Understanding How Family Influences and Support Students' Certainty of Engineering Major

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***Abstract*— This research paper explores how students' motivation from family influences and family recognition may provide particular support for students' certainty of an engineering major. This outcome has been linked to higher retention rates in engineering and is a useful way to understand students' pathways early on in their undergraduate careers. Family has a significant role in shaping a student and developing their values, skills, and socialization. For example, a family of engineers may emphasize math and physics, while a family of authors may emphasize creative writing and reading. Furthermore, in the United States, socioeconomic status is a major determiner in students' opportunities to engage in STEM outside of formal education and the types of careers with which families may be familiar. Prior studies indicate that talking about science at home is a particularly important predictor of students' STEM interests. Additionally, first-generation college students and students from lower socioeconomic backgrounds may have higher family pressure to choose engineering as a track for upward mobility.**

However, much of the prior work examining familial influences on STEM or engineering students' career pathways has focused on K-12 or students' decisions about engineering as a major in college. In contrast, this study explores the role of family on students' career pathways during college through a variety of related constructs and answers the research question, "What family and background factors predict undergraduate engineering students' surety of major?" In this work, we draw on Yosso's framework of Community Cultural Wealth to understand how familial capital can support student pathways through engineering. Familial capital refers to those cultural knowledges nurtured among family or kin that support a sense of community history, memory, and cultural intuition.

The data for this study comes from a larger mixed-methods project focused on characterizing latent diversity in engineering. A national survey of 3,711 students from 32 ABET-accredited first-year engineering programs measured over a dozen underlying attitudes, beliefs, and mindsets including epistemic beliefs, motivation, innovation self-efficacy beliefs, personality, STEM role identity, and demographics. We used multiple linear regression to predict engineering students' surety of major as influenced by their motivation (i.e., controlled or autonomous), reported family recognition of them as engineers, and demographics characteristics. Additionally, we included whether students had family members, particularly parents with STEM degrees to understand how knowledge of STEM careers might support students' pathways. The results of this work provide insights into how a family may function as particular supports for students even from afar in a university setting.

Keywords—diversity, recruitment, persistence

I. Introduction

For the past decade there have been calls for the need to increase the number of students earning bachelor's degrees in STEM disciplines [1], and many or most of these graduates will need to come from four populations that are traditionally underrepresented in STEM [2]: racially and ethnically minoritized students (i.e., Black, Latinx, and Indigenous), women and non-binary students, low-income students, and first-generation college students (i.e., first-in-family with a four-year degree). These groups together form a large group of marginalized and minoritized students who, despite their disparate identities and backgrounds, share the experience of being underrepresented and subject to bigotry and oppression in academia and the wider world. Although the number of marginalized and minoritized students entering STEM has increased over time, and although they start their degree programs with similar interest in STEM, they drop out at much higher rates than their non-marginalized peers [3]. Some research indicates that there are performance disparities in

introductory STEM courses linked to the systematic underrepresentation of marginalized and minoritized students [4]. However, more research suggests that students transfer out of STEM because of chilly academic climates, perceptions future of success in engineering, or interests and career goals that are no longer aligned with their major; what's more, these factors can have a stronger effect in institutional contexts with predominantly majority populations (i.e., Predominately White Institutions with significant gender imbalance [5,6]).

These trends indicate significant structural issues in engineering education that must be addressed for equitable education. Specifically, we need to focus on challenging inequitable educational structures, value the knowledge skills and abilities diverse learners bring with them rather than focusing on deficits, and understand how to develop competencies that often function differently for diverse groups [7]. To this end, the National Academies (2017) outlined eight areas of potential deeper inquiry: sense of belonging, growth mindset, utility goals and values, behaviors related to conscientiousness, intrinsic goals and interest, academic self-efficacy, pro-social goals and values, and positive future self or identity. These interpersonal and intrapersonal competencies can be developed through classroom interactions [9,10], co-curricular support programs [11], mentoring [12], and extracurricular experiences [13]. These findings underscore the need for research to examine strategies that include both institutional and individual measures collectively for retention. One individual-level factor that may affect engineering student retention is the role of family, which may support students to continue in engineering or encourage them to consider other majors. In this study, we frame the role of family in terms of the social and cultural capital provided through families, as well as potential sources of recognition. Below, we expand upon the theoretical underpinnings of this framing, drawing on previous work on students from marginalized groups [14,15,16].

