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A multi-year study of engineering self-efficacy in the US: exploring gender differences in a small engineering program

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ABSTRACT

This study presents the baseline results of an ongoing study at a small liberal arts university in the US and explores the gender differences in engineering self-efficacy, preparedness, and engagement in undergraduate engineering students. Data from the first timepoint of the survey was used to identify factors such as high school grade point average (GPA), math preparedness, high school mentoring, and college extracurricular involvement, and their correlations with engineering self-efficacy, as measured by the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) scale. Investigation of LAESE subscales revealed that students (regardless of gender) who entered college having previously studied calculus reported greater engineering self-efficacy. Results indicate that women enter college with greater math preparation and high school GPA, however, self-efficacy is not any stronger than that of their male peers. However, women had greater coping self-efficacy and math outcome expectations compared to their male peers. These findings suggest a pipeline issue, where only the women with strong preparation self-identify as being capable of earning an engineering degree. The study also provides information about the differential experiences of women in engineering and suggests future factors to explore more deeply, such as mentoring and club involvement.

KEYWORDS

LAESE, college preparation, undergraduate, self-efficacy, inclusion, gender

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INTRODUCTION

Over the last several decades, there has been a steady increase in the United States in the number of students receiving Bachelor of Science degrees in engineering, however, the percentage of women earning these degrees nationally has remained stable at 20% for over 20 years (National Center for Engineering and Science Statistics [NCSES], 2019). The percentage of undergraduate women in different engineering majors varies from a high of about 50% in fields such as environmental engineering and biomedical engineering, to a low of about 13% for computer engineering (Roy, 2018). There remains a great interest in understanding how to increase this percentage by improving recruitment of women to university engineering programs and retaining them in the programs throughout their studies. It is well-recognized in the literature that the pipeline of students interested in STEM begins equal for girls and boys but as early as middle school the proportion of female students interested in STEM begins to decrease (Dasgupta & Stout, 2014; Maltese & Tai, 2011; Sontgerath & Demetry, 2019). By the time students are in high school, the majority of students (80%) who choose to major in STEM have already made that choice because of their interest in mathematics and science (Maltese & Tai, 2011). Although much work remains to improve retention of women prior to entering college, interventions can also be made at the university level to recruit and retain women in the engineering majors. In fact, understanding women's experiences in college programs can help educators understand why all students, especially underrepresented populations, may enter or leave programs (Holland et al., 2011).

Many studies have looked into reasons why fewer women pursue engineering careers and why women may leave the field at various time points throughout their careers. Maltese and Tai (2011) concluded from a study of a cohort of 4,700 students (half of whom were women) in a national longitudinal study starting in 8th grade and found that gender had no independent predictive effect on persistence in STEM. However, gender differences in factors such as self-efficacy, feelings of inclusion and belongingness, and math preparedness, have been correlated with persistence or intentions to persist in the engineering career path (Concannon & Barrow, 2010; Fisher et al., 2019; Mamaril et al., 2016; Marra & Bogue, 2006; Morris et al., 2019; Schaefers et al., 1997). Feelings of inclusion and belonging as well as math readiness are both strong indicators of retention in engineering, while conclusions about self-efficacy are more nuanced.

Self-efficacy, or the belief in one's ability to accomplish a goal, is an important factor in whether a student successfully completes their engineering degree (Mamaril et al., 2016; Marra et al., 2009). However, research on gender differences in engineering student self-efficacy and changes in self-efficacy with time as it relates to the persistence of women in engineering programs can be conflicted in their conclusions. A longitudinal study of women throughout their engineering education found a loss of self-efficacy with time, most sharply after their first year of college, and the students who did not stay as engineering majors reported a lack of self-confidence as a barrier to completing their degrees (Brainard & Carlin, 1998). Based on the literature, women in engineering programs have indicated lower, the same, or higher self-efficacy than their male peers. In addition, other researchers have found that math and science performance does not account for the number of women pursuing careers in engineering (Nauta et al., 1998). Besterfield-Sacre et al (2001) surveyed first year students at two points throughout the academic year across fifteen institutions (public and private) using the Pittsburgh Freshman Engineering Attitude Survey (PFEAS) and found that women students exhibited lower self-confidence in their background knowledge and skills, problem solving abilities, and overall engineering abilities than their male identified peers. Survey results from the second time point showed changes in self-confidence were not consistent across the different schools, indicating a need to further investigate the role of curriculum, mentoring, and freshman engineering experiences, for example, in these differences (Besterfield-Sacre et al., 2001). A single time point survey of students in the engineering classroom found that women had lower self-efficacy and academic confidence than the men and these variables were strongly and positively correlated with GPA (Vogt et al., 2007). There are also studies that report no significant differences in self-efficacy with gender (Hackett & Betz, 1992; Malicky, 2003; Marra et al., 2007; Meinholdt & Murray, 1999; Schaefers et al., 1997). Some studies even note that women college students report high self-efficacy, which the authors reason may be because women who enter into engineering programs already feel confident in their abilities to complete their engineering degrees (Backer & Halualani, 2012).

