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The Relationship Between Engineering Identity and Belongingness on Certainty of Majoring in Engineering for First-Generation College Students

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Abstract
This paper seeks to understand the factors that support first-generation college students' certainty of majoring in engineering. Data used in this study came from thirty-two four-year ABET-accredited institutions across the United States which has a total sample of 790 first-generation college students. We used the frameworks of engineering role identity and sense of belonging to understand the factors that influence first-generation college students' certainty of majoring in engineering. Certainty is referred to as the degree of confidence or decisiveness an individual has with regard to their chosen occupational plans. First, we examine how first-generation college students' engineering role identity constructs directly impact their certainty of majoring in engineering. Second, we examine how a sense of belonging influences certainty of majoring in engineering for first-generation college students. This work illustrates the factors that are important for first-generation college students' certainty of majoring in engineering and can help identify areas that can support and hinder students' progression towards their degree completion.

Background
Developing an identity as an engineer and feeling a sense of belonging in an engineering academic pathway has been repeatedly shown in prior literature to have a significant impact on students' persistence (Geisinger & Raman, 2013; Godwin & Potvin, 2016; Marra, Rodgers, Shen, & Bogue, 2012; Pierrakos, Beam, Constantz, Johri, & Anderson, 2009). An ethnographic study by Foor, Walden, and Trytten (2007) following the trajectory of Inez, a diverse, low income, first-generation college student, enrolled in an engineering major at a Predominately White Institution is an example of the interplay of these two constructs. Inez's experiences in her engineering courses and department can be summed up in one of her narrative statements, "I just wish that I belonged more in this whole engineering group, with the students and the teachers …" (Foor et al., 2007, p. 104). As Inez actively attempted to achieve her educational and professional aspirations, she was met with opposition by the structures of her institution, workload related to school and employment, and her interactions with faculty and peers. Working 30 hours a week and taking 15 credits, Inez had difficulty maintaining good grades, which led her decision to switch from one engineering major to another. In the classroom environment, Inez's knowledge and competence was questioned by a physics instructor and she observed her instructors play favoritism with students who have had co-op experiences, "being 'a co-op' puts one in elite company at this institution …" (Foor et al., 2007, p. 110). Inez's story is a powerful account of what many racial/ethnically diverse, low income, first-generation college students may face in engineering. Nevertheless, through perseverance and focus, Inez persisted in completing her engineering degree. At the end of the interview, Inez's advice was "try to make people feel more welcome. That may be hard, but I never felt like I was welcome[d]" (Foor et al., 2007, p. 113).

Inez's perseverance despite feeling unwelcomed in her engineering classes and department is perhaps a result of having a developed and lasting identity as someone who can do engineering. Although not explicitly cited in the article, we hypothesize that Inez was able to successfully navigate engineering, despite many challenges and lack of belonging, because she was able to see herself in the role of being an engineer and positioned herself accordingly, even when others and her institution did not. Authoring an identity as an engineer involves a socially constructed and dynamic process of positioning oneself and being positioned by others that has been framed through three interrelated constructs, interest, recognition, and performance/competence (Godwin, 2016; Godwin, Potvin, Hazari, & Lock, 2016; Hazari, Sonnert, Sadler, & Shanahan, 2010). Drawing from the experience of Inez and our hypothesis that identity is important to students' belongingness and persistence in engineering, we quantitatively examine how authoring of an engineering identity impacts first-generation college students' certainty of engineering major. Certainty is referred to as the degree of confidence or decisiveness an individual has with regard to their chosen occupational plans (Hartung, 1995) and is an important concept in understanding career development (Daniels, Clifton, Terry, Manduk, & Hall, 2006; Durr & Tracey, 2009). We focus on first-generation college students because they bring significant skills and knowledge to the profession (Smith & Lucena, 2016); however, the current engineering climate may not support these students in their engineering pathways (Walton, Logel, Peach, Spencer, & Zanna, 2015).

Objective of the Study

In this study, we use the frameworks of identity and sense of belonging to understand first-generation college students' certainty of majoring in engineering. First, we examine how first-generation college students' engineering role identity constructs of interest, recognition, and performance/ competence directly impact their certainty of majoring engineering. Second, we examine how belongingness effects certainty of majoring engineering for first-generation college students to answer the following research questions:

RQ1: Which engineering role identity constructs (i.e., interest, recognition, and performance/ competence) support first-generation college students' in engineering certainty of majoring in engineering?