A. Community Cultural Wealth

This study draws from Yosso's theory of community cultural wealth (CCW) to frame our investigation and discussion of family influences on students' commitment to engineering. Traditional discussions of capital focused on economic (wealth and material possessions), social (networks and obligations), and cultural (qualifications and cultural knowledge) capital [16]. Yosso's framework expands upon this work by drawing from critical race theory (CRT) to acknowledge other sources of capital: aspirational, navigational, resistant, linguistic, and familial capital. Like CRT, CCW challenges deficit thinking and deficit based approaches that blame students of color and their families for poor academic performance instead of institutionalized racism and classism [16]. Creating a theory that acknowledges and codifies the capital that students of color and their communities possess provides a mechanism for resisting this type of thinking and a framework for utilizing these forms of capital to address inequality. It also provides a framework for discussing similar issues among other marginalized and minoritized groups of students, such as first-generation students. This study focuses on Yosso's conceptualization of familial capital and traditional discussions of social capital, but also draws from aspects of social and navigational capital (see Table 1 for more information about the different types of capital).

Social capital, i.e. "the goodwill that is engendered by the fabric of social relations and that can be mobilized to facilitate action" (p. 17) is frequently linked to success in a variety of fields [17], but is particularly pertinent for first-year engineering students as they navigate a new setting (higher education) and a new culture (engineering). Familial capital, which includes networks but also messages about coping, connection, and critical consciousness, also plays a key role in leading students to begin pursuit of engineering degrees and then persevere in the face of difficulty [18].

TABLE I. TYPES OF CAPITAL FROM YOSSO'S THEORY OF COMMUNITY CULTURAL WEALTH.

Capital	Definition
Familial Capital	"Cultural knowledges nurtured among familia (kin) that carry a sense of community history, memory and cultural intuition" (p. 79). Familial capital may be abstract (e.g. pedagogies of the home; cite) or more concrete—it includes connections to and resources, knowledge, and care from families, but also the cultural wealth embedded in extended communities and accessed through schools, sports, and other social groups.
Social Capital	Social capital can be described as the "networks of people and community resources" (p. 79) that individuals have access to. A commonly cited example of social capital is a friend or acquaintance who recommends someone they have worked with previously.
Navigational Capital	The "skills of maneuvering through social institutions" (p. 80), such as knowing how to persevere in a competitive or hostile environment, are referred to as navigational capital. This is often used to characterize the skills and knowledge that helps students of color succeed in predominantly white universities or other racist institutions.
Aspirational Capital	"The ability to maintain hopes and dreams for the future, even in the face of real and perceived barriers" (p. 77). This form of capital includes resilience (e.g., persevering despite difficulty) and the pursuit of upward mobility. An example of its manifestation is the parent who encourages their child to pursue an education and sacrifices and labors to support their success.
Resistant Capital	"Those knowledges and skills fostered through oppositional behavior that challenges inequality" (p. 80). Some examples of this form of capital include strategies for countering racist messages from the media, or information about the history of racism and how it has been successfully resisted in the past.
Linguistic Capital	"The intellectual and social skills attained through communication experiences in more than one language and/or style" (p. 78). Although research consistently shows the benefits of learning multiple languages and familiarity with multiple cultures, this strength is overlooked in immigrant and second-generation students of color in favor of negative assumptions about their skills and family lives.

B. Recognition and Familial Capital

Much of the previous work examining familial capital in engineering students focuses on knowledge and support obtained through kinship ties. For example, a qualitative study of engineering students of color and the community cultural wealth they relied on found that familial capital was discussed in terms of motivation and sense of community [19]. Some of the work in this area blurs the boundaries between familial and navigational capital, such as a study of Black men pursuing engineering graduate degrees, but the focus remains on familial capital as a source of emotional strength and support [20]. However, studies of low-socioeconomic-status (SES) and first-generation engineering students found that all had family or community members (aka 'fictive kin') who recognized them as engineers and supported their developing identities [21,22], bringing to light the potential link between familial capital and engineering identity through the path of family recognition.

