Confidence in Pursuing Engineering: How First-Generation College Students' Subject-Related Role Identities Supports their Major Choice

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***Abstract*—This full research category paper examines how first-generation college students' mathematics and physics identity support the development of an engineering identity and how the three STEM identities support students' commitment to choose an engineering major. This study focuses on first-year, first-generation college students in engineering (*n* = 616). The purpose of only focusing on first-year students was to understand how their decision to pursue engineering is shaped before engaging in engineering or college coursework. Structural equation modeling was used to test direct and indirect paths of students' STEM identities on engineering major commitment. First-generation college students' perceptions of themselves as capable and interested mathematics learners supported their views of themselves as capable physics and engineering learners. Forming an identity as a math and physics person supported the development of an engineering identity. First-generation college students' engineering identity supported their confidence of choosing an engineering major. However, female and Latinx first-generation college students were less likely to see themselves as physics people. Female first-generation college students were also less confident about their choice to pursue engineering. The findings elucidate the difference each subject-related role identities have on first-generation college students' developing engineering identity and confidence in their major choice.**

Keywords—first-generation college students, engineering identity, physics identity, mathematics identity

I. Introduction

First-generation college students who enroll in engineering programs in some way see themselves as individuals who can do engineering and become engineers (i.e., hold or are developing an engineering role identity). Subject-related role identities in STEM contexts have been measured using three interrelated constructs: interest, recognition, and performance/competence beliefs. This continuously developing engineering identity is cultivated through learning experiences before and during college. However, schools with an overrepresentation of low-income students, many of whom are also first-generation college students, are often disenfranchised from experiences that can help shape their subject-related identities (i.e., mathematics, physics, and engineering).

Studies have found that students who saw themselves as physics, mathematics, or broadly STEM people were more likely to choose to major in engineering [1]–[4] and more likely to choose an engineering industry career [4], [5]. Specifically, Cass and colleagues [6] found that mathematics identity significantly predicted students' choice of an engineering career, even after controlling for background factors (i.e., parents' level of education) and SAT/ACT math scores. Developing an engineering identity or seeing oneself as a STEM person has important implications for students' trajectories into and through engineering. Studies that focus on students who are the first in their families to attend college capture experiences once in higher education. Few studies focus on first-generation college students prior to postsecondary enrollment. A possible rationale may be that the first-generation college student designation is only assigned once students apply to college and once enrolled in college. As well, few studies (e.g., [3], [7]) have focused on how first-generation college students' pre-college experiences support identity development and have sought to understand how subject-related identities inform their choice of college major.

This study expands our understanding of how particular subject-related role identities inform first-generation college student's decision to pursue an engineering major. The first-generation college student sample for this study are enrolled in their first semester in college; thus, we posit that the identities they developed are a result of their pre-college experiences. The present study does not report specific pre-college experiences that supported identity development; instead, it examines how subject-related role identities informed first-generation college students' confidence in pursuing an engineering degree.

II. THEORETICAL FRAMING

This study uses a role identity framework in the context of specific subject-related domains (i.e., mathematics, physics, and engineering). Stets and Burke [8] described role identity as "acting to fulfill the expectations of a role, coordinating and negotiating interaction with role partners, and manipulating the environment" to meet the needs of the role being acted out [p. 226]. An individual who takes on a role identity (i.e., being an engineer) adopts the meanings and expectations that accompany the specific role "and then act[s] to represent and preserve these meanings and expectations" [8, p. 227], and meanings are negotiated through interaction with others. Stets and Burke's [8] conceptualization of role identity sits in tandem with identity in the education literature (e.g., [9]). Gee [9] developed an approach to understand identity by emphasizing the importance of individuals "acting and interacting in a given context" and the interchange of "being recognized as a certain 'kind of person,' in a given context" based on one's performance [p. 99].

