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# **A Longitudinal Mixed-Methods Study of Women's Achievement and Attrition in Undergraduate Engineering Education**

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# **A Longitudinal Mixed-Methods Study of Women's Achievement and Attrition in Undergraduate Engineering Education**

## **ABSTRACT**

The proportion of women earning engineering bachelor's degrees in the United States has increased only slightly in the past twenty years from 18% to 21%, and addressing their persistent underrepresentation in these fields remains a national priority. This paper presents preliminary results of a longitudinal mixed-methods research project designed to advance our understanding of women's underrepresentation in engineering, by examining the factors that influence their educational outcomes, in ways that are aligned with our understanding of the sociocultural context of engineering education. The aims of this project are to: 1. model patterns of major changing behavior among undergraduate women entering and exiting an engineering program prior to graduation; 2. elucidate the cultural ecosystem of undergraduate engineering education and its relation to women's achievement motivation; and 3. complicate the discourse on identity in engineering education with an examination of structural modes of power, privilege and inequality within the disciplines. In this presentation, we focus on the initial quantitative results of the first aim and provide insight into the ongoing research process for the subsequent aims. We apply descriptive statistics and survival analysis methods to analyze institutional data from a racially diverse sample of 10 cohorts of undergraduate women in engineering programs ( $N=380$ ) at a mid-sized public research university and address the overarching research aim to understand: How are demographic characteristics, major-switching patterns, and course-enrollment factors related to retention and graduation among undergraduate women in engineering? We discuss findings including whether and when background factors such as women's income, race, high school GPA, SAT scores, and scholarship program participation matter to undergraduate engineering outcomes. Finally, we discuss the next phases of data collection as well the implications of this investigation into women's academic choices and outcomes in undergraduate engineering education.

## **INTRODUCTION**

The proportion of women earning bachelor's degrees in engineering has increased only slightly in the past twenty years from 18% to 21%, and addressing their persistent underrepresentation in these fields remains a national priority [1], [2]. However, among social scientists and engineering education researchers, there is a tendency to either *quantify* factors that influence the participation of women in engineering statistically or *qualify* the nature of women's experiences in engineering programs descriptively. When these approaches meet, they typically are not designed to study patterns over time nor do they include a critical examination of structural barriers to success for women. For this area of research to yield results that are actionable (*i.e.*, address implications for teaching, advising, and enrollment management) and authentically interpreted (*i.e.*, consider the nature of the engineering education context and diversity of women's experiences therein), an interdisciplinary approach that employs mixed methods with a longitudinal design is warranted. Such a nuanced investigation of women's choices and outcomes in undergraduate engineering education requires (a) analysis of large-scale enrollment data to identify trends, (b) deep exploration of how contextual factors influence

student motivation, and (c) integration of quantitative and qualitative data to draw inferences that are grounded in relevant psychological and educational theory.

This *Work in Progress* paper presents the preliminary results of an explanatory sequential mixed-methods research study seeking to address the following research questions: (1) What patterns of engineering major-switching and course-taking behavior are related to retention and graduation among undergraduate women from 2007 to 2016? (2a) How do perceptions of the undergraduate engineering education ecosystem compare among women who persist in the major and those who do not? (2b) Which experiences in this context are most meaningful to their achievement motivation in the field? The long-term goal of this work is to advance our understanding of women's underrepresentation in engineering, and factors that influence their educational outcomes, in ways that are aligned with our understanding of the sociocultural context of engineering education.

## **Background Literature**

Well-established theories and models describe the factors associated with student retention and the conditions that promote student success and learning [3, 4, 5, 6]. These are primarily Input-Environment-Output models in which students arrive with a set of background characteristics (*e.g.*, race, gender, career preferences, values, socio-economic status, prior experiences) and then enter and interact with peers and faculty and staff within the institutional environment. Terenzini and Reason created the Comprehensive Model of Influences on Student Learning and Persistence, which synthesizes the models of Astin, Tinto, and Pascarella [7]. Terenzini and Reason's model includes four major constructs: precollege characteristics and experiences; organizational context; peer environment; and, individual student experiences. The nature of students' engagement in curricular and co-curricular experiences and with faculty and peers directly impacts their success and learning. Still within the undergraduate engineering education context, differentiated experiences and outcomes have been identified among students across race and gender [8] - [10]. Additionally, the role of community colleges in educating women in science and engineering has gained increased attention over the past 15-20 years [11]. A comprehensive investigation of student success in engineering education must address issues of academic and social integration, perceptions of self, and the background characteristics that may shape the student experience.

