Defining first-generation and low-income students in engineering: An exploration

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Abstract

First-generation (FG) and/or low-income (LI) engineering student populations are of particular interest in engineering education. However, these populations are not defined in a consistent manner across the literature or amongst stakeholders. The intersectional identities of these groups have also not been fully explored in most quantitative-based engineering education research. This research paper aims to answer the following three research questions: (RQ1) How do students' demographic characteristics and college experiences differ depending on levels of parent educational attainment (which forms the basis of first-generation definitions) and family income? (RQ2) How do 'first-generation' and 'low-income' definitions impact results comparing to their continuing-generation and higher-income peers? (RQ3) How does considering first-generation and low-income identities through an intersectional lens deepen insight into the experiences of first-generation and low-income groups?

Data were drawn from a nationally representative survey of engineering juniors and seniors (n = 6197 from 27 U.S. institutions). Statistical analyses were conducted to evaluate respondent differences in demographics (underrepresented racial/ethnic minority (URM), women, URM women), college experiences (internships/co-ops, having a job, conducting research, and study abroad), and engineering task self-efficacy (ETSE), based on various definitions of 'first generation' and 'low income' depending on levels of parental educational attainment and self-reported family income.

Our results indicate that categorizing a first-generation student as someone whose parents have less than an associate's degree versus less than a bachelor's degree may lead to different understandings of their experiences (RQ1). For example, the proportion of URM students is higher among those whose parents have less than an associate's degree than among their "associate's degree or more" peers (26% vs 11.9%). However, differences in college experiences are most pronounced among students whose parents have less than a bachelor's degree compared with their "bachelor's degree or more" peers: having a job to help pay for college (55.4% vs 47.3%), research with faculty (22.7% vs 35.0%), and study abroad (9.0% vs 17.3%). With respect to differences by income levels, respondents are statistically different across income groups, with fewer URM students as family income level increases. As family income level increases, there are more women in aggregate, but fewer URM women. College experiences are different for the middle income or higher group (internship 48.4% low and lower-middle income vs 59.0% middle income or higher; study abroad 11.2% vs 16.4%; job 58.6% vs 46.8%).

Despite these differences in demographic characteristics and college experiences depending on parental educational attainment and family income, our dataset indicates that the definition does not change the statistical significance when comparing between first-generation students and students who were continuing-generation by any definition (RQ2).

First-generation and low-income statuses are often used as proxies for one another, and in this dataset, are highly correlated. However, there are unique patterns at the intersection of these two identities. For the purpose of our RQ3 analysis, we define 'first-generation' as students whose parents earned less than a bachelor's degree and 'low-income' as low or lower-middle income. In this sample, 68 percent of students were neither FG nor LI while 11 percent were both (FG&LI). On no measure of demographics or college experience is the FG&LI group statistically similar to the advantaged group. Low-income students had the highest participation in working to pay for college, regardless of parental

education, while first-generation students had the lower internship participation than low-income students. Furthermore, being FG&LI is associated with lower ETSE compared with all other groups.

These results suggest that care is required when applying the labels "first-generation" and/or "low-income" when considering these groups in developing institutional support programs, in engineering education research, and in educational policy. Moreover, by considering first-generation and low-income students with an intersectional lens, we gain deeper insight into engineering student populations that may reveal potential opportunities and barriers to educational resources and experiences that are an important part of preparation for an engineering career.

Background and Motivation

Promoting social mobility is an emerging outcome of interest for higher education – both in the popular media and from ranking such as U.S. News, which in 2018 added social mobility measures to its Best Colleges and Universities methodology (https://www.usnews.com/best-colleges/rankings/national-universities/social-mobility). CollegeNET also introduced a Social Mobility Index for colleges in 2019 (https://www.socialmobilityindex.org/). In order to promote social mobility, stakeholders in higher education including faculty instructors and researchers, academic advisors, deans and staff charged with creating and implementing support services, and administrators considering an institution's mission, strategic direction, and student outcomes, must understand the demographic characteristics and college experiences of so-called 'first-generation, low-income' students.

First-generation (FG) and/or low-income (LI) student populations are of particular interest in engineering education as our societal challenges require a growing engineering workforce while at the same time, engineering careers afford pathways for social mobility. According to a report by the U.S. Department of Education in September 2017 [1] approximately 60 percent of high school students who enroll in post-secondary education are first-generation college students in that neither parent/guardian has a baccalaureate degree. These students may be underrepresented in engineering programs. A 2016 estimate of self-reported first-generation college students found that first-generation students were about half as likely to be enrolled in an engineering major as their continuing generation counterparts [2]. Another 2012 study examining two public research-granting universities in the Midwest found that only 15 percent of students with an initial major of engineering were low-income Pell grant recipients [3].

The population of first-generation college students often overlaps with that of low-income students, as first-generation students are far more likely to come from a household with an annual income less than $50,000 (64% vs. 30% continuing generation students). First generation students are also more likely to identify with an underrepresented race/ethnicity (44% vs. 30%). Educational outcomes for FGLI students also fall behind those of their higher socioeconomic counterparts: first generation students are less likely to obtain a bachelor's degree or higher within ten years of post-secondary enrollment (27% vs. 55%), have higher drop-out rates, and have fewer opportunities in high school for advanced math preparation [1, 4-6].

The experiences of FGLI students have been thoughtfully examined in recent literature, particularly with respect to how these students select and persist in an engineering major through the

lens of social capital [7-14] and more recently considering FGLI students through the lens of engineering identity [15-17]. Social capital deficits have been identified including a lack of family knowledge about higher education and the field of engineering, fewer high school peers and role models who are college bound, lower access to high quality schools and teachers, and lower access to summer STEM camps and extracurricular activities such as robotics clubs [11, 16]. Recent work that challenges the predominant deficit model has found that FGLI students access a wider range of support resources once at college and possess an equally strong engineering identity that includes similar motivation towards engineering and belief in their competency as engineers, and more sense of belonging in the engineering major [11, 14-15].

However, this and the wider body of literature focusing on first-generation and low-income students suffers from inconsistent definitions of 'first-generation' and 'low-income' that belies a lack of recognition of how students' demographic characteristics and college experiences differ depending on levels of parent educational attainment and family income, and the intersection of the two. For example, the legislative definition according to the U.S. Department of Education is that neither parent has obtained a bachelor's degree. However, the National Center for Educational Statistics (NCES) has defined first-generation as students whose parents have not attended college [4] and in other reports as students whose parents have obtained no more than a high school degree [18]. Low-income is defined in various settings as either qualifying for federal Pell loans (a family income of less than $50,000), by self-reports of family income as low or lower-middle income, or by self-reports using quantitative income ranges which themselves are relative to the cost of living in a geographic region. Often these terms are used interchangeably, as proxies for one another, or as an indicator for another factor such as underrepresented minority status.