In this study, context should be understood as educational domains such as mathematics, physics, and engineering (i.e., as a "math person," "physics person," or engineer) and not professional identities (i.e., mathematician or physicist). The role identities students develop in the mathematics, physics, and engineering contexts are formed by both the product and byproduct of educational activities such as in-and-out-of-school exposure to the context. [10]–[12]. These identities are not an a priori component of participating in an activity but are made and remade when students adopt the roles, behaviors, and attitudes defined and shared in the given context [8], [9].

Students' authorship of a role identity in the subject-related context of mathematics, physics, or engineering is done through their interest, recognition, and performance/competence. Since the student sample in this study consists of undergraduates, the meaning and expectations associated with the subject-related role identities are contextualized to their life stage (i.e., the transition from secondary to postsecondary education). Students must be interested in the subject domain, believe they can master course content, and be recognized by members in their immediate environment (e.g., instructors, peers).

Interest plays a key role in framing role identity development and involves a personal desire to learn and understand in each context [10]. Interest is supported through students' interaction with their environment; that is, a situational interest can develop into an individual interest [13]. *Recognition* is both an external manifestation and an internal state required for identity development [11], [14]. Specifically, how others perceive a person is an incomplete representation of how they perceive themself; 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 [2], [14]. Lastly, an individual cannot be recognized as a certain kind of person unless they make visible (performs) their competence in particular domains (e.g., mathematics, physics, or engineering; [11]. *Performance/competence beliefs* are global or more general attitudes regarding one's capabilities. Carlone and Johnson [11] affirmed that a subject-related identity is fragile, contingent, situationally emergent, yet students' performance practices and their display of competence triggers recognition as a science type of person from individuals situated in their environment [11].

However, given the number of educational inequities that still exist, first-generation college students may not have been exposed to engineering-related activities or had the opportunity to take advanced coursework in mathematics and physics (e.g., [15], [16]). Therefore, rather than modeling subject-related role identities as a sequence of events (i.e., performing one's competence affords students recognition or performing one's competence subsequently promotes interest development [2], [17]–[19]). We offer a conceptualization of subject-related role identities that develop not through mediation processes, as has been modeled in general studies of engineering students [2], [19]–[21], but through mechanisms that can individually inform identity development (see Figure 1).

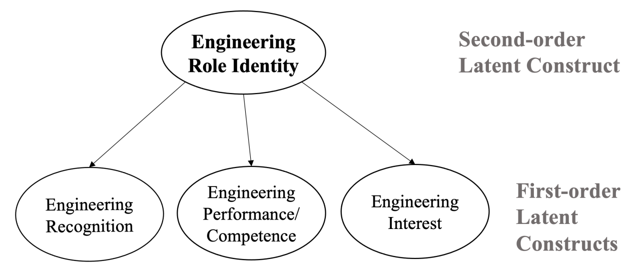

Fig. 1. Reconceptualized relationships that promote engineering role identity development

III. RESEARCH QUESTIONS

Using the current framing of subject-related role identity, we examined how identity supports first-generation college students' confidence in their major choice. The goal of the first research question was to expand modeling work using role identity constructs. Prior work modeled performance/ competence beliefs as mediated by interest and recognition (as first-order latent variables), see [2], [14], [17], [21]. A second-order latent variable (i.e., Figure 1) explicitly models the hierarchical structure of the factors [22] and supports the theory that the three first-order identity variables dynamically inform the development of subject-related role identities. The research question that expands the modeling work using the role identity constructs is,

1) Do the constructs of interest, recognition, and performance/competence beliefs measure an underlying second-order factor structure for the role identities in the context of mathematics, physics, and engineering?

Once a second-order factor structure was determined, we proceeded to answer the following research questions,

2) Does the development of mathematics and physics role identities foster the development of an engineering role identity?

3) Which subject-related role identities support first-generation college students' certainty of choosing an engineering major?

4) Are there differences in the types of subject-related role identities that develop across gender and race/ethnicity?