RQ2: Does a sense of belonging mediate the relationship between engineering identity constructs (i.e., interest, recognition, and performance/competence) and certainty of majoring in engineering?

Theoretical Framing

Authoring an Engineering Identity

To examine how first-generation college students in engineering develop identities as engineers, we borrow from the work of scholars in math, science, and physics education (Carlone & Johnson, 2007; Cribbs, Hazari, Sonnert, & Sadler, 2015; Hazari, Sonnert, Sadler, & Shanahan, 2010). They posit that *interest* plays a key role in the framing of role identity and involves a personal desire for learning and understanding in each context (Hazari et al., 2010). *Recognition* is both an external manifestation and internal state, which are required for identity development (Carlone & Johnson, 2007; Potvin & Hazari, 2013). How a person is perceived by others is an incomplete representation of how he/she perceived themselves, it is also important to understand how a student internalizes these beliefs in shaping who they are and how they position themselves in the world (Potvin & Hazari, 2013). Lastly, an individual cannot be recognized as a certain kind of person unless he/she makes visible (*performs*) their *competence* in particular domains (e.g., mathematics, physics, or engineering; Carlone & Johnson, 2007). These concepts have been used to understand students' choice of engineering at the transition from secondary education to higher education (Godwin et al., 2016; Verdín, Godwin, Sonnert, & Sadler, 2018), students' persistence in engineering (Godwin & Potvin, 2016), differences in first-generation college students' career aspirations (Verdín & Godwin, 2017).

Sense of Belonging

Individuals are naturally drawn towards establishing and sustaining a sense of belonging, it has been described as a necessary human motivation (Baumeister & Leary, 1995). A sense of belonging is present in multiple domains for example, belonging to one's university community and/or belonging in the classroom setting (Smith et al., 2012). Students who experience a sense of belonging are more likely to display "intrinsic motivation, … establish a stronger sense of identity, … and regulate their own behavior in the classroom consistent with social norms" (Osterman, 2000, p. 331). Literature suggests that an engineering identity precedes belongingness, but this relationship has not been tested longitudinally. However literature does demonstrate that identity development and feeling a sense of belonging are intimately related (Meyers, Ohland, Pawley, Silliman, & Smith, 2012; Osterman, 2000).

Methods

Data for this analysis were collected in the fall of 2017 semester as part of a larger project. A U.S. national survey was administered via paper-pencil format at 32 four-year, Accreditation Board for Engineering and Technology (ABET) accredited institutions in students' introductory engineering courses. A total of 3,815 students responded to the survey. The analysis for this study focuses only on the first-generation college student population (i.e., both parents having less than a bachelor's degree) in engineering, thus the overall sample size is 804 students. The demographic breakdown can be found in Table 1. Multiple imputation was used to account for missing values in the dataset using an expectation maximization bootstrapping from the Amelia II package. This approach accounts for missing completely at random and missing at random data robustly using modern methods for estimating both the missing data as well as error (Honaker, King, & Blackwell, 2011).

TABLE 1
Demographic Information for First-Generation College Students in Engineering

Student Classification	
First-generation college students	**804⁺**
Female	190 (24%)
Male	578 (72%)
Did not report or identify as female/male	36 (4%)
Race/Ethnicity⁺⁺	
Asian	96 (12%)
Black or African American	71 (9%)
Latino/a or Hispanic	159 (20%)
Middle Eastern or Native African	20 (2%)
Native American or Alaska Native	5 (~1%)
Native Hawaiian or other Pacific Islander	11 (1%)
White	475 (59%)
Another race/ethnicity not listed above	19 (2%)

Note. +Sample size after removing outliers. ++Students were given the opportunity to *mark all that apply* for their race/ethnicity classification, this table represents students who identified with a single group and those who marked more than one race/ethnicity are listed as multiple race/ethnicity groups marked.

Survey Instrument

The survey consisted of multiple items to measure students STEM identity (i.e., engineering, physics, and math), sense of belonging, certainty of majoring in engineering, and other affective measures not analyzed in this proposal. Responses for STEM identity were measured on a seven-point anchored numeric scale ranging from 0—"Strongly disagree" to 6—"Strongly agree." Prior work has shown strong validity evidence for the latent variables of engineering identity (Godwin, 2016; Verdín, Godwin, Kirn, Benson, & Potvin, 2018) and sense of belonging (Kirn et al., 2016; Smith et al., 2012; Verdín, Godwin, Kirn, et al., 2018). The engineering identity measures includes three items measuring interest, two items measuring recognition, and four items measuring performance/competence. A single item was used to capture students' overall engineering identity, "*I see myself as an engineer*." Responses for belongingness and career certainty were measured on a seven-point anchored number scale ranging from 0—"Not at all" to 6—"Very much so." Two measures of belongingness were used: belonging in the engineering major (three items) and belonging in the engineering classroom (three items). Lastly, a single measure was used to examine students' certainty of majoring in engineering, "*I feel sure about my choice of engineering as a major*."