Recognition by oneself and by important others is an important part of an engineering role identity development [23,24,25]. Engineering role identity has been linked to a number of important outcomes, including persistence in engineering [26,27]. Meaningful recognition is "when an individual perceives and internalizes this recognition" [28, p. 99]. A recent study described a two-step, sequential process of how recognition is both perceived and evaluated before it is integrated into a sense of self [29]. This work emphasizes that an evaluative step of both the person offering recognition and the quality of the recognition experienced by the student, in light of their beliefs about their own abilities to succeed in engineering, is essential to recognition being meaningful. In prior studies, recognition by family members has been an important component of meaningful recognition, particularly for early career undergraduate students in a development of an engineering identity [23]; however, studies of first-generation college students at a similar educational timepoint emphasize that recognition is not experienced equally, and that it may be less important for first-generation college students, in comparison to interest in the subject [30].

C. The Current Study

Given the need to improve retention and persistence of marginalized and minoritized students in engineering, a study of familial capital and surety of engineering major has much to offer. Familial capital has many aspects, but in this study we focus on connections to engineering (e.g., family background in engineering) and family involvement in students' pursuit of engineering degrees (e.g., family contributed to engineering choice). Additionally, studying family recognition as a source of familial capital has the potential to expand our understanding of engineering identity and familial capital, and to identify a potential resource to improve student outcomes. We approached this study through the lens of a central research question ("What family and background factors predict undergraduate engineering students' surety of major?") and with three hypotheses:

- H1: Familial capital (recognition, engineering background, and involvement in choice of major) will predict students' surety of major.
- H2: Surety of major will be significantly impacted by previous experiences of marginalization and minoritization, and students with underrepresented identities (e.g., racially and ethnically minoritized students (i.e., Black, Latinx, and Indigenous), marginalized gender identities, and first-generation status) will report lower engineering commitment than their peers.
- H3: The effect of familial capital on students' surety of major will be moderated by gender, first-generation status, and race, indicating that it is a source of support for marginalized and minoritized students.

II. Method

A. Participants

Data were collected from 32 U.S. ABET accredited institutions and 3711 undergraduate engineering students enrolled in their first engineering class. All participants who completed the survey items included in this analysis were included in this study (n = 2120). Participants self-reported their demographics using multi-select options (i.e., "choose all that apply") and were provided with the option to write-in a response. The resulting sample was made up mostly of White (51.47%), male (57.94%), continuing-generation students (53.2%), with Asian (8.06%) and Latino/a/x (6.52%) making up the next largest racial/ethnic groups (see Table 2 for more information). This sample is consistent with representation in the field overall, as approximately 80% of bachelor's engineering degrees are awarded to men and 60% are awarded to White students [31].

TABLE II. Demographic information from study sample.

Category	Frequency	
	Count	***Percentage***
Race/Ethnicity[a]		
Asian	299	8.06
Black/African American	156	4.20
Latino/Latina/Latinx	242	6.52
Middle Eastern	36	0.97
Multiracial	195	5.25
Native American/Alaska Native	0	0.00
Native Hawaiian/Pacific Islander	7	0.19
White	1910	51.47
Write-In	30	0.81
Not Answered	836	22.53
First-Generation Status		
Continuing-Generation	1976	53.25
First-Generation	897	24.17
Not Answered	838	22.58
Gender Identity[a]		

Identify applicable funding agency here. If none, delete this text box.