IV. Method

A. Data

Data for this study came from a survey administered in Fall 2017 in introductory to engineering courses at 32 four-year, ABET-accredited institutions across the United States. A total of 3,711engineering students responded; from this sample, 616 (17%) specified their parents' level of education as either "less than a high school diploma," "high school diploma/GED," or "some college or associate/trade degree" (i.e., first-generation college students) and were enrolled in college for less than one year. We only focused on students who were in their first year in college and are the first in their families to attend college. The purpose of only focusing on first-year students was to understand how their engineering identity is shaped before engaging in engineering or college coursework. Demographic information about the first-generation college student sample can be found in Table I.

TABLE I. Demographic Information of First-Generation College Students

	Female	Male
Overall	161	475
Asian	23	60
Black or African American	14	34
Latino/a or Hispanic	24	93
Middle Eastern or Native African	3	9
Native American or Alaska Native	4	5
Native Hawaiian or another Pacific Islander	1	4
White	90	282
Another race/ethnicity not listed above	4	9

Note. Students were allowed to select all race/ethnicities they identified with.

B. Analysis

Structural equation modeling was used to test the relationships between latent constructs. We followed the following data analysis procedures: 1) checking for assumptions of univariate and multivariate normality, 2) examining the measurement model through confirmatory factor analysis, 3) examining overall structural model fit.

Second-order factors are latent variables whose indicators are themselves latent. The first-order and second-order latent variables were examined before testing the structural paths. Examining the second-order factor structure helped answer our first research question. A second-order factor "tests a theory-based account for the patterns of relationships among the first-order factors ... assert[ing] that second-order factors have direct effects on lower-order factors" [23, p. 339]. Second-order factors are usually more parsimonious models, that is, simple models with greater explanatory predictive power [23], [33], [35]. The three latent significant correlations justified testing a second-order latent construct [23], [35]. Therefore, we created three latent constructs (i.e., interest, recognition, and performance/competence beliefs) for each subject into a second-order construct (i.e., math identity, physics identity, and engineering identity). After establishing a reliable second-order factor structure we proceeded to test for relationships between constructs.

Following, we examined the relationship between gender (i.e., female and male) and race/ethnicity, listed in Table I, for the subject-related role identity latent variables using multiple-indicators multiple-cases (MIMIC) modeling. MIMIC models examine differences in intercepts and factor means; this technique "assume[s] that all other measurement and structural parameters … are the same across all levels of the covariates (groups)" [23, p. 305]. MIMIC models are ideal for variables with small sample sizes, like group membership, e.g., race/ethnicity and gender [23].

All analyses were run using the *cfa* and *sem* functions in the lavaan package [24] in the R statistical programming software version 3.5.3 [25].

C. Survey Measures

Engineering, physics, and mathematics identities consist of three constructs (i.e., interest, recognition, and performance/ competence beliefs). Prior work has shown strong validity evidence for the constructs of engineering identity [26], [27], physics identity [2], [10], and mathematics identity [17]. For all subject-related role identity measures, students were asked, "To what extent do you agree or disagree with the following statements?" Students rated their response using a 7-point anchored numeric scale, ranging from "0-Strongly disagree" to "6-Strongly agree."

V. Results

Data were screened to verify assumptions of univariate and multivariate normality. Determining whether data were univariate and multivariate normal is important to select an estimator and test statistic with robust standard errors. Data were within the univariate normality recommended cut-off values [28], [29]. Multivariate normality was examined using Mardia's Test [30]; data were not multivariate normal. Therefore, a Satorra-Bentler ($SB\chi^2$) mean adjusted test statistic will be reported to account for non-normality in the distributions [31]. A robust maximum likelihood (MLM) estimator was selected. MLM corrects for both the model chi-square and the parameter estimates' standard errors deviations from a normal distribution [23], [32].

A. Measurement Model

The measurement models were examined using confirmatory factor analysis. The first-order factor structure had a Satorra-Bentler adjusted chi-square test for goodness of fit of $SB\chi^2 = 973.78$, $df = 396$, $p < .000$. Fit indices were all within acceptable ranges suggesting good model fit [23], [33], CFI of 0.94, TLI of 0.93, RMSEA of 0.058 with a 90% confidence interval of [0.051, 0.058], and an SRMR of 0.04.

