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First in the Family: A Comparison of First-Generation and Non-First-Generation Engineering College Students

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First in the Family:

A Comparison of First-Generation and Non-First-Generation Engineering College Students

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Abstract—This study investigates first-generation and non-first-generation engineering undergraduates' math/science identities, subject-related interests, and career plans. First-generation students are an understudied, but growing population. Understanding how these self-beliefs and background factors affect students' engineering choice can help widen pathways into engineering which continues to be defined as "pale and male." Additionally, identity has predictive value for practical outcomes like engineering choice in college. The data for this study comes from the nationally representative Sustainability and Gender in Engineering (SaGE) survey completed by 6,772 college students who enrolled in first-year English courses at 2- and 4-year colleges across the U.S. Data were analyzed using t-test and chi-square tests for linear and dichotomous outcomes respectively. Our results show differences in first-generation students' identities, interests, performance/ competence beliefs, and family support for science. These differences can serve as a stepping stone towards understanding the trajectories of first-generation college students in engineering. By understanding underrepresented students' identities, performance, and backgrounds, specific strategies can be developed to support these students in our engineering programs.

Keywords—first-generation college student; identity; career plans; family support

I. INTRODUCTION

The President's Council of Advisors on Science and Technology have stated that there is a significant need for recruiting and retaining more engineering students [1]. However, a longitudinal study of students' academic records at several large engineering institutions showed that students who matriculate into engineering have higher persistent rates than those in other areas of study, highlighting that the deficiency of engineers is not due to retention but recruitment. In large part, first-generation students attend 2-year institutions and transfer into 4-year engineering programs at higher rates than non-first-generation students [2], [3]. Engineering has lower migration rates into the discipline after the first year than other fields; students who do not matriculate into engineering in their first semester have a lower chance of going into the field later on in their academic careers [4]. Combined, these trends differentially impact first-generation students than their peers who are not first-generation.

The changing demographics of the United States, in terms of college enrollment, demonstrate an upward trend in the enrollment of first-generation college students in higher education. Although there are few recruitment or outreach efforts directly targeting this growing population of first-generation college students interested in engineering, this demographic offers a significant contribution to the nation's engineering workforce [5]. Additionally, students from diverse backgrounds can improve the quality of solutions for engineering problems through alternative perspectives [6]. This argument for increased diversity in engineering appeals to the improvement of engineering outcomes. An additional need for diversity in engineering takes a social justice perspective, that access to engineering and the social and economic capital that an engineering career offers, as well as the solutions generated, should be representative of the U.S. population [7]. With an increasing number of first-generation college students entering universities, and the need for more engineers [8], this population has the potential to improve the variety of who is represented in engineering and offer unique perspectives to help solve important engineering challenges.

While first-generation students have potential to increase the size of the engineering workforce, they face many educational obstacles. The experiences and challenges that first-generation students face in the higher education system demands further research attention. The U.S. Department of Education classifies first-generation college students as those who came from families where neither parent obtained a four-year college degree [9]. These students are disproportionately Latinos and African-American students and have greater missed opportunities in the quality of their mathematics education [10], [11]. In the 2007-2008 academic year, the National Center for Education Statistics reported the following percentages of college students whose parents had a high school diploma or less: 25 percent of White parents, 32.2 percent of Asian parents, 35.6 percent of Native American parents, 45 percent of African-American parents, and 48.5 percent Latin American parents [12]. Previous studies found that poor classroom and academic climate, low academic achievement, difficulty with conceptual understanding, low self-efficacy, inadequate high school preparation, lack of interest, alternative career goals, and minority status increased students' chances of leaving engineering [13]. These trends make first-generation students a high risk population for attrition in engineering.

