## Introduction

Studies have shown that a strong engineering identity in a student's early years increases motivation, persistence, and achievement [1-3]. As a result of this research, engineering programs have been working to create curricula and develop cultures that encourage students to see themselves as engineers. Additionally, building and maintaining a strong engineering professional identity has been shown to help recruit and retain individuals from historically excluded identities into engineering higher education and the engineering, science, and technology workforce [4-8]. The current analysis is situated in the final years of an NSF-funded study grounded in the frameworks of PCIR identity [9] and social capital [10]. The larger study focuses on the professional identity of upper-year engineering students as they enter the workforce, and the impacts of internship experiences on engineering professional identity particularly for first-generation, low-income students.

At this point in the grant, we have analyzed the dataset to critically examine the impact of using various definitions for "first generation" and "low income" labels as well as using an intersectional lens when considering "first-generation, low-income" students [11]. Secondly, we did a deep dive into the dataset to study the rates of internship participation amongst engineering students nationally, and the demographic, experiential, institutional, and field factors associated with the likelihood of having an internship [12]. We have also conducted ten semi-structured interviews with first-generation and/or low-income engineering students to probe their internship experiences, assets and barriers during the process of obtaining and completing their internships, and their perceptions of components of engineering identity in relation to their internships. The first qualitative analysis exploring internships' impact on recognition for first-generation and/or low-income students is currently under review for the 2022 ASEE annual conference.

In this particular paper, we hypothesize that by the time underrepresented students are in the later years of their undergraduate engineering experiences, those who remain in engineering programs will have learned to activate particular components of engineering identity to compensate for circumstances that may undermine other components (such as lower self-efficacy and less recognition of being an engineer, but higher interest), enabling them to persist. Thus, we seek to answer the following research questions:

**RQ1:** Do the components of engineering professional identity vary by students' gender and URM status in the later years of engineering higher education?

**RQ2:** For women and URM students that have been retained in engineering programs, if some components of identity are lower, are others higher?

## Theoretical Grounding

The PCIR framework focuses on three aspects of a students' disciplinary identity: belief in their **P**erformance/**C**ompetence in disciplinary tasks, **I**nterest in the discipline, and **R**ecognition that others see them as a student in that discipline [9]. This model has been used extensively in recent years in engineering education. However, few studies have focused on the components of identity as outcome variables in their analyses [9]. Further, much of the prior research using the PCIR identity framework has focused on engineering student identity and primarily examines early-year college students [1-3]. This work extends the PCIR identity framework to generate new knowledge pertaining to later-year undergraduate students and what factors are associated with various components of engineering identity as they prepare to enter the workforce.

## Methods

Data were drawn from an existing 2015 nationally representative, multi-institutional survey of engineering juniors and seniors (n = 6191 from 27 institutions). The survey was part of an NSF-funded longitudinal study designed to explore students' experiences in their engineering programs, their self-concepts and interests related to engineering and innovation, and their career goals. Details of the survey are presented elsewhere [12]. All procedures were approved by the IRB at the authors' institutions.

Three identity measures were operationalized from items on the survey and their reliability was assessed using Cronbach's Alpha: **Competence Beliefs** ($\alpha = 0.879$), **Engineering Career Interest** ($\alpha = 0.847$), and **Interpersonal Recognition**, ($\alpha = 0.736$). These variables are proxies for the constructs in the identity model based on measures available in an existing dataset. For the purpose of this study, we operationalized both gender and race/ethnicity as single binary variables: Female (0, 1) and URM Status (0, 1). These primary variables are presented in Table 1. Covariates were also considered in a linear regression analysis (Table 2).

A two-sample independent t-test was used to analyze differences in the three identity components by gender and then by URM status. A one-way ANOVA using a Bonferroni adjustment for multiple comparisons further examined differences between identities considering the intersection by gender and URM status together.