Varying definitions have a potentially large impact on results of research studies in terms of both the number of students included in the FG/LI category and in terms of the conclusions reached by comparing FG/LI students to non-FG/LI groups. A recent paper analyzing data from the Educational Longitudinal Study of 2002, a nationally representative longitudinal sample of roughly 7,000 10th grade students followed over a period of 10 years, found that depending on the level of educational attainment and how many parents were considered, the number of students considered first-generation ranged from 22% to 77% [19]. Furthermore, the definition of first-generation impacted the size of differences in outcomes measured in their statistical analysis.

In order for engineering education researchers to continue to illuminate the experiences, challenges, and opportunities for FG/LI students engaged in engineering higher education, and design programming to better support these students, how the populations are defined and how they are related must be better-understood in the literature and amongst stakeholders. Moreover, the engineering education community must start to explore how the intersection of these identities impacts their research conclusions.

Research Questions

This research paper aims to answer the following three research questions:

> **RQ1:** How do students' demographic characteristics and college experiences differ depending on levels of parent educational attainment (which forms the basis of FG definitions) and family income?
>
> **RQ2:** How do FG and LI definitions impact results comparing FG/LI students to their continuing-generation and higher-income peers?
>
> **RQ3:** How does considering first-generation and low-income identities through an intersectional lens deepen insight into the experiences of FG and LI groups?

Methods

Survey Instrument

Data were drawn from a national survey of engineering juniors and seniors. 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. The survey was administered in Winter/Spring 2015 to over 35,000 engineering undergraduates at a stratified, quasi-random sample of 27 U.S. engineering schools. These 27 institutions represented the landscape of ~350 engineering schools in 2014 in terms of size and other institutional characteristics related to the intent of the study. A total of 7,179 students responded to the survey; of these respondents, 6,187 students were classified as "juniors", "seniors", or "5th-year seniors", in keeping with the study's sampling plan. See Gilmartin, et al. for a detailed technical report that provides extensive information about the study objectives and research questions, sampling framework, response rates and nonresponse bias, and respondent characteristics [20]. All procedures were approved by the Institutional Review Boards at Stanford University and Elizabethtown College.

Variables considered in the analysis

Students were classified into groups for comparison based on their response to questions about parental educational attainment and family income growing up. The questions about parental education attainment first asked respondents "Whom do you refer to as Parent 1?" with exclusive choices of: mother, father, stepmother, stepfather, grandmother, grandfather, legal guardian, and other with a fill-in-the-blank response. Respondents were then asked "How much education did your Parent 1 complete" with choices of: did not finish high school, graduated from high school, attended college but did not complete degree, completed an Associate degree (AA, AS, etc.), completed a Bachelor degree (BA, BS, etc.), completed a Master degree (MA, MS, MBA, etc.), completed a Doctoral or Professional degree (JD, MD, PhD, etc.), don't know or not applicable, or I prefer not to answer. The same two questions were then asked for Parent 2. With respect to family income, respondents were asked "When you were growing up, would you describe your family as:" with exclusive choices of low income, lower-middle income, middle-income, upper-middle income, high income, or I prefer not to answer. For parental attainment level, the groups were defined by the highest level of attainment of either parent, or of only

Parent 1 if respondents only indicated one parent. In all cases, the data is coded as missing if the response is 'I don't know.'

Statistical analyses were conducted to evaluate differences amongst these groups with respect to demographic characteristics (underrepresented racial/ethnic minority (URM), women, URM women), college experiences (internships/co-ops, having a job, conducting research, and study abroad), and engineering task self-efficacy (ETSE) which is a respondent characteristic that may be targeted in educational interventions (i.e., outcome indicator for evaluation of impact of an intervention). All of these measures were collected on the survey instrument via self-report by student respondents to fixed-choice survey questions.

Table 1. Variables compared between students classified as first-generation/low-income based on definitions

Demographic Characteristics	
URM	Underrepresented racial/ethnic minority status in response to 'racial or ethnic identification' including Latinx, African American, Native American or Pacific Islander* (reference group: non URM responses including white and Asian American)
Female	Question about sex (reference group: male)
Female URM	Both URM and female (reference group: all others)
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
Engineering self-efficacy	
ETSE	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"

***** 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 **[21]**

Statistical Analyses

1. Comparisons of demographic characteristics and college experiences across varying levels of parental educational attainment and family income level.

A set of mutually exclusive groups was created based on respondents' answers to questions about parental educational attainment.

- **No College** – students for whom parent(s) did not finish high school or graduated high school, but did not attend college or complete any degrees.
- **Less than Associate's Degree** – students for whom at least one parent attended college, but did not complete a degree.
- **Less than Bachelor's Degree** – students for whom at least one parent completed an Associate's degree, but did not complete a Bachelor's degree.
- **Bachelor's or Higher** – students for whom at least one parent completed a Bachelor's or graduate degree.

A second set of mutually exclusive groups was created based on respondents' answers to the question about self-reported family income growing up.

- **Low income** – students who reported growing up low-income.
- **Lower-middle income** – students who reported growing up lower-middle income.
- **Middle or higher income** – students who reported growing up middle-income, upper-middle income, or high income.

On measures of demographic characteristics and college experiences, statistical comparisons between the proportions of samples in each mutually exclusive group were conducted using the chi-squared test with Bonferroni adjustment for multiple comparisons. Statistical comparisons between the mean value of ETSE in each mutually exclusive group were conducted using one-way Anova. Post-hoc comparisons amongst groups were performed using Tukey HSD. For all comparisons, statistical significance is determined at the 0.05 level.

2. Comparisons of demographic characteristics and college experiences between a first-generation group and a continuing-generation group, employing different definitions of who is considered to be first-generation.

To assess the impact of selecting one particular definition for 'first-generation', three different sets of comparison groups were developed to compare a 'first-generation' group to a 'continuing-generation' group on measures of demographic characteristics and college experiences. Similar analyses for two different sets of 'low-income' versus 'high-income' comparisons are underway at the time of this writing. Statistical comparisons were done using the chi-squared test with a significance level of 0.05. The three sets of comparison groups were:

- **FG-No College** – 'First-generation' is defined as students whose parent(s) highest level of educational attainment was high school or below; continuing-generation is defined as students whose parent(s) had any college experience.
- **FG-LessAssociates** – 'First-generation' is defined as students for whom no parent has an Associate's degree or higher; 'continuing-generation' is defined as students whose parent(s) have any college degree (including Associate's).
- **FG-LessBachelors** – 'First-generation' is defined as students for whom no parent has a Bachelor's degree; 'continuing-generation' is defined as students whose parent(s) have a Bachelor's or graduate degree.