Data Analysis

For this analysis, R programming language and statistical software system version 3.4.3 (*R: A Language and Environment for Statistical Computing*, 2017) was used and the lavaan package (Rosseel, 2012) was used to conduct the confirmatory factor analysis and structural equation model. Model fit was tested using the fit indices that were suggested by (Kline, 2016), (Brown, 2015), and (Hu & Bentler, 1999).

Results

To conduct the analyses, outliers were removed from the dataset, using Mahalanobis distance 52 cases were removed, resulting in 752 first-generation college students. Zero-order correlations for the variables used in this analysis were examined and found to be within acceptable ranges. All variables were found to be within acceptable limits of univariate normality. Multivariate normality was not found in our dataset, therefore a robust maximum likelihood (MLM) estimator was used. The measurement model was analyzed for each group of constructs using a confirmatory factor analysis and the structural model was analyzed using structural equation modeling. Overall, the fit indexes suggest good model fit, as shown in Table 2 and Table 3. All factor loadings, item reliability, construct reliability, and average variance extracted were within acceptable ranges, shown in Table 4 and Table 5.

This study examined two research questions, thus two models were tested. Both models suggest an overall measure of good structural model fit. Model 1, seen in Figure 1, examines the relationship between engineering identity building constructs (i.e., interest, recognition, and performance/competence) in first-generation college students' certainty of majoring in engineering demonstrated overall good model fit. Model 2, seen in Figure 2, examines how measures of belonging to the engineering major and classroom mediate the relationship between engineering identity building constructs and certainty of majoring in engineering.

Research Question 1, Model 1

We tested the factors that supported first-generation college students' certainty of engineering major. The significant paths predicting certainty of engineering major were students' interest in engineering, performance/competence beliefs, and an overall engineering identity measure (Figure 1). Interest in engineering was more influential in their certainty of career path (β = .39, $p < .001$) compared to performance/competence beliefs (β = .24, $p < .01$) and students' perceptions of seeing themselves as engineers (β = .17, $p < .001$).

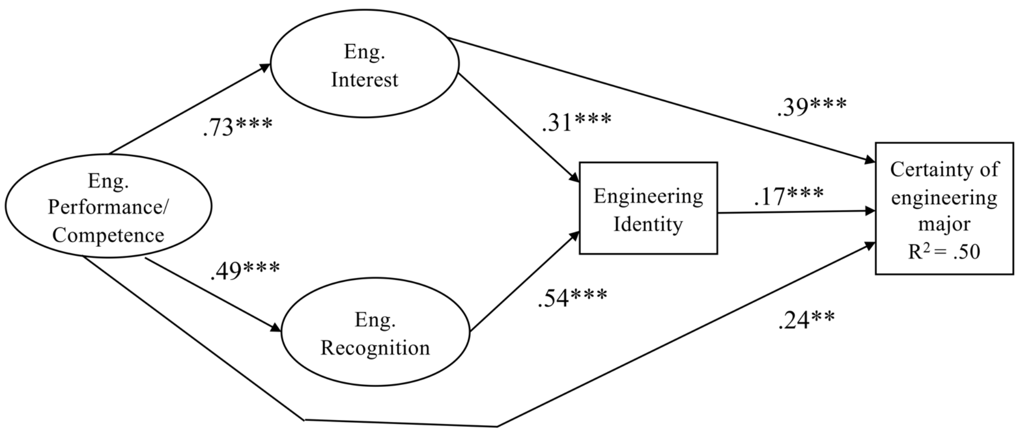

FIGURE 1. Structural equation model between engineering identity constructs and certainty of majoring in engineering. Non-significant values were removed for parsimony and only paths with $p < .05$ are included in this model. Note, * $p < .05$, ** $p < .01$, and *** $p < .001$

Research Question 2, Model 2

In examining the effect of belongingness in the model, the engineering identity constructs were not direct predictors of certainty of engineering major (Figure 2). Students' feelings of belonging in their engineering major mediated the relationship between interest, performance/competence, and engineering identity onto certainty of majoring in engineering (β = .82, $p < .001$). Whereas, students' feelings of belonging in the engineering classroom was not predictive of first-generation college students' certainty of majoring in engineering.