**Table 1.** Primary variables considered in the analysis *(modified from [10])*

| | |
|---|---|
| **Identity Measures** | |
| **Competence Beliefs** | Average of 5 items on a 5-point scale asking 'how confident are you in your abilities to do the following at this time?' (5 being the highest confidence). Sample items include "Design a new product or project to meet specified requirements" and "Conduct experiments, build prototypes, or construct mathematical models to develop or evaluate a design" |
| **Engineering Career Interest** | Average of 2 questions on a 5-point scale asking, how likely is it that your work will involve engineering in the next: 1) 5 years, and 2) 10 years? |
| **Interpersonal Recognition** | Average of 4 questions on a 5-point scale asking, how often do you talk to your 1) peers and 2) professors about 1) engineering topics and 2) engineering careers? |
| **Demographic Characteristics** | |
| **URM** | Underrepresented racial/ethnic minority status in response to 'racial or ethnic identification' including Latinx, African American, Native American or Pacific Islander* |
| **Female** | Question about sex |

* Respondents were asked to 'mark all that apply'; any respondent that indicated one or more items in a group considered to be an underrepresented ethnicity or race in engineering in the U.S. was coded as URM []

**Table 2.** Covariates considered in the analysis *(modified from [10])*

| | |
|---|---|
| **Academic Standing and Performance** | |
| **Academic Standing** | Self-reported current academic year, ranging from junior to senior to 5th year students |
| **GPA** | Self-reported overall institutional GPA |
| **College Experiences** *While an undergraduate, have you done (or are you currently doing) for at least one full academic or summer term: (binary measures where 1 = yes, 0 = no)* | |
| **Internship** | Worked in a professional engineering environment as an intern/co-op |
| **Research** | Conducted research with a faculty member |
| **Job** | Work-study or other type of job to help pay for college education |
| **Study Abroad** | Participate in study abroad |
| **Environmental Factors** | |
| **Field** | Field of engineering, includes 8 fields (Mechanical engineering used as baseline) |
| **Institution** | 4 classifications based on research/non-research and large/small engineering program (research/ large used as baseline) |

Finally, linear regression modeling examined the relationships between gender, URM status, and the three measures of identity when controlling for covariates such as GPA, class standing, college experiences, field of engineering, and institution type. Regression models were built sequentially with first a simple model using only gender and URM status as predictors, followed by a model including an interaction term. Next, a model was run controlling for all the covariates, followed by the same model including an interaction term on gender and URM status.

## Results

### *Differences in EPI components by gender and URM status*

Amongst the students in our dataset, the three components of engineering professional identity did not vary by URM status but did vary by gender. Female identities had statistically lower competence beliefs and engineering career interest but higher interpersonal recognition. Effect sizes were small to moderate, with the largest difference in the competence beliefs measure.

**Table 3.** Comparison of means. Cohen's d effect size measure shown below for significant effects.

| | Female | Male | URM Status | Non-URM Status |
|---|---|---|---|---|
| **Competence Beliefs** | 2.18*<br>n = 1603<br>(-0.433) | 2.53<br>n = 3714 | 2.36<br>n = 701 | 2.43<br>n =4516 |
| **Engineering Career Interests** | 3.13*<br>n = 1597<br>(-0.163) | 3.26<br>n = 3708 | 3.22<br>n =702 | 3.23<br>n = 4505 |
| **Interpersonal Recognition** | 2.60*<br>n= 1608<br>(0.158) | 2.47<br>n = 3720 | 2.56<br>n = 703 | 2.51<br>n =4524 |

*difference significant with p <0.001

*Differences in EPI components considering intersectional identities*

Considering both gender and URM status together, trends did not substantially change (Table 4). Using a Bonferroni multiple comparisons adjustment with a $p<0.05$ significance level, on every identity measure the female groups are not statistically different from one another, and male groups are not statistically different from one another. Engineering career interest and interpersonal recognition resulted in gender differences that are no longer significant for the URM students; female URM are not statistically different from male URM (nor from female non-URM). Examining the intersectional sample sizes, means, and standard deviations suggests this may be due to the small sample sizes and large standard deviations amongst the URM students. On every identity measure the male non-URM students are statistically different from the female URM and female non-URM students.

**Table 4.** One-way ANOVA considering intersectional identities.
F-test indicated significant differences between groups on all three identity measures at the $p<0.01$ level. Details in the narrative.

| | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| **Competence Beliefs** | FURM | 236 | 2.1475 | .91062 |
| | FnURM | 1259 | 2.1701 | .80952 |
| | MURM | 448 | 2.4728 | .89329 |
| | MnURM | 3004 | 2.5350 | .81152 |
| | *Total* | *4947* | *2.4180* | *.84010* |
| **Engineering Career Interest** | FURM | 235 | 3.1106 | .91550 |
| | FnURM | 1254 | 3.1292 | .81564 |
| | MURM | 450 | 3.2756 | .82261 |
| | MnURM | 2998 | 3.2607 | .80705 |
| | *Total* | *4937* | *3.2215* | *.81828* |
| **Interpersonal Recognition** | FURM | 236 | 2.6133 | .78356 |
| | FnURM | 1264 | 2.5930 | .72580 |
| | MURM | 450 | 2.5439 | .85171 |
| | MnURM | 3006 | 2.4667 | .77358 |
| | *Total* | *4956* | *2.5129* | *.77172* |