All first-order factor loadings exceeded the minimum cut-off values of 0.70 [23]. Indicator reliability, evaluated by individually squaring the standardized factor loadings were above 0.50, demonstrating that each item measured above 50 percent of the true-score variance [23]. The construct reliability, evaluated using Cronbach's alpha values were above the recommended value of 0.70 [34]. All average variance extracted values were above the recommended 0.50 value indicating the constructs achieved convergent validity. A summary of all first-order factor loadings, item reliability, construct reliability, and average variance extracted can be found in Table II.

The test statistics for the measurement model were, $SB\chi^2$ = 1119.32, *df* = 420, $p < .000$. Fit indices were all within acceptable ranges suggesting good model fit [23], [33], CFI of 0.92, TLI of 0.92, RMSEA of 0.058 with a 90% confidence interval of [0.055, 0.062], and an SRMR of 0.05. All second-order factor loadings can be found in Figure 2.

B. *Structural Model*

Once the measurement model was evaluated, we examined the structural paths (i.e., relationships between latent constructs and the single indicator *I feel certain about graduating with an engineering* degree). The overall model fit had a Satorra-Bentler adjusted chi-square test for goodness of fit of $SB\chi^2$ = 1258.92, *df* = 509, $p < .000$. The values for the fit indices were all within acceptable ranges suggesting good model fit [23], [33], CFI of 0.92, TLI of 0.92, RMSEA of 0.06 with a 90% confidence interval of [0.056, 0.068], and an SRMR of 0.05.

VI. Discussion of Findings

This section presents the relationships found in the structural equation model; each subsection pertains to the research questions posed in Section III. We discuss our findings' significance in light of prior work.

A. *Confirming an underlying second-order factor structure for each subject-related role identity*

We tested a second-order factor structure for all three subject-specific STEM identity measures; the results support the theoretical standpoint that the constructs of interest, recognition, and performance/competence beliefs support the underlying latent variables of engineering, physics, and mathematics role identities for early-career first-generation college students.

Second-order standardized factor loadings are analogous to standardized regression coefficients, i.e., beta estimates. With every one standard deviation increase in the predictor variable the outcome variable standard deviation changes by the beta

TABLE II. MEASUREMENT MODEL FOR FIRST-ORDER LATENT CONSTRUCTS

Latent Variable	Indicator	Std. Factor Loading	*SE*	Item Reliability	Construct Reliability	Average Variance Extracted
Math Interest	I am interested in learning more about math	.81	.06	.66	.88	.71
	I enjoy learning math	.92	.07	.84		
	I find fulfillment in doing math	.82	.07	.67		
Math Recognition	I see myself as a math person	.83	.09	.69	.81	.57
	My peers see me as a math person	.71	.08	.50		
	I've had experiences in which I was recognized as a math person	.74	.10	.55		
Math Performance/ Competence Beliefs	I am confident that I can understand math in class	.89	.07	.79	.92	.75
	I am confident that I can understand math outside of class	.86	.07	.74		
	I can do well on exams in math	.85	.07	.72		
	I understand concepts I have studied in math	.89	.07	.79		
Physics Interest	I am interested in learning more about physics	.82	.05	.67	.90	.77
	I enjoy learning physics	.94	.06	.88		
	I find fulfillment in doing physics	.86	.06	.74		
Physics Recognition	I see myself as a physics person	.82	.06	.67	.87	.59
	My instructors see me as a physics person	.69	.05	.48		
	My peers see me as a physics person	.77	.06	.59		
	Others ask me for help in physics	.79	.07	.62		
Physics Performance/ Competence Beliefs	I am confident that I can understand physics in class	.91	.08	.83	.94	.80
	I am confident that I can understand physics outside of class	.88	.07	.77		
	I can do well on exams in physics	.89	.08	.79		
	I understand concepts I have studied in physics	.90	.07	.81		
Engineering Interest	I am interested in learning more about engineering	.84	.05	.71	.91	.79
	I enjoy learning engineering	.92	.06	.84		
	I find fulfillment in doing engineering	.89	.05	.79		
Engineering Recognition	I see myself as an engineer	.82	.09	.67	.80	.51
	My instructors see me as an engineer	.58	.07	.34		
	My peers see me as an engineer	.68	.07	.46		
Engineering Performance/ Competence Beliefs	I am confident that I can understand engineering in class	.89	.06	.79	.89	.68
	I am confident that I can understand engineering outside of class	.83	.06	.69		
	I can do well on exams in engineering	.79	.06	.62		
	I understand concepts I have studied in engineering	.79	.06	.62		