Past studies have found that the probability of leaving a STEM major increases and reaches its peak around the third year of college in general [12]. Compared to male students, female students had a higher probability of leaving [12], [13], and underrepresented minority students had the highest attrition rate in engineering majors, compared to White and Asian students [14], [15]. Even after persisting until the third year in undergraduate education, they were more likely to leave a STEM major by the end of the fourth year [13]. Moreover, underrepresented minority students took longer and were less likely to attain a STEM degree and graduate within five years, compared to White students [16].

When students decided to leave engineering and/or STEM majors, they were more likely to switch their majors from a STEM major to a non-engineering or non-STEM major [14]. Their major-switching behaviors were influenced by the courses they were taking. For example,

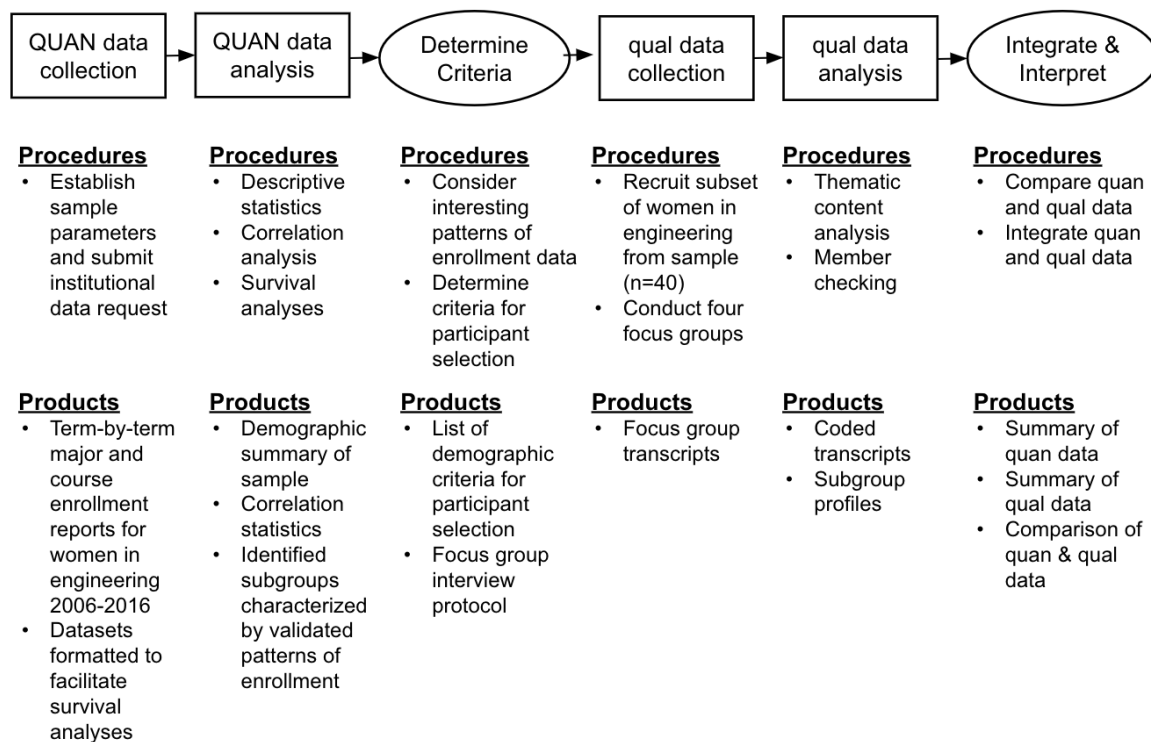
compared to White and Asian students, underrepresented minority students were more likely to switch out of STEM majors if they took non-STEM courses and obtained good grades. In contrast, underrepresented minority students were less likely to leave STEM majors if they took upper-level STEM courses [16]. Other factors, including SAT scores, high school GPA, students' academic performance, STEM and non-STEM ability, have been considered as possible contributors that can impact degree attainment, persistence, and attrition among students in higher education [15], [16].

## METHODS

This paper reports on a subset of the results of aforementioned research question 1: What patterns of engineering major-switching and course-taking behavior are related to retention and graduation among undergraduate women from 2007 to 2016? In this explanatory-sequential research design, quantitative enrollment data were collected first and will inform the collection of qualitative focus group data. The lens of *intersectionality* is used throughout the process to examine experiences among women across hierarchies of privilege and power that structure academic life. The future qualitative data will help to explain findings from the quantitative data and guide recommendations for policy and practice. See figure 1 for more details on the project research design and procedures.