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The educational system in America has been regarded as an "engine of social mobility that provides equal opportunities to all deserving students, irrespective of their previous background, upbringing, or life circumstances" [14, p. 1178]. However, sociologists have argued against this belief of upward social mobility through open opportunities for education [14]. In fact, the higher education culture in America creates "social reproduction," which constructs, retains, and recreates inequalities amongst groups based on access and equity patterns that limit participation of minority groups. Social class inequalities are created by institutions of higher education through their middle– and upper–class cultural norms of independence, which do not take into consideration students who come from working-class backgrounds, typically possessing norms of cultural interdependence [14]. First-generation students are likely to face this cultural disconnect in higher education due to their lack of social capital. Social capital as defined by Bourdieu is "the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" [15, p. 2]. In large, social capital not only encompasses income and socioeconomic status, but also inequalities of resources in the public education system [16]. These factors differentially affect first-generation students based on family structure. Students from first-generation families have lower parental education level than their peers that often defines their own socioeconomic status. Lower socioeconomic status families typically have less access to quality schools and teachers based on the locations in which they live. Additionally, the community values of first-generation students are not always directed towards the pursuit of a higher education. All of these factors, as well as community values, have an influence on students' academic achievement [16].

National studies have reported academic under preparation for first-generation college students who are typically falling behind their non-first-generation peers [14], [17], [18]. Certain privileges accessible to non-first-generation college students, such as parents with first-hand knowledge of the college process and procedures, study skills, and mentors in the college system are not present for first-generation college students [17], [19]. Previous research studies have reported that first-generation college students typically come from lower socioeconomic status household, are less prepared academically, have lower high school and college GPAs and lower SAT scores, have not participated in honor programs, have a part-time student enrollment status, have dependents, have geographical constrains with regards to college choice, and have greater drop-out rates when compared to non-first-generation students [7], [9], [11], [13], [15]. Additionally, first-generation college students often come from high schools with low college enrollment rates, have peers who are not college-bound, and have a lower understanding of what college is about, and possess less knowledge about the expectations of students in college and how to prepare for their first term compared to their peers [22]. The cultural mismatch first-generation students face in the higher education system is an unseen disadvantage that can hinder their performance, thus systemically reproducing differences in academic achievement and maintaining existing social hierarchy [14]. All of these factors naturally disadvantage this group's ability to see engineering as a possible career in college.

Family encouragement and interest have proven to foster academic achievement for students, even after controlling for socioeconomic status. Parents can enhance their student's interest in mathematics and science by helping their student see the importance of these courses, as well as emphasizing their importance in future careers [23]. Interest in mathematics and science as possible careers declines for many students at an early age. However, a recent study found that parental encouragement was more affective in increasing test scores than having parents who attending parent/teacher conferences or having at home resources (i.e. books, magazines, video games) [23]. These findings illustrate the importance of having family members that support students' STEM interests.

While there is significant research highlighting average differences between first-generation students and their peers on background factors, there has been a dearth of research on how first-generation students' attitudes and self-beliefs impact choice of major. The aim of this study is to examine differences between mathematics identity, self-perceptions of mathematics performance, and STEM-related interest for first-generation and non-first-generation college students in engineering and how this may influence career plans. Math was chosen as an area of interest because connections between math and choice of engineering have been found for STEM students [24], [25]. Math and science academic ability were also found to be significant predictors of admission and retention in engineering, while college student's self-confidence in math and science has been found to be a strong predictor of short-term and long-term persistence in engineering. However, a significant percentage of first year students are entering engineering with weak mathematics preparation [26]. For these reasons, understanding first-generation students' attitudes and self-beliefs can be an important part in understanding how to recruit and retain this population in engineering.

II. THEORETICAL FRAMEWORK

Identity has been researched in a wide range of theoretical perspectives and contexts including psychology, sociology, anthropology [27]. In recent years, identity has been used as an analytical tool for studying issues around theory and practice in education [28]. People have multiple identities that are connected to their performances in society. Role identity is an authoring of one's self in a particular context (e.g. in an engineering discipline) and how this concept remains changes over time [29]. As a student's identification with a particular field or subject grows, a student can begin to develop agency to make positive changes in their world based on who they see themselves to be. An individual's agency along with societal structures, which may also constrain an individual's possibilities [30], interact to develop students' authoring of themselves and the impacts they can make in their world.