3. Comparison of students' demographic characteristics and college experiences using an intersectional lens (i.e., the intersection of parents' education and family income)

Four groups were created using the following definitions: first-generation students are those whose parental educational attainment level is less than a Bachelor's degree; low-income students are those who self-reported growing up as low or lower-middle income. These definitions were chosen based on the results of the earlier analysis and to increase sample size and statistical power.

- **Both** first-generation **and** low-income
- First-generation **not** low-income
- Low-income **not** first-generation
- **Neither** first-generation **nor** low-income ('advantaged')

In our analysis, we use the term 'advantaged' for the students who are neither first-generation nor low-income. We consider these students to be potentially benefitting from *structural and educational advantage afforded to members of high income and continuing generation groups*. When we compare 'advantaged' students to those who are first-generation and/or low-income, we are making the assumption that FG/LI students *do not have the same structural and educational advantages,* but we recognize they may have other funds of knowledge they bring to their educational experiences.

On measures of demographic characteristics and college experiences, statistical comparisons between the proportions of samples in each mutually exclusive group were conducted using the chi-squared test with Bonferroni adjustment for multiple comparisons with significance at the 0.05 level.

For the purpose of these analyses, missing data (up to 15.7% on any given measure) were not imputed.

Results

In our dataset, 62.9% of the students had at least one parent with a bachelor's degree or higher (Fig. 1) while 21.4% reported growing up as low or lower-middle income (Fig. 2).

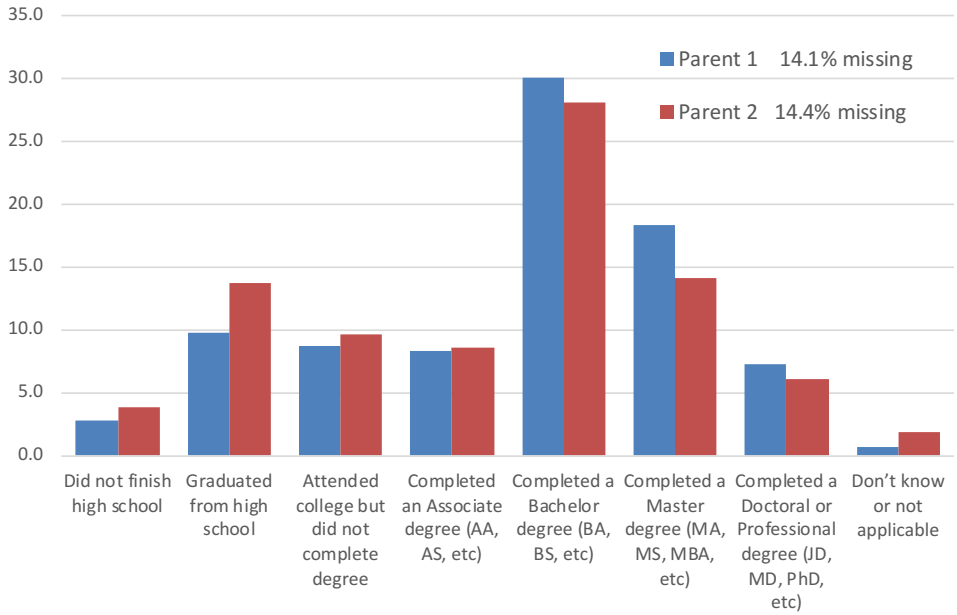

Figure 1. Percentage distribution of responses to two questions about parent 1 and parent 2 education levels.

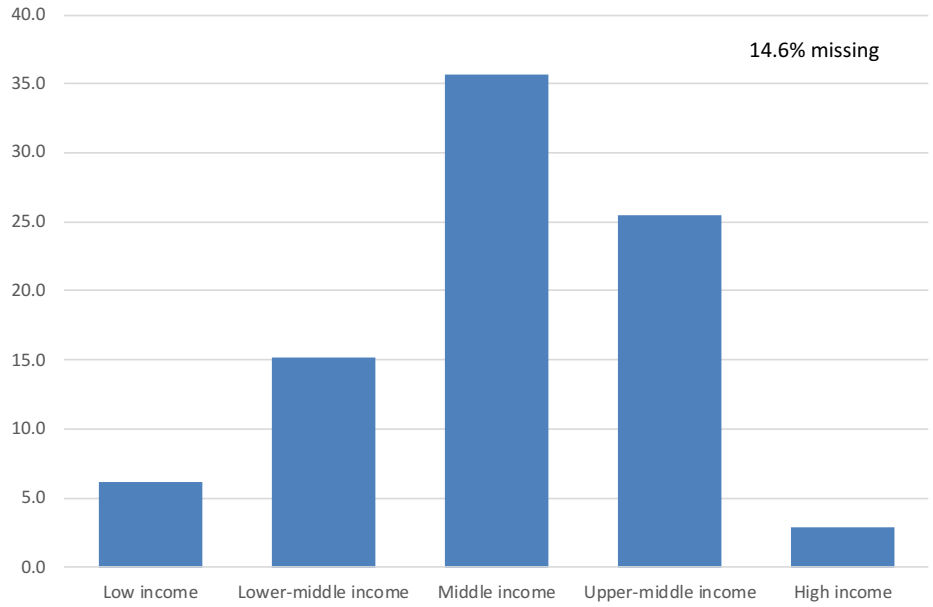

Figure 2. Percentage distribution of responses to the question "When you were growing up, would you describe your family as…"

FG/LI student characteristics depending on parental educational attainment and family income

(RQ1) How do students' demographic characteristics and college experiences differ depending on levels of parent educational attainment (which forms the basis of FG definitions) and family income?

Analysis comparing mutually exclusive groups of students based on parental educational attainment show that for every demographic characteristic analyzed, the proportion of students whose parents had no college experience is statistically different (at the 0.05 level) from the proportion of students who had at least one parent with a bachelor's degree or higher (Table 2):

- The proportion of URM students is the same for students whose parents had no college and less than an associate's degree, and is statistically higher compared to students whose parents had an associate's degree or higher.
- Similarly, URM women are represented at higher proportions in groups with parental educational attainment less than an associate's degree. The proportion of women in aggregate shows small statistical differences but no trend.
- Respondents are statistically different across income groups with higher family incomes at higher parental educational attainment levels.