To yield the most robust and representative sample, secondary data were collected from the enrollment records of 10 cohorts of undergraduate women in engineering at a mid-sized public research university in the Mid-Atlantic region of the United States (UNIV). The records included data on their personal demographics (e.g. race, neighborhood income, etc.), academic background (e.g. high school GPA, standardized test scores), and academic performance (e.g. critical engineering course outcomes, GPA, credits earned, years to degree). Prior to submitting the institutional data request, this project was submitted to and approved by the UNIV Institutional Review Board. The analytic techniques employed for research question 1 (the focus of this paper) included descriptive statistics, correlations, and survival analysis methods (Kaplan-Meier and Cox Proportional Hazard).

**Figure 2**  
*Full Study Research Design and Procedures*



## RESULTS

### Description of the Sample

All students in the sample attended UNIV between 2007 and 2016 and began in the Fall semester as first time freshman. The original sample  $N$  was 460 women in engineering majors but there were 69 duplicate cases and 2 cases with anomalies, and Spring cohorts. Moreover, there were 24 students who started their undergraduate education as non-engineering majors. Excluding these cases, the final sample was composed of 356 students. There were 87 underrepresented minority (URM) students. This group was created by combining students who are Black, Hispanic, Pacific Islander, or multiracial (mixed with at least one ethnic-racial group of American Indian, Black, Hispanic, Pacific Islander). Most of the students (83%) were from middle- income households, and many attended high school in suburban areas (48%), followed by rural (13%), city (10%), and town (3%). Upon entering higher education, most of the students (81%) took a lower-level to mid-level math course, whereas the remaining students took a mid- to upper-level math course. Among the two critical courses each in the chemical, mechanical, and computer engineering majors, students took 1.8 courses on average. About 44% of the students were supported by a scholarship program within the university. Moreover, about half of the students ( $n = 172$ , 48%) changed their major to either a different engineering major, non-engineering STEM major, or non-STEM major, and 288 students (81%) graduated and took about 4.5 years to graduate. Descriptive statistics of and correlations among demographic, academic, and outcome variables are presented in Tables 1 to 3.

**Table 1***Final Sample Demographics*

	N	Percentage
Cohort		
Fall 2007	26	7.3%
Fall 2008	18	5.1%
Fall 2009	35	9.8%
Fall 2010	25	7.0%
Fall 2011	25	7.0%
Fall 2012	39	11.0%
Fall 2013	51	14.3%
Fall 2014	38	10.7%
Fall 2015	57	16.0%
Fall 2016	42	11.8%
Ethnic-Racial Group		
Asian	58	16.3%
Black	66	18.5%
Hispanic	10	2.8%
Pacific Islander	2	0.6%
White	185	52.0%
Multiracial URM	9	2.5%
Multiracial Non URM	11	3.1%
Did not report	15	4.2%
Household Income		
Lower Income (Below \$48,500)	16	4.5%
Middle Income (\$48,500 - \$145,500)	295	82.9%
Upper Income (Above \$145,500)	41	11.5%
Did not report	4	1.1%
School Region		
Rural	45	12.6%
Town	9	2.5%
Suburban	172	48.3%
City	37	10.4%
Did not report	93	26.1%
Scholars Program Participant		
Yes	155	43.5%
No	201	56.5%

*Note.* N = 356

**Table 2***Entry Majors among the Full Sample*

	Frequency	Percentage
Major		
Engineering Majors	356	93.7%
Engineering	115	30.3%
Mechanical Engineering	88	23.2%
Computer Engineering	50	13.2%
Pre-Engineering	48	12.6%
Pre-Mechanical Engineering	26	6.8%
Pre-Computer Engineering	19	5.0%
Chemical Engineering	6	1.6%
Pre-Chemical Engineering	4	1.1%
Non-Engineering STEM Majors	13	3.4%
Biological Sciences	7	1.8%
Mathematics	2	0.5%
Computer Science	1	0.3%
Economics	1	0.3%
Environmental Science	1	0.3%
Environmental Science & Geography	1	0.3%
Non-STEM Majors	11	2.9%
Undergraduate Studies	8	2.1%
English	1	0.3%
Individual Study	1	0.3%
Music	1	0.3%