This research is focused on students' role identities as a "math person" or a "science person." The theoretical framework, used in this work, is constructed of three dimensions of students' self-beliefs that are central to their development: students' perceptions of their own performance/competence, beliefs that they are recognized by others, and their perceived interest in math or science. The performance and competence dimensions are not independent of each other [31]; students who believe that the can do well on course assessments (i.e. performance) respond similarly to items measuring their beliefs about being able to learn content knowledge (i.e. competence) as measured by confirmatory factor analysis [25]. A longitudinal study conducted by Cass et al. [32] found these dimensions of mathematics interest, performance/competence and recognition significantly predict choice of engineering career, irrespective of SAT/ACT math scores and background factors (i.e. parental education as a proxy for socioeconomic status). Students with a high level of self-perceived academic competence tend to persist at higher rates, have a greater chance of adopting mastery and/or performance approach goals, understand the material at a deeper level, and have better study skills [33]. Interest in the subject matter plays a key role in choosing engineering; students should have an understanding of the field of engineering in order to be attracted to it and have opportunities to develop their identity around engineering. The recognition factor of identity is related to the individual's beliefs that are recognized externally by professors, other students, and parents as an engineering student. This conceptual framework has been previously researched to identify students' physics and mathematics identity [25], [29], [31], [32], [34].

In addition to a role identity framework, students' career outcome expectations from Social Cognitive Career Theory (SCCT) were examined. SCCT has been widely used to investigate choice of engineering as a career. This theory is based on a social cognitive approach originally introduced by Bandura [35]. SCCT is founded on the triadic reciprocal relationship between personal and physical attributes, external environmental factors, and over behavior included in social cognitive theory. This model, first proposed by Lent, Brown, and Hackett [36], features three interlocking models including interest development, choice of career, and performance (described by self-efficacy) developed from previous work by the authors as well as a meta-analysis of current vocational career models and research. Outcome expectations, job aspects students' want in their future careers (e.g. making money, supervising others, etc.), are impacted by students learning experiences and self-efficacy and have an effect on interests, career goals, and choice actions related to students' career decisions. These aspects can tie identity theory via interests and performance/competence beliefs with career choice by understanding how first-generation student differ in what they hope to gain in their future careers.

III. Research Question

Utilizing these frameworks, we worked to address the following research questions:

How are first-generation college students different when compared to non-first-generation college students on: 1) family support and background factors; 2) math and science identity; and 3) career intentions?

IV. Methods

The data analyzed in this study comes from the nationally representative Sustainability and Gender in Engineering or SaGE (engineering.purdue.edu/ENE/Research/SaGE_survey_Godwin_2014) survey completed by 6,772 college students (55% female) who were enrolled in first-year English courses at 50 different 2 and 4-year colleges across the U.S during the fall semester of 2011. The colleges and universities were drawn from a stratified random sample taken from the National Center for Education Statistics (NCES). The development of this survey has been extensively addressed in previous studies [25], [29], [37] and thus will be briefly explained in this paper. The development of the SaGE survey was organized into three main sections: 1) a literature review to identify factors that may influence increased enrollment in engineering, 2) an extraction of items from previous national studies (FICSS, PRiSE, and FICS-Math) and, 3) open-ended responses from 83 high school science teachers across the nation via a survey administered on-line. The final survey consisted of 47 questions (i.e. anchored scale, multiple choice, and categorical responses) regarding students' career goals, high school science and math experiences, science enrollment and achievement as well as demographic information. This survey has been used in other studies to identify factors that influence students' attitudes towards engineering careers using the construct of mathematics and physics identity [25], [37], [38], as well as to investigate the association between engineering and sustainability-related topics in students' experiences [39]. To compare differences between first-generation students and their peers, pairwise comparisons were conducted for each of the research question topics. The data were analyzed using t-test and chi-square tests for anchored and dichotomous outcomes, respectively. Effect sizes were calculated by Cohen's d and Cramer's v for t-test and chi-square comparisons, respectively. All statistical analyses were conducted using the R programming language statistical software system [40].

V. Results and Discussion

Students who reported their male and female guardian or parent had completed a "bachelor's degree" or "master's degree or higher" were coded as non-first-generation students (4,206), and students who reported both male and female guardian or parent with "less than a high school diploma," "high school diploma/GED," or "some college or associate/trade degree" were coded as first-generation students (1,057) as consistent with the U.S. Department of Education's classification. Students who indicated "don't know" for both parents were eliminated from the study (1,509). First, the student demographics for first-generation and non-first-generation students were examined via descriptive statistics to understand the students encompassed in the groups. Latino/a students comprised a significantly larger portion of the first-generation students (30% versus 12%, v = 2.68) and Caucasian students comprised a significantly larger percentage of the non-first-generation students (84% versus 53%, v = 1.43) when compared using chi-square contingency table tests. This finding confirms the same trends as national reports that the first-generation population is a majority of students from Latino origins [41], [42].