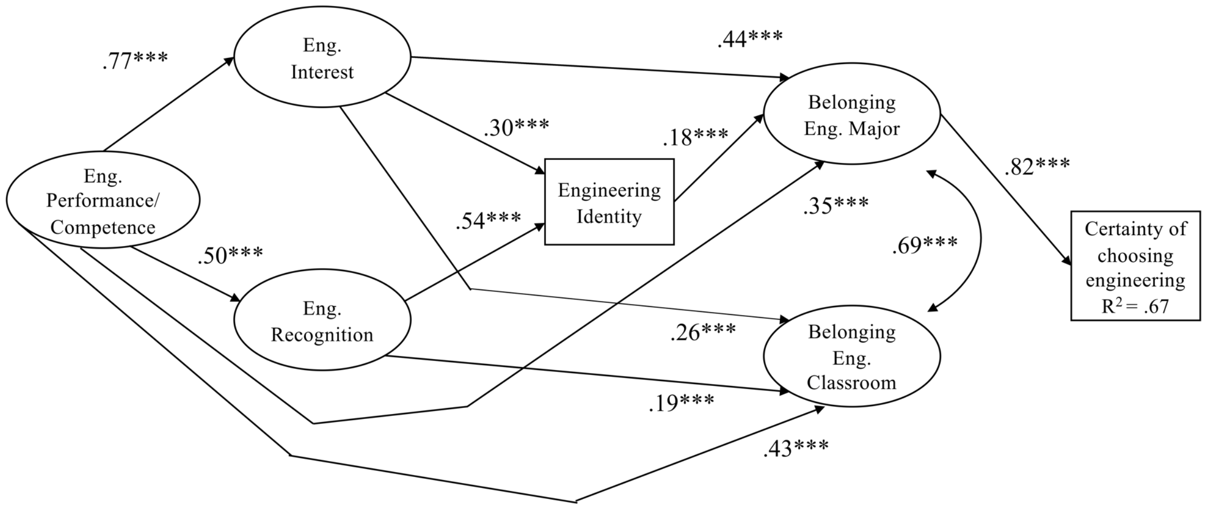

FIGURE 2. Structural equation model of engineering identity constructs, belongingness in engineering, and certainty of majoring in engineering. Non-significant values were removed for parsimony and only paths with p < .05 are included in the model. Note, * $p < .05$, ** $p < .01$, and *** $p < .001$

Discussion

The literature on first-generation college students has often centered around lack of academic preparation (Engle, 2007; Saenz, 2007), inadequate familial support (Raque-Bogdan & Lucas, 2016), challenges towards achieving future career goals (Fernandez, Trenor, Zerda, & Cortes, 2008), or lack of social and cultural integration (Pascarella & Terenzini, 2005). Our work moves away from understanding the first-generation college student population through a deficit lens in favor of exploring strengths that they bring with them into engineering. Our analysis revealed that these students' interest in engineering, beliefs about being able to understand and perform well in the subject, and seeing oneself as the type of person that can do engineering helped solidify their certainty of majoring in engineering. Our analysis reveals that institutional structures (i.e., the engineering classroom setting) are a cause for deterring their certainty of choice. Like Inez, the first-generation college students in our study struggled with feeling as though they belonged in the engineering classroom setting. Inez's desires to "belong more" is not an isolated incident, rather the need to belong in engineering is seen in first-generation college students in 32 institutions across the U.S.

Scholarly Significance

Engineering students' persistence or performance alone is not a sufficient outcome for educational research. We argue that, as engineering educators, we should be assessing how the social structures in our institutions hinder the progression of a vulnerable population in engineering, i.e., first-generation college students. This study is a first step in our continuing effort to unpacking the assets, first-generation college students bring with them to engineering and how the culture of engineering may deter their progression.

TABLE 2
Confirmatory Factor Analysis Estimates and Fit Indices

Models	X^2_{SB}	*df*	CFI	TLI	RMSEA	90% CI for RMSEA	SRMR
Engineering Identity Constructs	124.49	24	0.97	0.95	0.06	(0.054, 0.072)	0.04
Belongingness Constructs	79.53	8	0.99	0.99	0.06	(0.035, 0.076)	0.01

Note. CFI, acceptable values above 0.90; TLI, acceptable value above 0.90; RMSEA, value less than 0.05 indicate excellent fit and a value of 0.08 indicate moderate fit; SRMR, value of less than 0.08 considered good fit. Satorra-Bentler chi-square goodness of fit was significant for all latent constructs; this is mostly like due to the biased against large sample sizes (Lomax & Schumacker, 2004).