*Note.*  $N = 380$ ; Includes 24 students who began in non-engineering majors

**Table 3***Descriptive Statistics for Academic Variables*

	$M (SD)$	Range
High School GPA	3.92 (0.46)	2.58 – 4.50
SAT/ACT Math	658.74 (65.23)	480 – 800
Core Courses GPA	3.02 (0.84)	0.00 – 4.00
Last Cumulative GPA	3.18 (0.64)	0.00 – 4.00
Last Cumulative Credits	103.07 (35.26)	0 – 169
Years to Degree	4.5 (0.8)	3.0 – 10.5

*Note.*  $N = 356$



**Table 4***Intersection among the Sample Demographics*

	Ethnic-Racial Groups			
	Asian	Black	Hispanic	White
<i>n</i>	58	66	10	185
Income				
Lower Income (Below \$48,500)	0 (0%)	9 (13.6%)	0 (0%)	6 (3.2%)
Middle Income (\$48,500 - \$145,500)	43 (74.1%)	55 (83.3%)	10 (100%)	157 (84.9%)
Upper Income (Above \$145,500)	13 (22.4%)	2 (3%)	0 (0%)	21 (11.4%)
Did not report	2 (3.4%)	0 (0%)	0 (0%)	1 (0.5%)
School Region				
Rural	3 (5.2%)	3 (4.5%)	0 (0%)	33 (17.8%)
Town	2 (3.4%)	2 (3.0%)	0 (0%)	5 (2.7%)
Suburban	39 (67.2%)	30 (45.5%)	7 (70%)	79 (42.7%)
City	7 (12.1%)	12 (18.2%)	0 (0%)	12 (6.5%)
Did not report	7 (12.1%)	19 (28.8%)	3 (30%)	56 (30.3%)
Scholars Program				
Yes	14 (24.1%)	32 (48.5%)	5 (50%)	91 (49.2%)
No	44 (75.9%)	34 (51.5%)	5 (50%)	94 (50.8%)
Entry Major <sup>a</sup>				
Chemical Engineering	2 (3.4%)	2 (3.0%)	0 (0%)	5 (2.7%)
Computer Engineering	14 (24.1%)	16 (24.3%)	1 (10.0%)	29 (15.6%)
Engineering	30 (51.7%)	24 (36.4%)	3 (30.0%)	89 (48.1%)
Mechanical Engineering	12 (20.7%)	24 (36.4%)	6 (60.0%)	62 (33.5%)

*Note.* *n* = 319. <sup>a</sup> Only includes students who started in engineering majors.

**Table 5****Academic Outcomes Across Ethnic-Racial Groups**

	Ethnic-Racial Groups			
	Asian	Black	Hispanic	White
<i>n</i>	58	66	10	185
Leavers	26 (44.8%)	35 (53.0%)	3 (30%)	75 (40.5%)
Graduated				
Yes	46 (79.3%)	51 (77.3%)	8 (80.0%)	158 (85.4%)
No	12 (20.7%)	15 (22.7%)	2 (20.0%)	27 (14.6%)
Core Courses GPA; <i>M (SD)</i>	3.00 (0.76)	2.89 (0.79)	2.69 (1.14)	3.13 (0.76)
Last Cumulative GPA; <i>M (SD)</i>	3.18 (0.51)	3.02 (0.63)	2.80 (0.72)	3.27 (0.65)
Last Cumulative Credits; <i>M (SD)</i>	99.89 (36.54)	104.00 (36.25)	99.90 (37.45)	105.60 (32.84)
Years to Degree; <i>M (SD)</i>	4.46 (0.66)	4.60 (0.66)	4.44 (0.50)	4.50 (0.90)
Graduated within 5 years	41 (70.7%)	43 (65.2%)	8 (80.0%)	141 (76.2%)