Category	Frequency	
	Count	*Percentage*
Agender	14	0.38
Female	219	5.90
Male	2150	57.94
Genderqueer	17	0.46
Transgender	18	0.49
Not Answered	799	21.53
Spurious Entries[b]	81	2.18

[a] Participants could select multiple responses, and so percentages may not total to 100%
[b] Students who used the write-in to provide frivolous or antagonistic comments (e.g., "I identify as an attack helicopter"; n = 77) or selected all available options without providing a write-in (n = 4)

B. Measures

The dependent variable, surety of major, was created using responses to two items ("I feel committed to engineering" and "I feel sure about my choice of engineering as a major"). Of the 6 predictors, 4 were demographic items (gender, first-generation status, race/ethnicity, and family background in engineering), some of which had groups too small for analyses, and so new categories were created for analysis. The process of aggregating demographic data for analysis brings significant limitations and challenges. We provide a transparent discussion of these decisions here but also acknowledge that this approach is limited. The experiences of all aggregated groups are not the same, but we also argue that there are some shared experiences within an engineering culture that has been historically constructed as white and male. For the gender analysis, students were placed into two categories (cismen, n = 1530; and marginalized genders, n = 590). This approach captures some of the reality of the impact of a masculine culture on students who do not identify as cismen. Similarly, students were placed into three categories for the race/ethnicity analysis (white, n = 1470; Asian, n = 215; and racially and ethnically minoritized students, n = 435). This approach groups Black/African American, Indigenous, and Latinx students together due to small sample sizes. The results of this approach to aggregation can provide some insight into the experiences of students who are well represented in a system, that privileges whiteness, (i.e., Asian students) and students who are underrepresented (i.e., Black/African American, Indigenous, and Latinx students). Students were asked to report the highest level of education for two parents/guardians and were coded into two groups (continuing-generation, n = 1484; first-generation, n = 636; if at least one parent was indicated to have completed some college or an associate/trade degree, the student was considered a continuing-generation student). Family background in engineering was a category created from participant responses to an item about their parents, siblings, or other relatives and their professions (non-engineering occupation, n = 1557; engineering occupation, n = 563).

The remaining two predictors were created from participant responses to 7-item Likert scales. Family recognition was measured using four items. Three were from iterations of the performance/competence, interest, and recognition (PCIR) scale and asked about recognition from parents ("My parents see me as a PHYSICS person/MATH person/ENGINEER") and one from a new set of items that asked about family recognition in general ("My family calls me an engineer"). Lastly, participant responses to an item about their choice of future career ("Which of the following people have contributed to your selection of a career path?") were used to create the family contribution variable (no family contribution, n = 1350; family contribution, n = 2361) if participants indicated their parents, siblings, or relatives contributed to their decision to pursue engineering.

C. Analyses

A moderated hierarchical regression was used to test the relationship between the predictors (motivation, family recognition, family background, family contributions, gender, race, and first-generation status) and surety of major. The first model examined all of the predictors individually (thus testing H1 and H2), while the second tested family recognition as a moderator (H3). An ANOVA was used to compare the model fits and determine whether the second model fit the data significantly better than the first.

III. Results

For full results of the regression analysis, see Table 3. The first regression model tested H1 and H2 and had mixed results. Family recognition, gender, and first-generation status (FGS) predicted surety of major, with increased recognition (H1) and cismen reporting higher commitment to engineering as predicted (H2). Family background, contributions to engineering choice, and race did not predict surety of major, and the relationship between FGS and surety of major was in the opposite direction (it was hypothesized that marginalized students would report lower surety of major, while these results indicate that first-generation students reported significantly higher commitment to engineering than their peers; b = .19, p = .003). The second model tested for interactions between students' identities and familial capital. Since only family recognition was significant in the first model, it was the only variable tested as moderator in the second model, also to mixed effect. Family background and contributions to engineering choice remained non-significant, and first-generation status was not a significant moderator. Gender moderated the relationship between family recognition and surety of major, with increased recognition closing the gap between cis men and students with marginalized gender (Figure 1). Race also moderated the recognition/surety relationship, with Asian students benefiting less from increased family recognition than white, Black/ African American, Latinx, and Indigenous students (Figure 2). (Figure 2).

IV. Discussion

Our first hypothesis—that familial capital (recognition, engineering background, and involvement in choice of major) would predict students' surety of major—was partially supported by our results. Family recognition predicted surety of major, as expected. However, and in contrast to previous work [32], family occupation and contribution to choice of career did predict students' surety of major. This finding suggests that active recognition from family is more important than

TABLE III. RESULTS OF MODERATED HIERARCHICAL REGRESSIONS.