TABLE 3
Structural Equation Model Fit Indices

Models	X^2_{SB}	P- value	*df*	CFI	TLI	RMSEA	90% CI for RMSEA	SRMR
Model 1 (Figure 1)	159.20	$p < .001$	39	0.96	0.95	0.07	(0.059, 0.078)	0.03
Model 2 (Figure 2)	328.43	$p < .001$	107	0.97	0.96	0.06	(0.050, 0.062)	0.04

Note. CFI, acceptable values above 0.90; TLI, acceptable value above 0.90; RMSEA, value less than 0.05 indicate excellent fit and a value of 0.08 indicate moderate fit; SRMR, value of less than 0.08 considered good fit. Satorra-Bentler chi-square goodness of fit was significant for all latent constructs; this is mostly like due to the biased against large sample sizes (Lomax & Schumacker, 2004).

TABLE 4
Factor Loadings and Reliability Estimates of Confirmatory Factor Analysis for Figure 1

Latent Variables	Indicators	Unstd./ Std. factor loadings	*SE*	Item reliability (r^2)	Construct reliability	Average variance extracted
Engineering: Interest					.90	.77
	Q3Eng_h: I am interested in learning more about engineering.	0.56*/.87	.03	.76		
	Q3Eng_i: I enjoy learning engineering.	0.66*/.93	.03	.86		
	Q3Eng_j: I find fulfillment in doing engineering.	0.63*/.88	.04	.67		
Engineering: Recognition					.79	.55
	Q3Eng_e: My instructors see me as an engineer.	0.99*/.75	.06	.56		
	Q3Eng_f: My peers see me as an engineer.	1.14*/.88	.06	.77		
Engineering: Performance/Competence					.89	.65
	Q3Eng_k: I am confident that I can understand engineer in class.	1.01*/.84	.04	.71		

	Q3Eng_l: I am confident that I can understand engineer outside of class.	1.04*/ .84	.04	.70		
	Q3Eng_m: I can do well on exams in engineer.	1.01*/.79	.04	.62		
	Q3Eng_n: I can overcome setbacks in engineer.	0.91*/.80	.04	.64		

Note. * $p < .001$, acceptable values of item reliability (r^2) > .50, construct reliability > .70, and average variance extracted > .50

TABLE 5
Factor Loadings and Reliability Estimates of Confirmatory Factor Analysis for Figure 2

Latent Variables	Indicators	Unstd./ Std. factor loadings	SE	Item reliability (r^2)	Construct reliability	Average variance extracted
Engineering: Interest					.90	.77
	Q3Eng_h: I am interested in learning more about engineering.	0.79*/.87	.04	.76		
	Q3Eng_i: I enjoy learning engineering.	0.84*/.92	.04	.84		
	Q3Eng_j: I find fulfillment in doing engineering.	0.85*/.85	.04	.72		
Engineering: Recognition					.79	.55
	Q3Eng_e: My instructors see me as an engineer.	0.99*/.73	.05	.53		
	Q3Eng_f: My peers see me as an engineer.	1.11*/.82	.05	.67		
Engineering: Performance/Competence					.89	.65
	Q3Eng_k: I am confident that I can understand engineer in class.	1.09*/.78	.04	.61		
	Q3Eng_l: I am confident that I can understand engineer outside of class.	1.08*/ .76	.04	.58		
	Q3Eng_m: I can do well on exams in engineer.	1.20*/.82	.04	.67		
	Q3Eng_n: I can overcome setbacks in engineer.	1.04*/.82	.04	.67		
Belonging: Engineering Major					.93	.79
	Q4a: I feel comfortable in engineering.	1.09*/.84	.04	.71		
	Q4b: I feel I belong in engineering.	1.20*/.93	.04	.84		
	Q4c: I enjoy being in engineering.	1.06*/.91	.04	.82		
Belonging: Engineering Classroom					.85	.70
	Q4d: I feel comfortable in my engineering class.	1.10*/.93	.04	.87		
	Q4e: I feel supported in my engineering class.	0.92*/.77	.04	.59		
	Q4f: I feel that I am part of my engineering class.	0.95*/.80	.04	.64		

Note. * $p < .001$, acceptable values of item reliability (r^2) > .50, construct reliability > .70, and average variance extracted > .50

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