*Note.* *n* = 319

**Table 4***Correlations Among Demographic, Academic, and Outcome Variables*

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. URM <sup>a</sup>	-												
2. Income <sup>b</sup>	-.12*	-											
3. School Region <sup>c</sup>	.20**	-.01	-										
4. High School GPA	-.29***	-.09	-.15*	-									
5. SAT/ACT Math	-.29***	.07	-.04	.45**	-								
6. Math Course Level	-.08	.09	-.05	.29**	.50***	-							
7. Scholars Program <sup>d</sup>	.04	.03	-.02	.32**	.41***	.33***	-						
8. Core Courses GPA	-.16**	-.04	-.04	.38**	.35***	.25***	.19**	-					
9. Major Change <sup>e</sup>	.08	.06	.05	-.31***	-.29**	-.24**	-.18*	-.42**	-				
10. Last Cumulative GPA	-.19***	.03	-.10	.49**	.40***	.35***	.33**	.65**	-.15*	-			
11. Last Cumulative Credits	-.02	-.03	.01	.17**	.12*	.14*	.21**	.19**	.08	.53**	-		
12. Years to Degree	-.02	-.08	.17*	-.32***	-.21**	-.30**	-.39*	-.35*	.25**	-.45**	.15*	-	
13. Graduated <sup>f</sup>	-.07	-.04	-.00	.20**	.07	.13*	.18**	.19**	.03	.52**	.79**	-. <sup>g</sup>	-

Note.  $N = 356$ . \*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ .

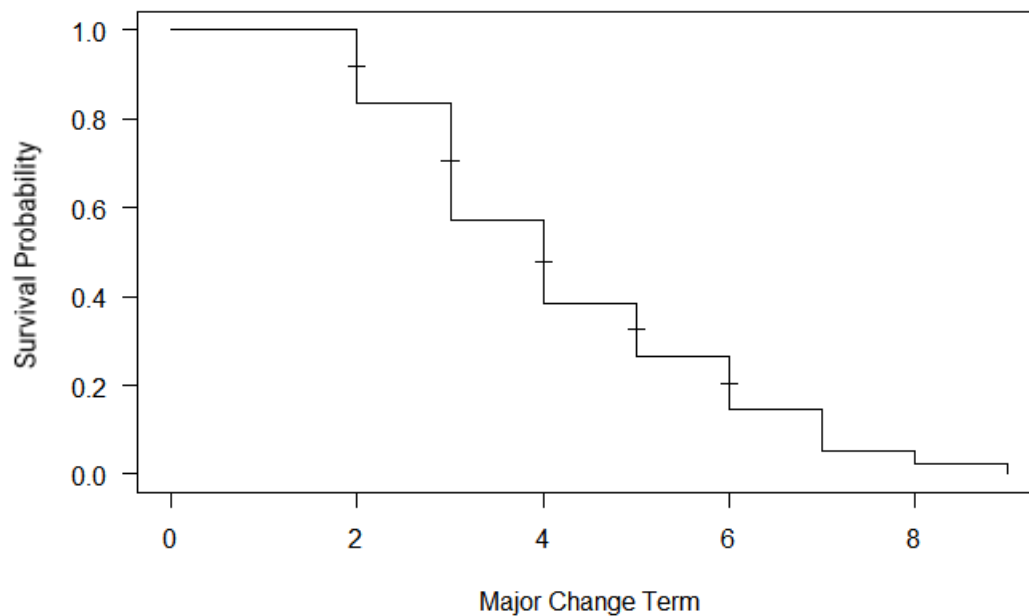
<sup>a</sup> Underrepresented Minority (Black, Hispanic, Pacific Islander, or multiracial): No = 0, Yes = 1. <sup>b</sup> Lower, Middle, Upper level income: 0, 1, 2. <sup>c</sup> School region: Rural = 1, Town = 2, Suburban = 3, City = 4. <sup>d</sup> Scholars Program: No = 0, Yes = 1. <sup>e</sup> Major Change: No = 0, Yes = 1. <sup>f</sup> Graduated: No = 0, Yes = 1. <sup>g</sup> The correlation between years to degree and graduated cannot be determined as the value of graduate variable is constant at 1.

## When do undergraduate women who start in an engineering major switch to a non-engineering STEM major, to a non-STEM major?

Kaplan-Meier models were conducted to identify when undergraduate women who started in an engineering major switched to a non-engineering major. As shown in Figure 2, survival probability of staying in their entry engineering major dropped sharply in the first four semesters of undergraduate program and continued to decrease throughout 9 semesters (see Table 5).

**Figure 2**

*Survival Probability Estimates for Major Change Among Undergraduate Women Who Started as an Engineering Major*



**Table 5**

*Survival Probability Estimates for Major Change Among Undergraduate Women Who Started in Engineering and Left the Major*

Leavers <i>n</i>	Stayers <i>n</i>	Time in Semester	Number of Students Who Left Engineering	Survival Probability
164	192	2	27	0.84
		3	41	0.57
		4	28	0.39
		5	18	0.26
		6	17	0.15
		7	13	0.05
		8	4	0.02
		9	3	0.00

*Note.* Total *N* = 356.