Note. All factor loadings had a *p*-value less than .001

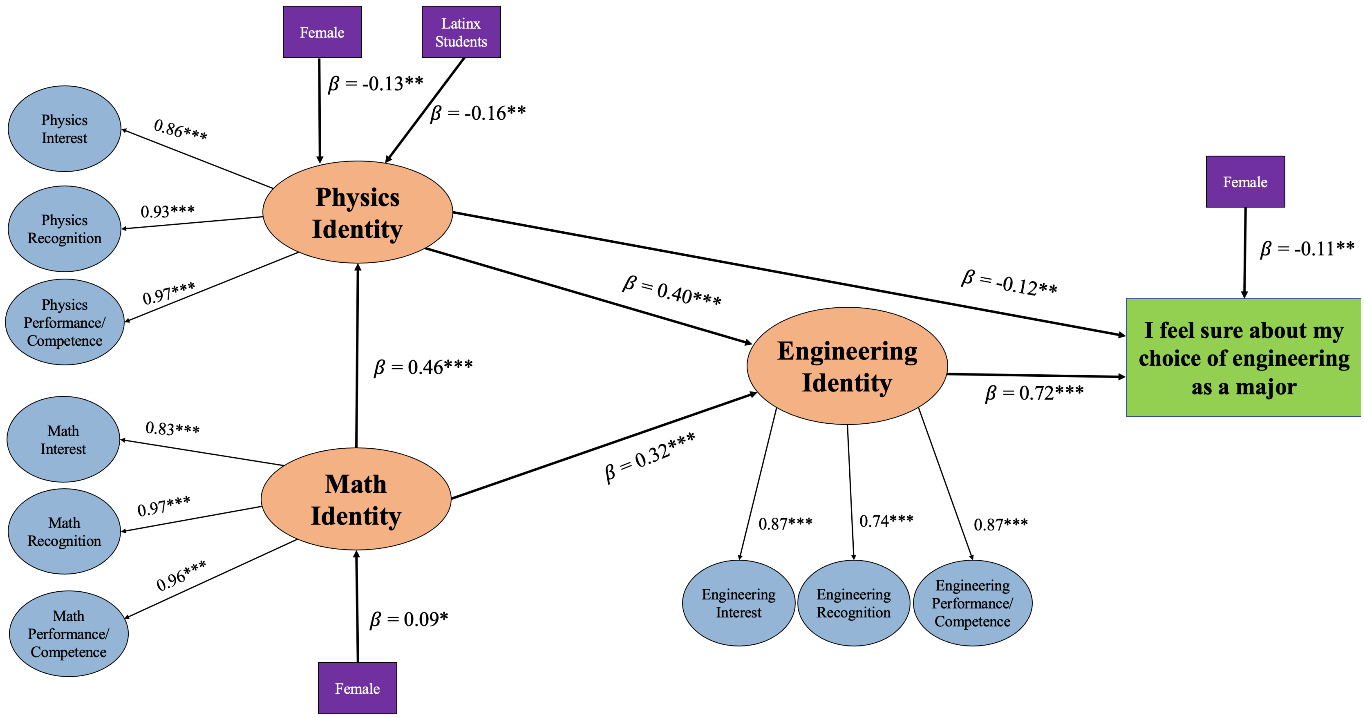

Fig. 2. Structural equation model of subject-related role identities. First-order latent constructs are represented in blue. Second-order latent constructs are represented in soft orange. * $p < .05$; ** $p < .01$; *** $p < .001$

estimate [23]. Modeling the subject-related role identities as second-order latent constructs allowed us to understand which construct explains more variance in the overarching identity factor structures. We found that for mathematics role identity, math recognition had the highest standardized factor loading of β = 0.97, followed by math performance/competence beliefs with a loading of β = 0.96, and math interest with a loading of β = 0.83. Students tend to be exposed to mathematics content for a more extended period of time, thus affording them opportunities to gain confidence in their abilities to understand the subject and be afforded more opportunities to be recognized as a math person.