Table 2. The demographic characteristics of each group at varying level of parental educational attainment. Groups with the same color band are statistically similar.

			FGExclusive				
			No College	**Less than Assoc**	**Less than Bach**	**Bach or Higher**	Total
Underrepresented Racial/Ethnic Minority (URM) status	not URM	Count	351_a	308_a	406_b	3401_b	4466
		% within FGExclusive	70.2%	77.4%	87.3%	89.6%	86.6%
	URM	**Count**	**149_a**	**90_a**	**59_b**	**394_b**	**692**
		% within FGExclusive	**29.8%**	**22.6%**	**12.7%**	**10.4%**	**13.4%**
female	male	Count	388_a	$298_{a,\ b}$	360_a	2621_b	3667
		% within FGExclusive	76.1%	72.7%	75.9%	67.7%	69.7%
	female	**Count**	**122_a**	**$112_{a,\ b}$**	**114_a**	**1248_b**	**1596**
		% within FGExclusive	**23.9%**	**27.3%**	**24.1%**	**32.3%**	**30.3%**
FURM	not female URM	Count	474_a	377_a	$455_{a,\ b}$	3698_b	5004
		% within FGExclusive	93.1%	92.9%	96.0%	95.9%	95.4%
	female URM	**Count**	**35_a**	**29_a**	**$19_{a,\ b}$**	**160_b**	**243**
		% within FGExclusive	**6.9%**	**7.1%**	**4.0%**	**4.1%**	**4.6%**
LI	Not low-income	Count	169_a	202_b	289_c	3262_d	3922
		% within FGExclusive	33.1%	49.0%	61.2%	85.2%	75.1%
	low-income	**Count**	**341_a**	**210_b**	**183_c**	**565_d**	**1299**
		% within FGExclusive	**66.9%**	**51.0%**	**38.8%**	**14.8%**	**24.9%**

Each subscript letter denotes a subset of FGExclusive categories whose column proportions do not differ significantly from each other at the .05 level.

For every college experience analyzed, the proportion of students whose parents had no college experience is statistically different than the proportion of students who had at least one parent with a bachelor's degree (Table 3):

- Higher rates of participation in internship, research, and study abroad, and lower rates of working to help pay for college, are seen with higher parental educational attainment.
- The students having parents with no college, less than an associate's degree, and less than a bachelor's degree are all statistically similar with respect to rates of participation in work-study/job to pay for college, research with faculty, and study abroad.
- The proportion of students with an internship is statistically different for various groups with a trend for more internships at higher parental education levels.

Table 3. There are higher rates of participation in internship, research, and study abroad for parental education at a bachelor's and above, and lower rates of work-study/job to pay for college. The populations of students having parents with no college, less than an associate's degree, and less than a bachelor's degree are all statistically similar in terms of college experiences with the exception of internships. Groups with the same color band are statistically similar.

			FGExclusive				
			No College	**Less than Assoc**	**Less than Bach**	**Bach or Higher**	Total
Internship	no internship	Count	276_{a}	$219_{a, b}$	$212_{b, c}$	1597_{c}	2304
		% within FGExclusive	53.7%	53.3%	45.1%	41.1%	43.7%
	internship	**Count**	**238_{a}**	**$192_{a, b}$**	**$258_{b, c}$**	**2285_{c}**	**2973**
		% within FGExclusive	**46.3%**	**46.7%**	**54.9%**	**58.9%**	**56.3%**
job	no work	Count	239_{a}	176_{a}	199_{a}	2044_{b}	2658
		% within FGExclusive	46.4%	42.8%	42.2%	52.7%	50.4%
	work-study or job for college	**Count**	**276_{a}**	**235_{a}**	**273_{a}**	**1837_{b}**	**2621**
		% within FGExclusive	**53.6%**	**57.2%**	**57.8%**	**47.3%**	**49.6%**
research	no research	Count	401_{a}	308_{a}	372_{a}	2524_{b}	3605
		% within FGExclusive	78.0%	74.6%	79.0%	65.0%	68.3%
	research	**Count**	**113_{a}**	**105_{a}**	**99_{a}**	**1359_{b}**	**1676**
		% within FGExclusive	**22.0%**	**25.4%**	**21.0%**	**35.0%**	**31.7%**
studyabroad	no study abroad	Count	467_{a}	380_{a}	426_{a}	3210_{b}	4483
		% within FGExclusive	90.7%	92.0%	90.4%	82.7%	84.9%
	study abroad	**Count**	**48_{a}**	**33_{a}**	**45_{a}**	**673_{b}**	**799**
		% within FGExclusive	**9.3%**	**8.0%**	**9.6%**	**17.3%**	**15.1%**

Each subscript letter denotes a subset of FGExclusive categories whose column proportions do not differ significantly from each other at the .05 level.

Analysis looking at mutually exclusive grouping of income levels shows that for every demographic characteristic analyzed, the proportion of students who self-reported growing up low-income is statistically different than the proportion of students who self-reported growing up middle-income or higher (Table 4):

- Significantly higher proportions of URM students and URM women students report low-income backgrounds compared to middle-income or higher backgrounds. The proportion of women in aggregate, however, appears to increase with each income bracket, suggesting that among engineering students, non-URM women are more likely to come from higher-income backgrounds, not URM women.
- With respect to URM students and URM women, self-reported lower-middle income is a statistically distinct group in the middle.

Table 4. For every demographic characteristic analyzed, the students are statistically different across the range of self-reported income groups. Groups with the same color band are statistically similar.

			LIExclusive			
			low-income	lower-middle	middle or higher	Total
Underrepresented Racial/Ethnic Minority (URM) status	Not URM	Count	225_a	743_b	3489_c	4457
		% within LIExclusive	60.8%	81.8%	90.0%	86.5%
	URM	**Count**	**145_a**	**165_b**	**388_c**	**698**
		% within LIExclusive	**39.2%**	**18.2%**	**10.0%**	**13.5%**
female	male	Count	289_a	$675_{a, b}$	2703_b	3667
		% within LIExclusive	76.3%	72.3%	68.6%	69.8%
	female	**Count**	**90_a**	**$259_{a, b}$**	**1240_b**	**1589**
		% within LIExclusive	**23.7%**	**27.7%**	**31.4%**	**30.2%**
FURM	Not female URM	Count	337_a	876_b	3788_c	5001
		% within LIExclusive	88.9%	94.3%	96.3%	95.4%
	Female URM	**Count**	**42_a**	**53_b**	**145_c**	**240**
		% within LIExclusive	**11.1%**	**5.7%**	**3.7%**	**4.6%**

Each subscript letter denotes a subset of LIExclusive categories whose column proportions do not differ significantly from each other at the .05 level.