*Controlling for covariates*

Linear regression modeling allowed us to determine if the differences in the mean values of the three identity components hold when we control for other factors. In the final regression models, gender remains the only significant demographic factor for both competence beliefs and engineering career interest when controlling for covariates (Tables 5 and 6). However, URM status becomes the more significant demographic factor in explaining differences in interpersonal recognition when controlling for other covariates (Table 7). In all cases, the interaction terms remained nonsignificant and was not included in the final models.

Regarding other covariates, internships and research experiences are associated with higher competence beliefs and interpersonal recognition, while studying abroad is associated with lower engineering career interest. Being in civil engineering is associated with higher engineering career interest and interpersonal recognition but lower competence beliefs, while being in the industrial engineering field is associated with lower engineering career interest.

**Table 5.** Linear regression on **Competence Beliefs** controlling for all covariates. $R^2 = 0.110$.

| | B | Std. Error | Beta | t | sig |
|---|---|---|---|---|---|
| **(Constant)** | **2.008** | **.072** | | **27.955** | **<.0001** |
| **female** | **-.367** | **.025** | **-.202** | **-14.643** | **<.0001** |
| (URM) status | -.018 | .034 | -.007 | -.550 | .583 |
| **Current academic standing** | **.106** | **.017** | **.087** | **6.305** | **<.0001** |
| GPA | .005 | .009 | .008 | .570 | .569 |
| **Internship** | **.253** | **.024** | **.150** | **10.639** | **<.0001** |
| **Research** | **.192** | **.025** | **.107** | **7.538** | **<.0001** |
| **Job** | **.087** | **.023** | **.052** | **3.840** | **<.0001** |
| Study Abroad | -.076 | .032 | -.033 | -2.412 | .016 |
| Research U Small EGR | -.020 | .032 | -.009 | -.634 | .526 |
| Non-Research Large EGR | .069 | .046 | .022 | 1.486 | .137 |
| Non-Research Small EGR | .055 | .031 | .025 | 1.785 | .074 |
| Aerospace Engineering | .112 | .060 | .028 | 1.882 | .060 |
| Chemical Engineering | -.091 | .045 | -.030 | -2.017 | .044 |
| **Civil Engineering** | **-.297** | **.040** | **-.113** | **-7.490** | **<.0001** |
| Electrical Engineering | .027 | .034 | .013 | .804 | .422 |
| Industrial Engineering | -.061 | .055 | -.016 | -1.114 | .265 |
| Materials Engineering | -.048 | .070 | -.010 | -.680 | .497 |
| Other Engineering | .056 | .033 | .028 | 1.704 | .088 |

*Competence beliefs* (Table 5)*:* When holding constant other factors, individuals identifying as female have significantly lower competence beliefs (-0.37 on a 5-point scale) compared to individuals identifying as male while URM status is not a significant predictor of competence beliefs. Other significant factors are having an internship (0.25 higher), research experience (0.19 higher), or job to pay for college (0.09 higher), class standing (0.1 points higher for each year), and being in the civil engineering field (0.30 lower).

*Engineering Career Interest* (Table 6)*:* Holding constant other factors, individuals identifying as female have significantly lower engineering career interest (-0.092 on a 5-point scale) compared to individuals identifying as male while URM status is not a significant predictor of engineering career interest. Other significant factors are having studied abroad (0.20 points lower), being in the civil engineering field (0.13 higher), and being in the industrial engineering field (0.29 lower).