When examining the second-order latent construct of physics role identity, physics performance/competence beliefs had the highest standardized factor loading of β = 0.97, following physics recognition and interest having loadings of β = 0.93 and β = 0.86, respectively. Prior work found that out-of-school activities such as tinkering with mechanical devices, participating in science/mathematics competitions, and engaging in conversations about science with friends or family members supported first-generation college students' interest and recognition as someone that can be a physics person [3]. Physics is offered as a formal course in high school, most often in the final years of students' high school pathway. Additionally, identities in physics have often been framed by students as less accessible than other STEM identities [55]; nonetheless, the factor loadings demonstrate the importance of first-generation college students' perceptions of themselves as capable learners (i.e., understanding and performing well) in physics. In the present study, we found that first-generation college students' perceptions of being capable physics learners (i.e., performance/competence beliefs) had the highest effect on their physics identity.

We examined the second-order latent construct of engineering role identity. We found that engineering interest had the highest standardized factor loading of β = 0.87, following engineering performance/competence beliefs β = 0.86, and engineering recognition β = 0.74. While efforts are being made to incorporate engineering content into the K-12 curricula (see [36], [37]), there are still concerns about how engineering content is represented, that is, as an isolated course versus a support towards science instruction [38]. Given the current state of engineering in students' pre-college education, it is interesting that first-generation college students are displaying slightly more interest in engineering than physics and mathematics. A recent study found that engineering interest can be supported through students tinkering knowledge from home (i.e., repairing/taking apart household items) [7]. Perhaps these informal at-home experiences could explain the modestly higher interest in engineering. Lastly, being recognized as someone that can do engineering currently had the lowest effect on first-generation college students' engineering identity. It is possible that formal engineering experiences, where one can perform their capabilities, were not available to these students. An ad hoc descriptive analysis of students' response to the question, "Have you participated in Project Lead the Way?" revealed that most of our first-generation college students sample (85%) did not have this experience in high school. While Project Lead the Way is not the only form of engineering-related exposure, it was the only out-of-school pre-college variable captured in the survey.

The development of a subject-related role identity is a result of exposure to course material inside and outside of the classroom [3], [39], [40]. Thus, the kinds of identities afforded to students through school activities could help them "change, grow, and learn" based on images of the identities represented in the activities [41, p. 240]. Eisenhart and Finkel posited, "if the activities of school science represent identities that are interesting, believable, and possible for students to achieve (given existing demands and expectations)," then students are more likely to pursue these identities [41, p. 240].

The purpose of this section was to understand how the first-order constructs supported the subject-related role identities. Having established a reliable second-order latent construct for each subject-related role identity allowed us to move forward and examine the next research questions.

B. Mathematics and physics role identity supported the development of an engineering role identity

Studies have found that subject-related role identities in mathematics and physics are important towards pursuing an engineering career [1], [2], [4]; the present study confirms that these identities are also important for the development of an engineering identity for first-generation college students. Specifically, a math identity had a direct effect onto students' development of a physics identity (β = .46, p < .001) and engineering identity (β = .32, p < .001). Shanahan and Nieswandt [42] found that high school students reported that science people were also those with mathematics ability and interest. Additional studies have documented that mathematics preparation was a strong predictor of physics success, albeit with a broad student sample [43], [44]. Warne and colleagues [45] found that students who had taken AP Calculus had a higher career interest in engineering; perhaps exposure to advance mathematics content supported students' mathematics identity and, in turn, interest in an engineering career or students with strong engineering career intentions took opportunities to prepare themselves for higher education. Studies overwhelmingly emphasize the importance of AP mathematics and science courses on students' pursuit of a STEM career [46]–[48]. However, Houston and Xu's [49] examination of post-secondary remedial mathematics course taking found that students who were low-income and whose parents only had a high school level of education were more likely to be in remedial mathematics courses in college. This reality emphasizes a need to better understand the unique experiences of first-generation college students.