In terms of college experiences (Table 5):

- Low and lower-middle income groups are statistically similar to each other, but statistically distinct from students self-reporting a family income of middle-income or higher.
- The participation rates for internships and study abroad is lower for low income levels, and the proportion of students with work-study/job to pay for college is higher.
- The exception is in research experiences, where low-income and middle-income or higher groups have similar participation rates.

Table 5. There are lower rates of participation in internship and study abroad for lower and lower-middle family income levels, and higher rates of work-study/job to pay for college. Groups with the same color band are statistically similar.

			LIExclusive			
			low-income	lower-middle	middle or higher	Total
Internship	No Internship	Count	203_a	475_a	1621_b	2299
		% within LIExclusive	53.7%	50.6%	41.0%	43.7%
	Internship	**Count**	**175_a**	**463_a**	**2328_b**	**2966**
		% within LIExclusive	**46.3%**	**49.4%**	**59.0%**	**56.3%**
job	Did not work	Count	147_a	399_a	2100_b	2646
		% within LIExclusive	38.7%	42.5%	53.2%	50.2%
	Worked to pay for college	**Count**	**233_a**	**540_a**	**1849_b**	**2622**
		% within LIExclusive	**61.3%**	**57.5%**	**46.8%**	**49.8%**
research	No Reearch	Count	$273_{a, b}$	693_b	2630_a	3596
		% within LIExclusive	72.0%	73.8%	66.5%	68.2%
	Research	**Count**	**$106_{a, b}$**	**246_b**	**1322_a**	**1674**
		% within LIExclusive	**28.0%**	**26.2%**	**33.5%**	**31.8%**
studyabroad	Did not study abroad	Count	339_a	832_a	3303_b	4474
		% within LIExclusive	89.0%	88.6%	83.6%	84.9%
	Studied Abroad	**Count**	**42_a**	**107_a**	**647_b**	**796**
		% within LIExclusive	**11.0%**	**11.4%**	**16.4%**	**15.1%**

Each subscript letter denotes a subset of LIExclusive categories whose column proportions do not differ significantly from each other at the .05 level.

Engineering task self-efficacy (ETSE) showed no statistical difference depending on parental educational attainment or self-reported family income level categories (mean: 2.43, stdev: 0.84).

Definition's Impact on Comparison to an 'Advantaged' group

(RQ2) How do FG and LI definitions impact results comparing FG/LI students to their continuing-generation and higher-income peers?

Despite variation in students' demographic characteristics and college experiences by parental educational attainment and family income, differences between FG/LI students and students who were not FG/LI ('advantaged') remain statistically significant using the three definitions we tested of "first-generation" (ie, 'no college', 'less associates', less bachelors') (Tables 6 and 7). Moreover, we did not observe statistical differences in ETSE no matter how the first-generation variable was defined. However, while all differences are *statistically* significant employing any definition of first-generation, the largest differences are observed in the demographic characteristics URM and low-income when we use the 'no college' cutoff (29.8% URM vs 11.7%; 66.9% vs 20.3%). Using the Bachelor's cutoff results in the largest differences in college experiences of research (22.7% vs 35.0%), study abroad (9.0% vs 17.3%), and working to pay for college (56.1% vs 47.3%).

Table 6. Comparisons in demographic characteristics between first-generation and advantaged groups are statistically significant using any definition of first generation, but the size of the differences vary particularly on measures of URM and low income. Groups with the same color band are statistically similar.

			Only HS/ No College cutoff		Less than Associate's cutoff		Less than Bachelor's cutoff	
			FG	Continuing	FG	Continuing	FG	Continuing
Underrepresented Racial/Ethnic Minority (URM) status	Not URM	Count	351_b	4115_a	659_b	3807_a	1065_b	3401_a
		% within FGC	70.2%	88.3%	73.4%	89.4%	78.1%	89.6%
	URM	Count	149_b	543_a	239_b	453_a	298_b	394_a
		% within FGC	**29.8%**	**11.7%**	**26.6%**	**10.6%**	**21.9%**	**10.4%**
female	male	Count	388_b	3279_a	686_b	2981_a	1046_b	2621_a
		% within FGC	76.1%	69.0%	74.6%	68.6%	75.0%	67.7%
	female	Count	122_b	1474_a	234_b	1362_a	348_b	1248_a
		% within FGC	**23.9%**	**31.0%**	**25.4%**	**31.4%**	**25.0%**	**32.3%**
FURM	Not female URM	Count	474_b	4530_a	851_b	4153_a	1306_b	3698_a
		% within FGC	93.1%	95.6%	93.0%	95.9%	94.0%	95.9%
	Female URM	Count	35_b	208_a	64_b	179_a	83_b	160_a
		% within FGC	**6.9%**	**4.4%**	**7.0%**	**4.1%**	**6.0%**	**4.1%**
LI	Not low-income	Count	169_b	3753_a	371_b	3551_a	660_b	3262_a
		% within FGC	33.1%	79.7%	40.2%	82.6%	47.3%	85.2%
	Low-income	Count	341_b	958_a	551_b	748_a	734_b	565_a
		% within FGC	**66.9%**	**20.3%**	**59.8%**	**17.4%**	**52.7%**	**14.8%**

Table 7. Comparisons in college experiences between first-generation and advantaged groups are statistically significant using any definition of first generation, but the size of the differences vary particularly for research, study abroad, and working to pay for college. Groups with the same color band are statistically similar.