**To what extent do demographic characteristics and course enrollment factors contribute to the likelihood of a student switching from an undergraduate engineering major to a non-engineering STEM major, to a non-STEM major? Which demographic characteristics and course enrollment factors predict completion of an undergraduate engineering degree within five years?**

Cox proportional hazard (CPH) models were conducted to identify demographic characteristics and course enrollment factors that may: (1) contribute to the likelihood of a student switching from an undergraduate engineering major to a non-engineering or non-STEM major; and (2) predict completion of an undergraduate engineering degree. High school GPA, concordant SAT/ACT math score, level of math course, number of core courses taken, and core courses GPA were used as predictors.

CPH results showed that the hazard ratio for major change among those who took more core courses was 0.57 (95% CI [0.44, 0.73];  $p < 0.001$ ) or reduced by 43%. High school GPA and the level of math courses were significant predictors of completion of an undergraduate engineering degree within five years. Specifically, at a given instance of time, having a higher high school GPA increases the likelihood of graduating with an engineering degree within five years by a factor of 1.96 (95% CI [1.13, 3.38];  $p < 0.05$ ) or 96%. Additionally, starting at a higher level of college math increases the likelihood of graduating with an engineering degree within five years by a factor of 1.08 (95% CI [1.00 to 1.16];  $p < 0.05$ ) or 8%.

**To what extent do demographic characteristics and course enrollment factors contribute to the likelihood of a student switching to an undergraduate engineering major from a non-engineering STEM major or non-STEM major?**

We did not have a sample size sufficient to answer this question statistically; however, we wish to present some demographic data that will inform our qualitative inquiry into the experiences of women who switch to an engineering major. Twenty-four students in our sample started in non-engineering majors and switched to an engineering major. Thirteen of these 24 students began in non-engineering STEM majors; 11 began in non-STEM majors. The most frequent entry major among these 24 students was *undergraduate studies* (or undecided)  $n = 8$ , followed by *biological sciences*  $n = 7$ . Most of these students (over 70%) switched to engineering within their second or third semester. Nineteen of these 24 women (79%) ultimately graduated in engineering.

## **DISCUSSION**

Our findings are in many ways consistent with past literature on the topic of women's success in undergraduate engineering and also extend the knowledge in this area. Prior results cite a peak in leaving STEM majors at the third year or sixth semester [12]; however, our results indicate a pronounced rate of attrition within the first four semesters for women in engineering. Additionally, past work examining the factors impacting persistence point to the importance of the type of courses taken and prior academic performance [15, 16]. These prior results are consistent with our findings that taking more core courses in the major and having a higher math course placement serve as protective factors for attrition for women in undergraduate engineering.

Implications for research include the need for more information on additional aspects of the undergraduate engineering ecosystem that inform women's experiences such as relationships with faculty, family influence, and access to co-curricular experiences (e.g., clubs and internships). These factors can be added to statistical models to assess their impact on women's success and attrition in engineering and also explored qualitatively through interviews. This study also provides several implications for practice including the suggestion that advising staff and undergraduate program administrators encourage early success in core courses and look to add extra support for students beginning in lower level math courses.

One major limitation of this study is working with secondary data sources, particularly from institutional records. These data, which are not collected primarily for research purposes, are prone to challenges with missingness, re-coding, and interpretation issues (e.g., when there are gaps in the student records for a number of reasons). Future plans for this ongoing work are to disaggregate the results by major, race, and other background factors such as entry status (transfer vs first time freshman) to investigate additional distinctive experiences that are relevant to the achievement of women in engineering. Additionally, we will recruit participants from among the sample for four to five focus group sessions composed of participants with particular experiences of interest (e.g., those who switched to engineering from a different major, transfer students from community colleges). These focus groups will provide the necessary context and insight into the personal and structural factors (i.e., examining intersectional modes of power and privilege) that contribute to women's achievement and attrition in undergraduate engineering majors.

## **Conclusion**

This project addresses the national goal of increasing the percentage of women participating in fields where they are currently underrepresented (e.g., chemical engineering, computer engineering, and mechanical engineering). Ultimately, the expected outcomes of this project will generate information to improve practice in three areas: social science research, engineering education research, and higher education administration. As faculty, staff, and administrators are better informed on ways to identify patterns of behavior quantitatively and understand the motivations behind those behaviors qualitatively, there is increased opportunity to develop effective practices and well-timed interventions for inclusive engineering education. The impact of this work will be amplified and disseminated at outlets targeted to various stakeholder audiences including engineering education researchers.

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