Theokas and Saaris' [15] report, *Finding America's Missing AP and IB Students*, highlighted how low-income students are three times less likely to be enrolled in AP courses than their middle and high-income peers. Likewise, a study examining the math course taking sequence of high school students, using a nationally representative dataset, found that students whose parents' socioeconomic status was in the bottom quartile were less likely to have taken precalculus or calculus courses in high school [50]. In our sample of first-generation college students, when examining the high school mathematics courses taken, 52% indicated having taken an AP or International Baccalaureate (IB) mathematics course, 26% indicated taking a mathematics honors or another advanced mathematics course. These formal experiences in high school may help college students perform better in mathematics and, through this performance, be recognized by others and themselves as math people.

Our present study also found that a physics role identity supported an engineering role identity (β = .40, p < .001). When examining if the sample of students participated in physics courses before college, an overwhelming majority indicated having some exposure; 85% had either taken a regular physics course, honors, AP, IB, or another advanced physics course. Exposure to these courses for the students in this sample could have supported their claims of being both internally and externally recognized as a physics person. Additionally, we conjecture that first-generation college students could have been introduced to engineering in their physics course as this school subject lends itself towards bridging engineering content.

C. Engineering role identity supports first-generation college students' certainty of choosing an engineering major

We examined whether the three subject-related role identities supported first-generation college students' certainty of choosing an engineering major. Our final model demonstrates that first-generation college students' engineering role identity strongly supports their conviction towards choosing an engineering major (β = .72, p < .001). Cribbs et al. [1] found that mathematics interest and recognition supported students' choice to pursue engineering; however, we found that a mathematics role identity did not support first-generation college students' certainty to choose engineering. A physics role identity positively supported the development of an engineering role identity (β = .40, p < .001). Yet, a physics role identity had a negative effect on first-generation college students' certainty of choosing engineering (β = -.12, p < .01). Prior work found that a physics identity, using the indicator *"I see myself as a physics person"* supported students' choice to pursue engineering [2]. However, there are notable differences between prior work [2] and the present study. Prior work used a general college student sample (i.e., engineering interested students and non-engineering interested students). Thus, physics identity was a distinguishing factor between students (i.e., engineering interested students and non-engineering interested students) choice of majoring in engineering but not necessarily within engineering students' certainty of choosing engineering. Second, the factor structure representing physics role identity differs, i.e., mediation analysis versus second-order latent construct. Lastly, prior work [2] did not focus exclusively on first-generation college students. Our prior work, using a different sample of first-generation college students, found that a physics identity supported a career trajectory in health and medicine and the education sector over engineering [4]. While having developed an identity as a physics person supports developing an engineering identity, this identity may also lead students to choose different career paths.

D. Differences in the types of identities developed across gender and race/ethnicity

We examined first-generation college students' subject-related role identities through an intersectional approach (i.e., accounting for the intersection of race/ethnicity and gender). The gender variable was regressed onto each second-order latent construct. We found that female, first-generation college students were more likely to see themselves as a math person (β = .09, p < .05), while they were less likely to see themselves as a physics person (β = -.13, p < .01). An earlier study of first-generation college students found that women were less likely to be interested in physics and less likely to be externally recognized as a physics person [3]. As well, a significant difference was found between Latinx students, specifically, they were less likely to see themselves as physics people compared to all other students (β = -.16, p < .01). No other significant difference was found for the other racial/ethnic groups modeled in this analysis. Students develop subject-related identities through the backdrop of societal and institutional structures; in turn, they facilitate or constrain identity development [53]. Studies have reported a persistent gender gap in high school physics courses despite the increase in students taking physics in high school [10], [54].