			Only HS/ No College cutoff		Less than Associate's cutoff		Less than Bachelor's cutoff	
			FG	Continuing	FG	Continuing	FG	Continuing
Internship	No Internship	Count	276_b	2028_a	495_b	1809_a	707_b	1597_a
		% within FGC	53.7%	42.6%	53.5%	41.6%	50.7%	41.1%
	Internship	Count	238_b	2735_a	430_b	2543_a	688_b	2285_a
		% within FGC	**46.3%**	**57.4%**	**46.5%**	**58.4%**	**49.3%**	**58.9%**
research	No Reearch	Count	401_b	3204_a	709_b	2896_a	1081_b	2524_a
		% within FGC	78.0%	67.2%	76.5%	66.5%	77.3%	65.0%
	Research	Count	113_b	1563_a	218_b	1458_a	317_b	1359_a
		% within FGC	**22.0%**	**32.8%**	**23.5%**	**33.5%**	**22.7%**	**35.0%**
job	Did not work	Count	239_a	2419_a	415_b	2243_a	614_b	2044_a
		% within FGC	46.4%	50.8%	44.8%	51.5%	43.9%	52.7%
	Worked to pay for college	Count	276_a	2345_a	511_b	2110_a	784_b	1837_a
		% within FGC	**53.6%**	**49.2%**	**55.2%**	**48.5%**	**56.1%**	**47.3%**
studyabroad	Did not study abroad	Count	467_b	4016_a	847_b	3636_a	1273_b	3210_a
		% within FGC	90.7%	84.2%	91.3%	83.5%	91.0%	82.7%
	Studied Abroad	Count	48_b	751_a	81_b	718_a	126_b	673_a
		% within FGC	**9.3%**	**15.8%**	**8.7%**	**16.5%**	**9.0%**	**17.3%**

First-generation college and low-income status through an intersectional lens

(RQ3) How does considering first-generation and low-income identities through an intersectional lens deepen insight into the experiences of FG and LI groups?

First-generation college student and low-income status are often used as proxies for one another. In our dataset, the variables are highly correlated (Table 8). However, there may be patterns that emerge when considering the intersection of these two identities that are not accounted for when considering these groups separately. For our intersectional analysis, we chose the following definitions based on the prior results showing which groups have similar demographic characteristics and college experiences, and also recognizing the need for larger sample sizes and statistical power when considering intersectionality:

- First-Generation (FG) = parents' educational attainment less than a Bachelor's degree
- Low-Income (LI) = self-described growing up low or lower-middle income
- Advantaged = neither FGC nor LI, as defined above

Table 8. Parental educational attainment and self-reported family income growing up are highly correlated.

		How much education did your Parent 1 complete	How much education did your Parent 2 complete	When you were growing up, would you describe your family as:
How much education did your Parent 1 complete	Pearson Correlation	1	.507**	.409**
	Sig. (2-tailed)		0.000	0.000
	N	5316	5296	5238
How much education did your Parent 2 complete	Pearson Correlation	.507**	1	.388**
	Sig. (2-tailed)	0.000		0.000
	N	5296	5302	5227
When you were growing up, would you describe your family as:	Pearson Correlation	.409**	.388**	1
	Sig. (2-tailed)	0.000	0.000	
	N	5238	5227	5287

**. Correlation is significant at the 0.01 level (2-tailed).

In our dataset, excluding the 15.7% of missing data resulted in about two-thirds of students classified in our work as advantaged, meaning neither first-generation nor low-income (n=3551). Of the remaining one-third, 11% (n=551) are both first-generation and low-income (FG&LI), 7% are first-generation but not low-income (FG/notLI, n=371), and 14% are low-income but not first-generation (LI/notFG, n=748).

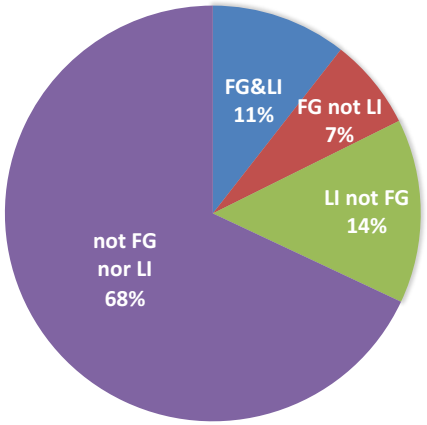

Figure 3. Distribution of students for intersectional analysis

For every demographic and college experience measure, the proportion of students who are both first-generation and low-income is statistically different compared to the proportion of students who are advantaged (Table 9). Additionally, FG&LI students in our sample are about twice as likely to be URM compared to FG/notLI or LI/notFG (33.5% compared to 17%), which are in turn about twice as likely to be URM as students in the advantaged group (9%). Low income students work to pay for college at a higher rate than students who are not low-income, regardless of parental education. Conversely, first-generation students are less likely to have an internship experience.

Table 9. FG&LI students are statistically distinct from advantaged students on every measure. FG&LI students also have a higher proportion of URM students than all other groups. Income level is the most important factor for working a job to pay for college, while parental educational attainment is most important for internships. Groups with the same color band are statistically similar.

			FG&LI	FG not LI	LI not FG	Advantaged	
Underrepresented Racial/Ethnic Minority (URM) status	Not URM	Count	352_{a}	301_{b}	599_{b}	3159_{c}	4411
		% within FGLIEx	66.5%	82.9%	82.4%	90.8%	86.5%
	URM	**Count**	**177_{a}**	**62_{b}**	**128_{b}**	**319_{c}**	**686**
		% within FGLIEx	**33.5%**	**17.1%**	**17.6%**	**9.2%**	**13.5%**
female	male	Count	412_{a}	$269_{a, b}$	$533_{a, b}$	2401_{b}	3615
		% within FGLIEx	75.3%	73.5%	71.6%	67.9%	69.6%
	female	**Count**	**135_{a}**	**$97_{a, b}$**	**$211_{a, b}$**	**1135_{b}**	**1578**
		% within FGLIEx	**24.7%**	**26.5%**	**28.4%**	**32.1%**	**30.4%**
FURM	Not female URM	Count	496_{a}	$348_{a, b}$	695_{a}	3401_{b}	4940
		% within FGLIEx	91.2%	95.6%	93.7%	96.4%	95.4%
	Female URM	**Count**	**48_{a}**	**$16_{a, b}$**	**47_{a}**	**128_{b}**	**239**
		% within FGLIEx	**8.8%**	**4.4%**	**6.3%**	**3.6%**	**4.6%**
Internship	No Internship	Count	311_{a}	$181_{a, b}$	353_{b}	1424_{c}	2269
		% within FGLIEx	56.6%	49.2%	47.4%	40.2%	43.6%
	Internship	**Count**	**238_{a}**	**$187_{a, b}$**	**391_{b}**	**2116_{c}**	**2932**
		% within FGLIEx	**43.4%**	**50.8%**	**52.6%**	**59.8%**	**56.4%**
job	Did not work	Count	224_{a}	$184_{b, c}$	$311_{a, c}$	1889_{b}	2608
		% within FGLIEx	40.7%	50.0%	41.7%	53.4%	50.1%
	Worked to pay for college	**Count**	**326_{a}**	**$184_{b, c}$**	**$435_{a, c}$**	**1651_{b}**	**2596**
		% within FGLIEx	**59.3%**	**50.0%**	**58.3%**	**46.6%**	**49.9%**
research	No Reearch	Count	419_{a}	283_{a}	529_{a}	2320_{b}	3551
		% within FGLIEx	76.2%	76.7%	71.1%	65.5%	68.2%
	Research	**Count**	**131_{a}**	**86_{a}**	**215_{a}**	**1222_{b}**	**1654**
		% within FGLIEx	**23.8%**	**23.3%**	**28.9%**	**34.5%**	**31.8%**
studyabroad	Did not study abroad	Count	500_{a}	340_{a}	650_{a}	2928_{b}	4418
		% within FGLIEx	90.7%	92.1%	87.2%	82.7%	84.9%
	Studied Abroad	**Count**	**51_{a}**	**29_{a}**	**95_{a}**	**612_{b}**	**787**
		% within FGLIEx	**9.3%**	**7.9%**	**12.8%**	**17.3%**	**15.1%**

