used in the CFA. To improve model fit, both face validity and modification indices were used to eliminate two items in the CFA procedure. The two items are "*I feel good when I am doing engineering*" and "*my advisor expects me to continue my career as an engineer*." The final number of items is 19 as shown in Table I. The reliability for the theorized factors was 0.91 for engineering interest, 0.88 for engineering competence, 0.88 for engineering recognition, and 0.79 for interpersonal skills competence. The model fit indices values of CFA were CFI = 0.95, TLI = 0.94, RMSEA = 0.06, SRMR = 0.05 and χ^2 = 2022.05; df = 171; p < .001, which were at the acceptable level [38]. Although the χ^2 test indicated no relationship among items and latent factors, the χ^2 test is not the definitive measure of goodness of fit when a relatively small sample size was used to test the CFA [39].

TABLE II
CORRELATION BETWEEN ENGINEERING IDENTITY AND INTENTION TO COMPLETE

Scale	1	2	3	4	5
1. Intention to complete	1				
2. Engineering identity	.14*	1			
3. Engineering interest	.17**	.70**	1		
4. Engineering competence	.08	.38**	.36**	1	
5. Engineering recognition	.16**	.66**	.64**	.31**	1
6. Interpersonal skills competence	.08	.31**	.21**	.24**	.30**

Note: * p<.05; ** p <.01; Minimum sample size: 291; Maximum sample size: 320

C. Pearson Correlation

The correlation analysis results are presented in Table II. Students' intention to complete their engineering graduate degree has a significant positive correlation with engineering identity (r = 0.14), engineering interest (r = 0.17), and engineering recognition (r = 0.16). Engineering graduate students' engineering identity is significantly and positively correlated with all four independent factors: engineering interest (r = .70), engineering recognition from others (r = 0.66), engineering competence (r = 0.38), and interpersonal skills competence (r = 0.31). Further, all four independent factors are positively and significantly correlated with each other, and the correlation range is between 0.21 and 0.64.

D. Sequential Multiple Linear Regression Models: Predicting Engineering Identity

Table III presents the three regression models to predict engineering identity. Model 1 shows that student characteristics explain just 1.4% of the variance in engineering identity. Model 2 introduces the three factors of academic engineering identity.

TABLE III
RESULTS OF MULTIPLE REGRESSION MODELS THAT PREDICT ENGINEERING IDENTITY OF GRADUATE STUDENTS

Variables	Model 1	Model 2	Model 3
Students' characteristics	β	β	β
Female	-.032	.005	.010
International	-.030	.011	.040
Civil/Environmental	.030	.041	.029
Mechanical	-.066	-.101*	-.097*
Master's with thesis	.070	.056	.062
Master's without thesis	.095	.033	.034
B.S. degree in engineering	.090	.082*	.084*
Work experience	-.049	-.038	-.032
Internship	.108	.075	.068
Graduate students engineering identity			
Engineering interest		.474***	.476***
Engineering competence		.118**	.092*
Engineering recognition		.301***	.275***
Interpersonal skills competence			.118**
R^2	.014	.593***	.604***
ΔR^2	-	.579	.025
Δ F test		132.41***	8.32**
N	287	287	287

Note: **p*< .05, ***p*< .01, and ****p*< .001.

These factors explain 57.9% of the variance in their engineering identity after excluding the 1.4% of 59.3% explained by characteristics variables. There was a collective significant effect between engineering interest, engineering competence, and engineering recognition, ($F(3, 274) = 132.41$, $p < .001$). Model 3 added the interpersonal skills competence variable as a part of engineering identity. The additional interpersonal skills competence factor was a significant factor and explains 2.5% of the variance in their engineering identity ($F(1, 273) = 8.32$, $p < .001$). The total final model explains 60.4% of the variance in engineering identity.

In Model 1, there are no significant predictors of engineering identity. In Model 2, all three engineering identity factors were significant. Three factors are engineering interest ($\beta = 0.474$), engineering recognition ($\beta = 0.301$), and engineering competence ($\beta = 0.118$). The significant positive coefficients explain that graduate students who have higher engineering interest, greater engineering recognition from others, and higher engineering competence are more likely to have stronger engineering identities. After adding covariates in Model 2, two student characteristic variables significantly predict engineering identity. A Bachelor's degree in engineering was a significant positive predictor ($\beta = 0.082$, $p < .05$) of engineering identity, meaning that graduate students who hold an engineering Bachelor's degree are more likely to have stronger engineering identities than engineering graduate students with a Bachelor's degree in another field. In addition, mechanical engineering students ($\beta = -0.101$, $p < .05$) had weaker engineering identities than electrical/computer engineering students. In Model 3, the newly added interpersonal skills competence variable ($\beta = 0.118$, $p < .01$) was a significant and positive predictor of engineering identity. All significant factors in Model 2 were also significant in Model 3.