A group comparison, using Welch's t-test, was conducted to find differences in academic performance of first-generation and non-first-generation students prior to college using an academic performance index, which is a scaled measure from 0 to 1 of students' prior high school course taking, level of course, and standardized tests scores [39], [43]. Non-first-generation students had a significantly higher academic performance average (55%) than first-generation students with an effect size of $d = 1.87$ ($p < 0.001$). This data set demonstrates the lack of academic preparation first-generation college students have received, which is consistent with previous research findings reporting lower academic achievement when compared to non-first-generation students [14], [17], [18]. This difference in students' academic performance begs the question of whether instructors and administrators need to focus more on supporting this population before the transition from high school to college. As well, research indicates students come from low socioeconomic status and are more likely to be from underrepresented groups. When asked if English was the primary language spoken at home, the data also revealed first-generation students were less likely to solely speak English at home ($p < 0.001$) with an effect size of $v = 2.07$.

Students were asked to rate the importance of the following outcome expectations for their future career satisfaction anchored from 0 ("not at all important") to 4 ("very important" – see Table II). First-generation students demonstrated significantly higher interest than their peers in "applying math and science" in their future career, as well as interest of "developing new knowledge and skills." First-generation students also reported, on average, higher interest in careers related to mathematics and engineering compared

TABLE I. FUTURE CAREER INTERESTS AND EXPECTATIONS

Statement	**Average for First-Generation**	**Average for Non-first-generation**	**Significance§**	**Effect Size (*d*)**
Outcome Expectations for Future Career **(0-"Not all important"; 4-"Very important")**				
Q1a: making money	**3.42**	3.28	***	0.68
Q1d: supervising others	**2.24**	2.13	**	0.17
Q1e: having job security and opportunity	**3.58**	3.53	*	0.10
Q1g: inventing/designing things	**1.88**	1.79	*	0.10
Q1h: developing new knowledge and skills	**3.17**	3.02	***	0.46
Q1j: having an easy job	**1.98**	1.76	***	0.74
Q1n: doing hands-on work	**3.07**	2.95	**	0.31
Q1o: applying math and science	**2.10**	1.96	***	0.25
Career Interest **(0-"Not at all likely"; 4-"Extremely likely")**				
Q26: Science Interest	2.01	**2.14**	**	0.30
Q27: Math Interest	**1.99**	1.88	*	0.14
Q3g-n: Engineering career interest	**1.30**	1.18	*	0.14
Q3a: Choosing a career in mathematics	**1.09**	0.97	*	0.17
Q3b: Choosing a career as math/science teacher	**0.82**	0.69	***	0.25
Q3e: Choosing a career in physics	**0.74**	0.64	**	0.17

§The level of statistical significance is coded in this column: * represents a statistical significance less than 0.05 but greater than or equal to 0.01, ** represents a statistical significance less than 0.01 but greater than or equal to 0.001, and *** represents a statistical significance less than 0.001

TABLE II. FAMILY SUPPORT OF MATH AND SCIENCE

Statement	**% of First-Generation**	**% of Non-first-generation**	**Significance§**	**Effect Size (*v*)**
Family Interest & Support **(0-Not marked; 1-Marked)**				
Q35Math_c: my family helped me with my schoolwork in this topic (math)	36%	**49%**	***	0.78
Q35Math_d: my family arranged for tutoring in this topic (math)	20%	**26%**	***	0.18
Q35Math_e: this topic (math) was a series of courses that I had to pass	50%	**55%**	**	0.12
Q35Math_f: this topic (math) was not a family interest	**38%**	33%	***	0.16
Q35Sci_c: my family helped me with my schoolwork in this topic (science)	20%	**32%**	***	0.90
Q35Sci_d: my family arranged for tutoring in this topic (science)	10%	**12%**	*	0.06
Q35Sci_e: this topic (science) was a series of courses that I had to pass	46%	**50%**	*	0.07
Q35Sci_f: this topic (science) was not a family interest	**43%**	34%	***	0.38

§The level of statistical significance is coded in this column: * represents a statistical significance less than 0.05 but greater than or equal to 0.01, ** represents a statistical significance less than 0.01 but greater than or equal to 0.001, and *** represents a statistical significance less than 0.001

to a higher science interest for non-first-generation college students.