Each subscript letter denotes a subset of FGLIEx categories whose column proportions do not differ significantly from each other at the .05 level.

Analyzing students who are both first-generation and low-income, compared to all other groups, also results in ETSE variation (Table 10). The students who are first-generation and low-income have lower engineering task self-efficacy than do all other groups, a difference that is statistically significant at the 0.05 level compared to the low-income/ not first-generation group.

Table 10. Engineering task self-efficacy is lowest for students who are both first-generation and low-income, a difference that is statistically significant at the 0.05 level compared to the low-income/not first-generation group.

FGLIEx	Mean	N	Std. Deviation
FG&LI	**2.3395**	549	0.91338
FG not LI	2.4482	368	0.85139
LI not FG	2.4823	746	0.86036
not FG nor LI	2.4243	3543	0.82212
Total	2.4253	5206	0.84030

Discussion and Implications

Understanding the first-generation, low-income population in engineering education is complicated by non-standardized categorizations that may include or exclude individuals based on the cutoff used for the level of parental educational attainment and the level of income considered 'low-income.' We analyzed an existing large, nationally-representative multi-institution dataset to determine how the demographic characteristics and college experiences of first-generation, low-income students in engineering programs change depending on how the group is defined and whether an intersectional lens is applied.

Demographic Characteristics

When considering a 'first-generation' population, it is important to recognize the similarities and distinctions in the groups of students whose parents have no college, less than an associate's degree (i.e., some college), less than a bachelor's degree (i.e., obtained an associate's degree), and a bachelor's degree or higher. In our dataset, the proportion of URM, women, and URM women is statistically similar whether parents attended 'no college' or some college without obtaining a degree ('less than associates'). The proportion of low-income students is statistically higher for each parental education level. When analyzing family income, the demographics of self-reported low-income students are statistically different from those of lower-middle income, as well as from middle-income or higher. The trends were the same for both measures: there are fewer URM students as parental education level increases, and as family income increases.

One key finding is the pattern that emerges when we examine gender, race/ethnicity, first-generation status, and low-income status. We see two distinct trends for women depending on their race/ethnicity. In aggregate, the relationship between the proportion of women and parental education level was not clearly linear, although there is a slight increase at the highest education brackets. The same increase in the proportion of women is observed when we examined family income level. However, the proportions of URM women are significantly higher at the lower education brackets and

lower income levels. Bringing these datapoints together, we conclude that non-URM women in our engineering student sample (composed mostly of white and Asian sub-groups) are more likely to have educationally and economically advantaged family backgrounds. URM women, on the other hand, are more likely to come from lower income backgrounds and have lower parental educational attainment. To the extent that previous research points to higher income backgrounds among undergraduate women in engineering relative to men, our data underscore the importance of asking "which groups of women are we speaking of?" To the extent that schools and colleges of engineering are pushing for greater gender diversity in their environments, our findings show that efforts to "recruit women" without attending to the structural inequalities that differentially affect different groups of women will replicate the largely white and Asian composition of the engineering student population.

College Experiences

When it comes to college experiences, students have similar participation whether their parents have no college, some college, or an associate's degree. With regards to family income, self-reported low-income and lower-middle income students had statistically similar participation rates. The trends were consistent: for the most part, students whose parents had less than a bachelor's degree or who were from family income levels below middle-income participated less in research with faculty, and study abroad, and they worked to pay for college at a higher rate, compared to students whose parents had bachelor's degrees or higher or grew up in middle-income or higher families.

A slightly more complex picture arose with internships, where there was more of a gradation of participation with parental education, and with research, where low-income students participated at the same rate as middle-income of higher students. It may be that some aspect of parental higher education provides the network, knowledge about entering a professional workforce, or some other dimension of social capital that enables students to participate in an internship. For research experiences, it may be that more resources are put towards sponsoring low-income students through programs such as those with NSF support. Internships, on the other hand, are controlled more in the free market with companies hiring individuals, perhaps without an overarching mission to increase pathways to industry for first-generation, low-income students in the same way we've seen in higher education trying to increase pathways to graduate school. These experiences are important in preparing students to enter either the engineering workforce or graduate school, and should be explored further given these findings.

Sampling and Statistical Considerations

When considering which definition to use to determine first-generation or low-income status, sample size and statistical power are among many factors to consider. Ultimately, in our dataset. for no demographic characteristics or college experiences are students whose parents had 'no college' the same as students whose parents have a 'bachelor's degree or higher'. Similarly, for no demographic characteristics of college experiences are students who self-report 'low-income' the same as students who self-report 'middle-income or higher' (with the exception of research with faculty).

While this most conservative definition of 'first-generation' (using a 'no college' cutoff) allows for comparing the most distinct populations, there is a tradeoff in statistical power and inclusion. Including students whose parental educational attainment is less than an associate's degree almost doubles the number of students considered first-generation in our dataset. Including students with

parents with less than a bachelor's degree almost triples the number of students considered first-generation compared to the most conservative definition, which is similar to published results on other nationally representative longitudinal datasets (Toutkoushian, et al., 2018). In our dataset when including lower-middle income, the number of students is 2.5 times as large as considering low-income students only. To the extent that patterns of participation in college activities is roughly the same between the three parental education levels and between the two income groups, our data suggest that increasing the size of the group better captures a segment of engineering students who do not experience college in the same way as do their more advantaged peers *and* offers a statistical benefit.