**Table 6.** Linear regression on **Engineering Career Interest** controlling for all covariates. $R^2 = 0.036$.

| | B | Std. Error | Beta | t | sig |
|---|---|---|---|---|---|
| **(Constant)** | **3.362** | **.073** | | **46.279** | **<.0001** |
| **female** | **-.092** | **.025** | **-.052** | **-3.627** | **<.0001** |
| (URM) status | -.017 | .034 | -.007 | -.499 | .617 |
| Current academic standing | -.038 | .017 | -.032 | -2.217 | .027 |
| GPA | -.007 | .009 | -.011 | -.725 | .469 |
| Internship | .060 | .024 | .036 | 2.488 | .013 |
| Research | -.021 | .026 | -.012 | -.834 | .404 |
| Job | .063 | .023 | .039 | 2.741 | .006 |
| **Study Abroad** | **-.195** | **.032** | **-.086** | **-6.069** | **<.0001** |
| Research U Small EGR | .054 | .032 | .025 | 1.699 | .089 |
| Non-Research Large EGR | .068 | .047 | .022 | 1.441 | .150 |
| Non-Research Small EGR | .033 | .031 | .016 | 1.075 | .283 |
| Aerospace Engineering | .077 | .061 | .019 | 1.271 | .204 |
| Chemical Engineering | -.118 | .046 | -.040 | -2.590 | .010 |
| **Civil Engineering** | **.132** | **.040** | **.052** | **3.303** | **.001** |
| Electrical Engineering | .070 | .034 | .034 | 2.059 | .040 |
| **Industrial Engineering** | **-.289** | **.055** | **-.077** | **-5.218** | **<.0001** |
| Materials Engineering | .006 | .071 | .001 | .091 | .928 |
| Other Engineering | -.101 | .033 | -.052 | -3.052 | .002 |

**Table 7.** Linear regression on **Interpersonal Recognition** controlling for all covariates. $R^2 = 0.084$.

| | B | Std. Error | Beta | t | sig |
|---|---|---|---|---|---|
| **(Constant)** | **2.003** | **.067** | | **29.694** | **<.0001** |
| female | .046 | .023 | .027 | 1.950 | .051 |
| **URM status** | **.102** | **.031** | **.045** | **3.253** | **.001** |
| Current academic standing | .007 | .016 | .007 | .469 | .639 |
| **GPA** | .024 | .009 | .041 | 2.867 | .004 |
| **Internship** | **.216** | **.022** | **.139** | **9.723** | **<.0001** |
| **Research** | **.270** | **.024** | **.163** | **11.336** | **<.0001** |
| **Job** | **.111** | **.021** | **.072** | **5.228** | **<.0001** |
| Study Abroad | .027 | .030 | .013 | .921 | .357 |
| Research U Small EGR | .084 | .030 | .040 | 2.835 | .005 |
| Non-Research Large EGR | .118 | .043 | .040 | 2.713 | .007 |
| **Non-Research Small EGR** | **.191** | **.029** | **.094** | **6.632** | **<.0001** |
| Aerospace Engineering | .092 | .056 | .024 | 1.636 | .102 |
| Chemical Engineering | .082 | .042 | .029 | 1.938 | .053 |
| **Civil Engineering** | **.122** | **.037** | **.050** | **3.277** | **.001** |
| Electrical Engineering | -.069 | .032 | -.035 | -2.191 | .029 |

| | | | | | |
|---|---|---|---|---|---|
| Industrial Engineering | .072 | .051 | .020 | 1.409 | .159 |
| Materials Engineering | .032 | .066 | .007 | .491 | .623 |
| Other Engineering | .000 | .031 | .000 | -.005 | .996 |

*Interpersonal Recognition* (Table 7)*:* Holding constant other factors, individuals identifying as URM have significantly higher interpersonal recognition (.102 on a 5-point scale) compared to individuals identifying as not URM while Gender is not a significant predictor of interpersonal recognition once other factors were controlled for. Other significant factors are GPA (0.024 higher with each third letter grade), having an internship (0.22 higher), research experience (0.27 higher), job to pay for college (0.11 higher), studying at a non-research small engineering program (0.19 higher), and being in the civil engineering field (0.12 higher).

## Discussion

In this study we sought to answer the research question **RQ1**: **do the components of engineering professional identity vary by students' gender and URM status in the later years of engineering higher education?** Our results indicate that competence beliefs and engineering career interests vary, on average, by students' gender but not URM status, with women reporting statistically lower measures of both even when considering covariates. This is consistent with other studies in the literature reporting that women have lower self-efficacy and pursue engineering careers at lower rates. However, the interpersonal recognition construct is more complex as it varies only with gender in a simple comparison of means, but with URM status becoming the significant predictor once covariates are considered. Results for all three identity components also show that URM women tend to be on one end of the spectrum with non-URM men on the other; non-URM men are statistically different than female URM and female non-URM on every identity measure.