V. Discussion

This study demonstrates that, with adaptation, frameworks previously developed for measuring the engineering identity of undergraduates, apply to graduate students. The academic factors included in several prior studies—engineering interest, competence, and recognition from others—explain 58% of the variance in engineering identity of graduate students ($R^2 = 0.58$). This is more than twice the variance explained in similar models of engineering identity in undergraduate students ($R^2 = 0.27$) [9]. In this study, engineering interest had the highest standardized coefficient, followed by engineering recognition from others and engineering competence. This ranking is similar to results from undergraduate engineering identity studies spanning first, second, third and fourth year students [9], [19]. In a study of first-generation, first-year engineering students, recognition was the strongest predictor of engineering identity [40]. However, engineering Master's and doctoral students perceived engineering interest, competence, and recognition differently from engineering undergraduate students based on the items for each factor. Important adaptations are discussed below.

In this study, engineering interest was the strongest predictor of engineering identity. Students who have higher interest in engineering are more likely to have stronger identification as engineers. While undergraduate items captured students' interest in learning engineering and positive attitude toward engineering, graduate items additionally captured interest in engineering work. One of the unique items from the graduate engineering interest scale is "*I enjoy engineering activities as part of my work week*." In interviews, graduate students emphasized interest in actually doing engineering as well as learning about it in class (which is the focus of undergraduate engineering interest items).

Engineering recognition from others required the most adaptation for Master's and doctoral students. In the pilot, limited changes to undergraduate engineering recognition items were made [9], but recognition did not factor out in the initial EFA. Recognition did emerge in the second EFA, after adding several items about the advisor and peers, informed by interviews and consultation with expert reviewers. This study shows that recognition from the advisor and graduate student peers is important. Similarly, in the final model, holding an engineering Bachelor's degree was also significant, an item that interviewees indicated to be an important form of recognition as an engineer.

Engineering competence had the lowest standardized coefficient among the three academic factors but was still a significant predictor for engineering identity. While most undergraduate items measured students' engineering competence and performance based on classroom settings (e.g., doing well on exams), graduate items measured competence level of more specific engineering skills such as designing, prototyping and finding solutions [41], which are important components of engineering design projects. In interviews, engineering graduate students explained that real-world research projects provided opportunities to develop their engineering competence and helped them to be innovative engineers, better in problem-solving and creating new engineering theories.

Further, interpersonal skills competence was important, with a higher coefficient than engineering competence in the final model. Graduate school requires a high level of communication skills, which fosters graduate students' engineering identities. These were identified in interviews as important to success as an engineer. This finding aligns with Choe, et al. [19], in that considering professional aspects of engineering (e.g., analysis, design, tinkering) improves prediction of engineering identity in undergraduates. Engineering identity studies on both engineering undergraduate and graduate students indicated the importance of professional aspects of engineering practice, although much more work is needed to study professional aspects of graduate identity development beyond communication.

Gender was not a significant predictor of engineering identity for graduate students in the regression models of this study, a result that contradicts prior engineering identity studies of undergraduates [7], [42]. Most of these prior studies focused on first-year students. However, the current study is consistent with a study of science graduate student identity, which also did not find variation by gender [43]. Future qualitative studies on gender and engineering identity in graduate students can help interpret this finding. For future studies, qualitative approaches might consider gender differences in engineering identity to provide rich descriptions.

Finally, engineering graduate students' intention to complete their engineering degrees has significant and positive correlation with their engineering identity, engineering interest, and engineering recognition. When students' engineering identities increase, their intention to complete degrees increases. This positive correlation is preliminary evidence that identity is worth investigating as a potential pathway to increasing retention in engineering graduate programs.

There are several limitations to note. The identity framework of interest, competence and recognition does not fully capture the dynamic nature of identity, nor does it consider other, non-academic or non-engineering aspects of graduate student identities. The results are based on relatively small sample sizes, a single institution, and a limited number of engineering disciplines, so they are not generalizable to a broader engineering graduate student population. Future work might consider other aspects of graduate student identities including, but not limited to, gender identity, racial/ethnic identity, and other roles of graduate students, including as researchers. There is also more work to be done understanding the professional aspects of graduate engineering identity, specifically as they relate to the role of design projects and other authentic engineering experiences in developing engineering identity.

VI. Conclusion

This study described development and adaptation of an engineering identity scale for engineering graduate students. The engineering identity scale contains four factors: engineering interest, engineering recognition from others, engineering competence, and interpersonal skills competence. In addition, all four factors were positive and significant predictors of engineering identity, explaining a particularly large portion of the variance. This study lays the groundwork for future investigations and interventions to foster engineering graduate students' engineering identities and retention.

Acknowledgment

The authors thank the other research team members: Carolyn Seepersad, Catherine Riegle-Crumb, Luis Martins, and Anita Patrick. They also thank many faculty members, administrators, and graduate students who contributed to data collection for this study.

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