Contrary to some previous literature indicating that fewer Latino and African American students were interested in mathematics careers [23], these results offer encouragement for finding ways to recruit more and diverse students in engineering. But, they also highlight potential challenges for first-generation students, their instructors, and administration in supporting these students academically in engineering programs. While recruitment strategies based on these attitudes and interests offer opportunities to persuade first-generation students to choose engineering in college, specific strategies to help these students navigate their engineering education and be successful in their programs are needed. We must not only recruit talented students with diverse backgrounds into engineering, but also promote their success and retain them in engineering careers. To maintain America's global competitiveness, we need innovative engineers capable of solving large, complex, global problems [44], [45]. These much needed future engineers will have to come from new sources of talent, including the growing population of first-generation students in higher education. There is a significant need for not just more engineers [46], [47], but a more diverse workforce of engineers which can lead to greater innovation [6].

Research studies have also suggested that STEM-interested students with low socioeconomic status choose engineering more often than science [29], [48]. In one study, students with lower socioeconomic status were also more likely to have taken Calculus in high school and had, on average, higher SAT math scores [48]. These students may focus on mathematics because they were encouraged by their school's guidance counselors who recommend a solid career in engineering for students talented in STEM [48]. This option may be more often prescribed because students with a degree in engineering can regularly earn more than their peers in entry-level positions with only a bachelor's degree. Often, careers in science or mathematics require additional education for graduates to be successful.

First-generation students reported a higher interest in "having an easy job," than non-first-generation students. Since first-generation students in this study reported demonstrating a significantly higher interest in applying math and science to their future career, we initially questioned first-generation students' understanding of the mathematics and engineering fields. While this may be one reason for both the desire to apply math and science and have an easy job were reported by these students, other explanations exist. These students may have a different perception about the concept of "having an easy job" as being less physically labor intensive. For many first-generation students, their parents are manual labors or agricultural workers. Having "an easy job" may equate to working in an air-conditioned building, making higher amounts of money, and using their intellect and education as the basis for their employment. Future qualitative work can explore these student perceptions about career expectations. . While studies suggest that students with at least one engineering parent, have greater chances of choosing an engineering major [26], [49]–[51], first-generation students who do not have parents that are in the engineering field, may be persuaded to pursue careers that offer significant economic capital and require higher academic training than the ones their parents possess. First-generation students may find a connection between engineering and a manual job their parent may hold. For example, in some of our previous work, one first-generation student spoke about his parent's job as the reason he wanted to enter the military and major in electrical engineering. This students' father was a veteran, but worked in appliance repairs. The student made the connection between his father's job and an engineering discipline so that he could "following in his father's footsteps" while pursuing an advanced degree [49].

Additionally, engineering students with lower socioeconomic status are less likely to be encouraged by their science teachers than their peers [48]. On average, non-first-generation students reported having a greater interest in science with an effect size of $d = 0.30$ ($p < 0.01$) than first-generation students. A study claims that "well-rounded" students, those who typically have a higher socioeconomic status, tend to have greater family encouragement towards science [48], our findings also validate this claim.

Our analysis suggests that first-generation students show a slightly greater interest in "having job security and opportunity" ($p < 0.05$). This finding may be consistent with their higher interest in careers in engineering and math. One study reported that students may be more likely to persist towards earning an engineering degree, regardless of any "negative views about certain aspects of engineering education," if they strongly believe an engineering degree will improve career security [26, p. 366].