	Model 1: No Interactions			Model 2: Family Recognition (Unmoderated Slopes)			Model 2: Family Recognition (Moderated Slopes)		
	b	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**
(Intercept)	2.11	0.14	**<0.001**	2.09	0.31	**<0.001**			
Family Recognition	0.59	0.03	**<0.001**	0.59	0.07	**<0.001**			
Family Background in Engineering	0.07	0.07	0.322	0.09	0.28	0.755	-0.01	0.06	0.931
Family Contributed to Engineering Choice	-0.15	0.08	0.065	-0.22	0.29	0.445	0.02	0.07	0.794
Gender (Cismen/Marginalized Gender)	-0.16	0.07	**0.015**	-0.70	0.25	**0.006**	0.13	0.06	**0.030**
First-Generation Status	0.19	0.07	**0.003**	0.67	0.26	**0.011**	-0.12	0.06	0.054
Race (Asian)	0.19	0.1	0.063	1.03	0.36	**0.004**	-0.22	0.09	**0.013**
Race (Black/ African American, Latinx, and Indigenous)	0.10	0.08	0.169	0.04	0.29	0.893	0.02	0.07	0.804

occupation or family contributions to an engineering choice of major. This result is encouraging for those searching for opportunities to support students' commitment to engineering, as it provides the opportunity for non-engineering families to positively influence students as much as engineering ones, opening new pathways and discourses about who can be an engineer. These results also emphasize a need to provide ways in which students can relate the engineering work they are doing in their educational experiences with concepts and scenarios that are relevant to their family lives or experiences [33]. Not only can this contextualization support students' interest and motivation in engineering but it can also support ongoing family recognition. These results also emphasize the need for future work to understand how different types of familial capital may have different effects for students from different groups.

We also found mixed support for our second hypothesis: that surety of major will be impacted by students' identities, and students from groups that have often struggled to persist in

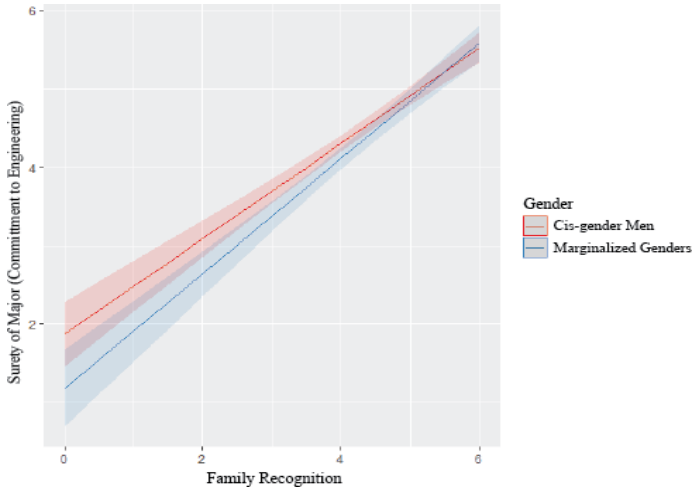
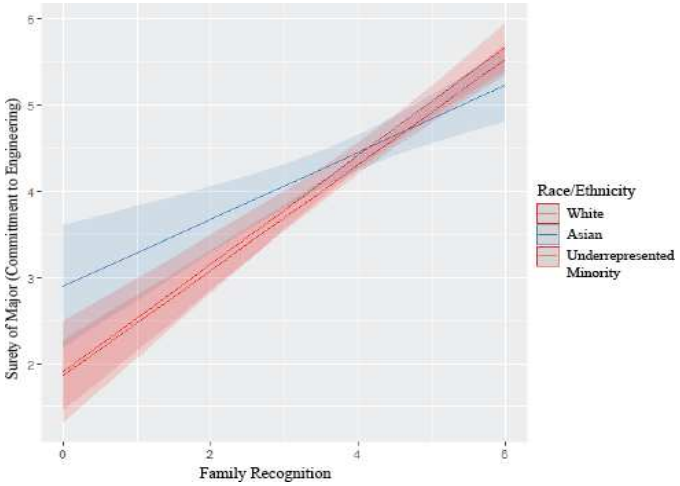