Our findings are consistent with prior work focused on high school adolescents. Simpkins et al. [55] found that Latinas rated their perceptions of their abilities in physics lower than all other groups. High school students discussed anyone as being capable of assuming a mathematics identity if they worked hard or were interested enough [56]. However, these same students tended to limit who can be a physics person or an engineer. Specifically, they discussed who can be a physics person as an identity held by elite (i.e., saw the world "differently" than most people) or "super smart" people [56, p. 41]. These limitations of who could assume the identity of a physics person was also found in the work of Carlone [40]. In Carlone's study [40], the personified physics identity high school girls held were "someone who is "naturally" smart, has "raw talent," and is male" [p. 405]. Interestingly, Carlone's ethnography [40] was based on a reformed-based physics curriculum (i.e., Active Physics) that sought to emphasize the "inclusion of relevant, real-world themes and collaborative, inquiry-based problems" with the purpose of broadening the meaning of science and who gets to assume the role of a scientist [p. 395]. While the girls in the physics course performed at par or better than the boys in the class, the classroom environment, created by the male physics teacher, reproduced a particular way of being a physics person that constrained girls' identification with the subject.

A contributing factor towards female students authoring of a physics identity is their ability to perform well in their coursework, be interested in the subject, and receive recognition by influential others (i.e., teachers and peers). Often students' who are recognized as physics type of people are those that confirm the white masculine orientation of male dominated disciplines like physics and engineering. If female and minoritized students are to see themselves as a physics person it is important that educators in the secondary educational context critically examine the types of identities they are celebrating in their classroom. We contend that educators at the secondary and post-secondary level need to dismantle the notion that to be a physics person or engineer, requires raw talent or natural ability. Future work should explore how recognition opportunities vary and are differently internalized by particular groups in White-dominated spaces.

Lastly, no specific gender or racial/ethnic group was more or less likely to see themselves as engineers. However, female, first-generation college students were less likely to be certain about choosing an engineering major compared to males (β = -.11, p < .01). This finding echoes earlier work which also found female, first-generation college students to be less certain about their chosen career path [3]. While female students may be uncertain about their chosen path, our findings do confirm that developing an engineering identity strongly supports students' certainty of career choice. Thus, developing an identity as someone that can do engineering is a mechanism that can support female students' certainty of their career pathway. Put differently, if we wanted to understand how to support female students' persistence in engineering, supporting their engineering identity development would be one approach to take.

Overall, the findings from this study emphasize that first-generation college students' mathematics and physics identities similarly support the development of an engineering identity. But there are some key differences in how this group receives recognition (and its role in students' engineering major certainty). Additionally, physics may play less of an important role than mathematics in students' engineering career decisions and certainty. Finally, there were significant differences by ethnicity and gender, particularly for Latina first-generation college students that indicate a need to more deeply explore opportunities and support for minoritized students' identity development.

VII. Limitations

There is still much to be learned about how first-generation college students develop subject-related role identities, specifically by focusing on in-and-out-of-school experiences in high school. This study is limited in that we did not gather detailed data of the in-and-out-of-school activities students engaged in prior to college. However, ample research do exist that helps create an understanding of the experiences that lead to interest development, performance beliefs, and invite recognition. Future work will focus on understanding the in-and-out-of-school activities that supported first-generation college students' subject-related role identities.

VIII. Conclusion

First-generation college students' perceptions as competent, recognized, and interested mathematics learners supported their views of themselves as capable physics and engineering learners (i.e., role identity development). Students choosing to go into engineering, in some way, identify themselves as individuals that can do engineering and be engineers based on exposure to course material and experiences both in and out of the classroom setting. Identity development should be understood as a construction process within a larger social context. A process that requires an individual to situate themself in a given context by adopting meanings and expectations that accompany the role perform the expectations and be recognized both internally and externally as an occupant in the given context [9], [11], [57]. Within engineering, there is a need to more critically examine how students' STEM identities develop differently within a system the privileges dominant identities of Whiteness, masculinity, and continuing generation students. This work begins to unpack the various ways in which students experience engineering. The quantitative results indicate an opportunity to more deeply explore the lived experiences of students who are first in their families to attend college.

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