Chi-square tests were conducted to analyze group differences in family interest in and support of science and mathematics (see Table II). Although first-generation students had high levels of interest in mathematics and mathematics related fields, these students reported lower levels of family support in mathematics. The lack of support in math and science, for first-generation students, may also account for the highly significant difference in reporting that these topics were "not a family interest." Having non-college educated parents equates to lacking social and/or cultural capital, which can undermined access to resources (i.e. math/science tutors) given to first-generation students. At the same time, this lack can lead to less informed decisions about the need to excel in the mathematics and science fields [52]. Research has demonstrated that parental beliefs and expectations can promote academic achievement in mathematics for students [23], [53]. A prior study reported that students whose parents met with mathematics teachers, counselors or attended training workshops on how to support student's mathematics skills made greater gains in mathematics than those who did not [53]. This kind of parental involvement in students' academics may be a challenge for first-generation students with parents that primarily speak a language other than English in the home. Students may be experiencing a difficult time translating mathematics terminologies to their parents, thus making it more challenging for the parents to provide support. Layered on top of the complexity of non-English speaking families are different cultural understandings the role of school in students' lives and how parents interact with this institution [54]. For some immigrant families, parents may not expect to have a lot of interaction with the teacher because that is not a common practice in their home country. The difficulty is often not only linguistic (schools regularly employ translators) but can also include working conditions (e.g.

multiple jobs) which do not allow parents to participate as readily in school activities. As well, some parents also have little schooling themselves, which creates a disconnect in understanding the role teachers in the American school system play in their children's lives. Some parents were even said to be “sensitive about the issue and aware of their own limitations in the eyes of their children” [54, p. 151]. However, this ethnographic study points out that life circumstances had prohibited these immigrant parents from receiving a formal education rather than explicit decisions not to pursue additional education opportunities [54]. Additionally, parents might not be aware of alternative ways of helping their student, such as tutoring services or online resources, to name a few. Parents may also be working long hours or have work schedules that conflict with their students' homework time. So, there are complex dynamics at play that can vary significantly and require different types of interventions. Efforts to support this population will require educators to actively engage with these students, as well as provide resources for parents to become involved in their student's academics.

The reported lack of family support towards math and science may hinder first-generation students' perceptions of themselves as math and science people. One of the most important subconstructs of identity theory is feeling recognized by others as the type of person who can fulfill a particular role (e.g. science person, math person, engineer, etc.). We found no significant differences in students' self-beliefs of performance/competence in math and science or feeling recognized by others in those areas. While differences in interest were found, with higher interest in math for first-generation students and higher interest in science for non-first-generation students, interest is only one subconstruct of identity. Other work has shown that believing that other see them as a “math person” or “science person” (e.g. recognition) is the most important factor for identity development [24], [25]. In order to begin to understand first-generation student's math identity, further research is required to uncover how this math interest is developed and who, if anyone, recognizes students.

These results are, overall, consistent with findings from several previous qualitative studies on first-generation students. However, these results offer insight into how students see themselves as math and science people (identity) and how they differed in expectations for career from their peers. First-generation students are similar in many ways to their peers. While non-significant results were not reported in this study, other identity subconstructs in math and science recognition and performance/competence beliefs were not any different between the two groups compared.

In utilizing a cross-sectional study design, the data gathered have some strengths: large statistical power, national representativeness in the sample, and the ability to test hypotheses surrounding events that were introduced to students naturally rather than through an intervention. This study design also has certain weaknesses, notably including the inability to draw causal conclusions. Rather, results are correlational in nature. The results do indicate substantial correlations between student responses and students' choice of major, but further work is necessary to indicate a causal direction to these relationships. For example, first-generation students may be interested in STEM-related careers because they see it as a way to “apply math and science” as an outcome expectation, or they may want to “apply math and science” because they have chosen a STEM-related career that does so. The direction of the effect cannot be determined from the data collected in this study.

VI. Conclusion

These results show significant differences in first-generation students' career outcome expectations, interest in math and science, career interests, and family backgrounds as compared to their peers. These differences have some implications for high school guidance counselors, college instructors, and engineering education researchers. When advising students for entry into college, ensuring that first-generation students have an understanding of the expectations and types of careers that they could possibly pursue in engineering could improve the match between students' interests and career outcome expectations. This approach could also improve retention of these talented and diverse students within engineering programs. In designing curricula or pedagogy, mapping how engineering meets desired outcome expectations (inventing/designing things through the engineering design process, developing new knowledge and skills, and doing hands on work in classroom environments through CAD drawing, prototyping, gathering data, etc.) could improve students' desires to continue in engineering. This work also highlights the needs for educators and schools to partner with first-generation students' parents to provide the support and resources that these families need. Finally, this research highlights areas of research in how first-generation students are prepared to enter college, how they choose engineering, and what factors can help support identity development in this group of students. Our future work will begin to explore these areas through mixed methods research.

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