Fig. 1. Relationship between family recognition and surety of major, moderated by gender (cismen/marginalized gender).

engineering will report lower engineering commitment than their peers. Surety of major was lower for students with marginalized genders (with a small effect size) and higher for first-generation students (small effect size). We found no differences by race/ethnicity. The findings for first-generation college students is consistent with the literature [34], further corroborating that first-generation college students' commitment to engineering is a source of capital and a strength that they bring to engineering. The results for the gender comparison emphasize the need for more work to address the masculine and exclusionary climate for women, non-binary, and trans students [35,36]. These students may receive implicit and explicit messages about belonging [37,38], stereotypes that allege lower STEM abilities [39,40,41,42,43] and cismen in STEM settings who perpetuate misogyny and sexism [44,45]. These results provide avenues for new questions about how institutions and instructors can begin to address structural inequities that disparately impact particular groups.

Finally, our third hypothesis—that the effect of familial capital will be moderated by gender, first-generation status, and race, decreasing surety gaps between marginalized and majority groups—was partially supported. Family recognition decreased gaps in surety for students with marginalized genders. However, we also found that family recognition functioned differently for Asian students than for white or Black, Indigenous, and Latinx students, with Asian students benefiting less from increased family recognition. A study of familial influence on Asian-American students' career choice goals, self-efficacy, and interest found that family support was linked to these outcomes; however, this support may be more influential when Asian American students consider less traditional careers, which have the potential to conflict with family expectations or cultural group norms [46]. A qualitative study of Asian women's engineering narratives also found an interplay between family support and cultural norms, which warrants further investigation [47]. Our results indicate that familial capital can be an important resource in increasing persistence for students with marginalized genders but may be a less important factor for Asian students and continuing-generation students. Future work

Fig. 2. Relationship between family recognition and surety of major, moderated by race (white/Asian/URM).



can explore why family recognition is less predictive of surety of major for some groups as well as the types of recognition experiences that benefit students with marginalized genders and how to foster them.

A. Limitations

Although our findings are intriguing, there are important limitations to keep in mind. The first is in regards to our creation of groups in our race and gender analyses. A necessary compromise to maintain statistical power, the creation of such groups can produce over-generalizations and so our findings should be interpreted with care. For instance, one finding is in regards to Asian students and the effect of family recognition on surety of major; although the Asian diaspora has some shared experiences, there is nonetheless a great deal of heterogeneity in the population, not to mention variability in how students lay claim to the label 'Asian' [48]. As a result, our findings in regards to race and gender should be considered tentative and in need of further validation and refinement in more targeted studies. Second, our analyses focused on familial capital broadly, and did not differentiate between the different familial relationships and how they affect familial capital (e.g., having a parent as an engineer versus a sibling or other relative may affect surety of major differently). Thus the effects of family background and contributions to the career pathway can't be ruled out entirely. Third, family recognition was assessed in this study using individual items that were not developed or tested for that purpose, as part of a much larger survey (150+ items) of latent diversity in engineering [49]. Given the results produced here, there is promise regarding the study of family recognition as a source of familial capital, but future work should expand upon and refine the measure used to produce better-validated results. Lastly, we acknowledge that the survey used in this analysis was not designed to measure community cultural wealth (CCW). This limitation is often noted as a drawback to studies in science, engineering, and mathematics education studies that examine CCW quantitatively, and stands in contrast to qualitative studies that frame CCW with intentionality and alignment in the research design. Designing and testing quantitative measures of CCW thus may be an important step in replicating and validating these findings in future work.

B. Conclusions

This work contributes to the growing body of research on familial capital, recruitment, and persistence in engineering. Our findings indicate how familial capital can be a resource for students' surety of major. Still, they are not a 'one size fits all' solution for recruiting or retaining students in engineering. Instead, these findings support the role of active recognition in early college choices rather than background or involvement, highlighting the critical importance of investigating how students perceive and internalize recognition from faculty, peers, and professionals.

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