Despite the differences in our samples depending on level of parental educational attainment and self-reported family income, statistical comparisons of demographic proportions and college experience participation rates remained statistically significant for a 'first-generation' group when compared to a 'continuing-generation' group, no matter what definitions were used. However, the size of the delta between groups is definition-dependent. Consistent with our earlier results, using the associate's cutoff results in the largest demographic differences particularly with URM and low-income. Using the bachelor's cutoff results in the largest differences in most college experiences.

Intersectional Insight

Considering students' identities as both, either, or neither first-generation and low-income adds additional insight to these results. In our dataset, we are able to examine family income and parent educational level through a more intersectional lens. In this analysis we used our recommended cutoffs of less than a bachelor's degree and lower-middle income or less. In our dataset, students who were both first-generation *and* low-income based on parents' education attainment less than a bachelor's degree and self-reported low or lower-middle income comprised 11% of the valid dataset, while students who were *neither* first-generation nor low-income (classified here as 'advantaged') comprised 68%. Students who were *one but not the other* were twice as likely to be low-income rather than first-generation (14% LI/notFG vs 7% FG/notLI).

While the parental educational attainment was highly correlated with family income (for both Parent 1 and Parent 2, whose educational attainment was also highly correlated to one another), patterns emerged with considering the intersection of these identities rather than thinking of them as proxies for one another. FGLI students in our sample are about twice as likely to be URM compared to FG/notLI or LI/notFG (33.5% compared to ~17%), which are in turn about twice as likely to be URM as students in the advantaged group (9%). Based on the earlier analysis, being low-income was a more important factor than being first-generation in terms of the proportion of women in aggregate; here we see that being *both* results in the lowest proportion of women (24.7%), while being *neither* (advantaged) results in the highest proportion of women (32.1%). As with earlier results, URM women have the opposite trend: being *both* results in the highest proportion of URM women (8.8%) while being *neither* results in the lowest proportion of URM women (3.6%). As noted earlier, these differences have substantial implications for educational policy and approaches to recruiting and supporting women and underrepresented minority students.

Additionally, there are two college experiences where one factor seems to matter more than the other. Low income students work to pay for college at a higher rate than students who are not low-income, regardless of parental education. Conversely, first-generation students are less likely to have an

internship experience, with students who have the lowest internship participation being both first-generation and low-income (43.4%) and advantaged students with the highest internship participation (59.8%). Again, this points to the possibility that family social capital gained by parental education is factoring into engineering students pursuing and successfully obtaining internships, independent from the need to work to pay for college which is most prevalent for low-income students regardless of parental education. It may even be that the need to pay for college and hold a steady job during the academic term, potentially over a long period of years, is an obstacle for students obtaining a short-term internship.

Finally, engineering task self-efficacy (ETSE) is lowest for FGLI students, with statistical significance compared to the LI/not FG group. In our earlier analysis that did not consider intersectional identities, ETSE was not found to be significantly different for any groups based on parental educational attainment or on family income. ETSE has been found elsewhere to be statistically different between women and men [22] and when considering the intersection of gender and race/ethnicity [23]. Similar to the reduction in self-efficacy for individuals who were both women and URM, it appears that being *both* first-generation and low-income is associated with lower engineering task self-efficacy more so than is each of those identities alone. The causal reasons for these relationships merit much further study in future research, and greater discussion about the context to and implications of these self-assessments is sorely needed.

Limitations

This analysis was conducted on an existing dataset, so the questions and measures were not created and administered principally to address these research questions. Furthermore, this dataset focuses on engineering students in their junior, senior, or 5th year of an engineering program. This has the limitation of excluding students who started in an engineering program and did not persist to the junior year. Therefore, conclusions about the demographic characteristics, in particular, cannot be applied to the population of students considering an engineering program or matriculating into an engineering program. For example, it may be that first-generation and low-income students are overrepresented in the population that does not persist. Care must also be taken when making statements about college experiences because juniors, seniors, and 5th year students are all included in this analysis. For example, the participation rate for internships does not necessarily represent the percentage of students that have an internship experience by the time they graduate, because juniors are less likely than seniors to have an internship (the number of juniors is about the same as the number of seniors in the dataset and a preliminary exploration of the data did not find that parental educational attainment nor family income was correlated with year in program). Ultimately, this dataset provides rich insight into the demographic characteristics and college experiences, on the whole, of engineering students about to enter the workforce.

The definitions explored in this study are not the only complicating factors when determining first-generation or low-income status. Students may be mentored, or not, by biological parents, step-parents, grandparents, older siblings, etc. Additionally, many individuals tend to normalize their experience growing up (the majority of students in this dataset reported growing up middle-income) which may drive self-reported data to the middle of the income distribution. On the other hand, quantitative income measures are highly relative; the Pell-eligibility threshold of a $50,000 annual family income affords a very different lifestyle in various areas of the country. Our survey instrument

was designed with a deep knowledge of higher education literature and took many of these factors into consideration. The decision was made intentionally to ask students to self-report their family income rather than relying on a quantitative measure because the respondents were geographically distributed across the country. Respondents were also asked to identify 'parent 1' and 'parent 2' and report each parent's educational attainment level, so they could select whichever one or two individuals they most considered to be their parents without the bias of suggesting a mother and father.

Conclusions

This study suggests that care must be taken when applying the labels "first-generation" and/or "low-income." In our dataset we found that the demographic characteristics and college experiences of engineering students greatly vary by parental educational attainment and family income. Selecting one cutoff over another in defining 'first-generation' and 'low-income' changes how we understand the size and scope of the difference between these engineering populations compared to their continuing-generation peers with more wealth. Based on our results, we recommend a 'less than bachelors' degree cutoff for first-generation, and 'lower-middle income' cutoff for family income, as the definitions that may offer the broadest benefit considering statistical technique and insight into educational equity. While no definition is able to perfectly capture the nuance of the various groups, our results suggest that these cutoffs are particularly appropriate for research questions and policy implications focusing on interventions in engineering programs in higher education.

We further analyzed the dataset using this recommended set of definitions to understand parental education and family income through an intersectional lens, and were able to glean more insight into the experiences of students who face structural disadvantage compared to engineering students from more educationally advantaged and economically advantaged backgrounds. These results suggest a number of questions for future research, engineering program development, and educational policy. In particular, further exploring the pattern that emerges when we examine gender, race/ethnicity, first-generation status, and low-income status, as well as the trade-offs in statistical power versus insight gained by considering intersectional identities, and the equity implications of the relationship between parental education, family income, and internship experiences amongst engineering students.

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