We also hypothesized that by the time underrepresented students are in the later years of their undergraduate engineering experiences, those who remain in engineering programs will have learned to activate particular components of engineering identity to compensate for circumstances that may undermine other components, enabling them to persist. **RQ2: For women and URM students that have been retained in engineering programs, if some components of identity are lower, are others higher?** Here, the picture is more complex, but trends suggest that while women and URM students in the final years of their engineering programs report lower competence beliefs and engineering career interests, women and URM students also report *higher* interpersonal recognition compared to non-URM men. These results are somewhat counterintuitive as we expected to see lower interpersonal recognition for underrepresented students because they do not fit the stereotypical image most people have of a white male engineer. We anticipated that higher interest in the engineering field would compensate for well-documented lower self-efficacy (which we also found) and lower recognition. It may be that underrepresented students have no choice but to use their agency to seek out interactions that can compensate for the systemic racism and sexism they encounter in their educational pathways.

Analysis of the interpersonal recognition construct led to the most complex and interesting results. It is important to reiterate that these analyses were run on an existing dataset rather than an instrument designed to measure identity, so the variables are operationalized as proxies for these constructs. The operationalization for competence beliefs is a validated measure of engineering task self-efficacy and has been used extensively in prior work using this dataset. Secondly, the operationalization for engineering career interest is a reasonably close proxy to the interest construct, adapted to focus on students in later years, considering that the original survey was intended to probe students' interests related to engineering and their career goals. Both measures had high reliability with a Cronbach's Alpha above 0.84. The interpersonal recognition operationalization, however, is a less direct proxy based on students reporting the frequency of conversations with two groups (peers and faculty) related to two topics (course content and career options). The Cronbach's Alpha value is reasonable at 0.736 but not as strong.

Future work will take a deeper dive into the components of this interpersonal recognition operationalization. For example, we hypothesize that career conversations help students envision themselves as a professional engineer, while in contrast students perceive that needing to discuss course content undermines others viewing them as a successful engineer. It may be that students who frequently engage with faculty may see themselves as less of an engineer because they perceive that successful engineering students do not attend office hours. In contrast, students who have frequent discussions with peers may have a support group that bolsters their sense of being an engineer. The regression model suggests that studying in a small engineering program at a non-research institution is associated with higher interpersonal recognition and supports the idea that a smaller, tight-knit group of peers is a way to enhance interpersonal recognition. Our current qualitative work upholds that engagement with an affinity group enhances recognition for underrepresented students. The interpersonal nature of recognition, with whom, and how it intersects with the technical components of recognition (such as others seeing facility or struggle with course content) is an area rich for future exploration.

Some of the limitations of this work include that the analysis was done on an existing dataset rather than on an instrument designed to measure identity, so the variables were operationalized as proxies. This is likely part of why the $R^2$ values on the regression models are quite low. Despite a relatively low goodness-of-fit measure, the regression models help corroborate the trends consistently emerging from this analysis. In future work, it will be important to view statistical analyses on these proxy identity measures alongside additional data such as interviews. Also, despite the unusually large sample size in this dataset, when examining intersectional groups, the power to detect differences may be lacking considering the sample size and large standard deviations compared to small effects measured on a 5-point scale.

In addition to the above-mentioned deeper exploration of interpersonal recognition, future work for this research group will focus on a similar analysis examining first-generation and low-income status rather than gender and URM status. Furthermore, this analysis suggests that having an internship may enhance two components of engineering identity, competence beliefs and interpersonal recognition, while surprisingly not predicting engineering career interests. We are using our qualitative interview data to better-understand the role of internships in impacting these three components of engineering identity. Finally, civil engineering was the only field associated with all three elements of engineering identify, and one of only two that were significant in any regression model. While that is not our research group's focus, engineering identity of civil engineering students may be worthy of further study.

## Conclusions

This work adds to the body of literature exploring engineering professional identity by focusing on upper-year underrepresented students who have been retained beyond the first two years in engineering programs and are on the precipice of launching careers in the engineering workforce. Results indicate that competence beliefs and engineering career interests vary by students' gender but not URM status, while URM status becomes the more important predictor for interpersonal recognition when considering covariates. Furthermore, the data suggest that women and URM students have lower competence beliefs and engineering career interests but may compensate by seeking out interactions that result in higher interpersonal recognition.


## Acknowledgements
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