Math readiness and preparedness are strong predictors of retention of all students in engineering programs (Moses et al., 2011). Maltese and Tai (2011) noted that poor math readiness will inhibit persistence in engineering, but a better predictor of persistence is interest in the career. In addition, other researchers have found that math and science performance does not account for the number of women pursuing careers in engineering. Besterfield-Sacre et al (2001) noted from their study of first year engineering students, that while women and men did not differ in measured skill level, women self-reported lower competency on engineering knowledge and skills. Women’s intention to persist in engineering has also been shown to depend on their belief in their ability to get good grades and mastering coursework, in contrast to men’s intention to persist based on their completion of coursework (Concannon & Barrow, 2010). Findings from prior empirical studies suggest that low numbers of women in engineering is not a result of poor math preparation. Recruitment and retention of women into STEM careers is more dependent on their interest in the field, self-concept, and the social support that they receive from peers and mentors that increase their sense of belonging in the field (Marra et al., 2007; Marra et al., 2009; Maltese & Tai, 2011).

Greater feelings of inclusion and belongingness increase student intentions to persist and actual retention in engineering programs. Low feelings of inclusion and belonging are often cited as reasons why students, particularly women and underrepresented students, leave STEM fields (Hausmann et al., 2009; Rainey et al., 2018; Strayhorn, 2018). A study by Rainey et al. (2018) indicated that white men are the demographic most likely to report a sense of belonging within STEM disciplines whereas women of color were the least likely, highlighting the structural and cultural features of universities, and the STEM curriculum and pedagogy that continues to privilege white men. Differences in feelings of belonging across genders may change throughout college, particularly between the first and second years. One study by Fowler and Meadows (2013) found that women begin college with a lower sense of belonging compared to their male peers but this difference decreases after the first year. Student involvement in clubs and activities early in their university career has been shown to increase their commitment to the university and in turn sense of belonging and persistence, as the involvement helps them feel like valued members of a community (Hausmann et al., 2009). Campus involvement has been shown to differ between genders, with women and minority students more likely to become involved in more professional development type activities than the majority of men, which helps to solidify their commitment and identification with the field (Holland et al, 2011). Belongingness of women students is also positively correlated with role models of the same gender, which has been shown to mitigate the effects of negative stereotypes and stereotype threat, a phenomenon where women are found to perform more poorly on tasks when primed with a stereotype of their gender (Dasgupta, 2011). Women students who have role models in "superior" positions can make upward social comparisons, which helps them feel more confident in their abilities and increases their sense of inclusion and belongingness in the field (Hoyt, 2013).

Study objectives

The purpose of this study was to better understand differences in women and men engineering students' self-efficacy at a small, private liberal arts engineering program in the US. The study is unique in that it is focused on student experiences from a small private liberal arts university (3700 undergraduates) with an engineering program offering Bachelors of Science degrees in Engineering. The engineering program consists of roughly 300 undergraduate students that take most of their engineering courses together throughout their undergraduate career. Data for this study was collected at two timepoints for a baseline assessment of the gender differences in the engineering student population. Data collected and knowledge of these differences across a variety of institutions will ultimately help identify gaps in academic, social, and emotional needs of students throughout their education process, with a recognition that these needs may be different across institution type, student genders, and timepoints throughout a students' academic career. Data collected will also help improve academic and social support systems for students as well as curriculum and pedagogical changes which may increase recruitment and retention of not only under-represented students but for all students. The research questions for this study were as follows:

1. Are there significant gender differences in engineering specific self-efficacy for engineering students at this small liberal arts university?

2. What academic preparation and performance factors are associated with higher engineering self-efficacy on 6 subscales for women? Factors include pre-college math preparedness, high school GPA, high school mentoring, and college extracurricular involvement.

METHODS

The current baseline study was an exploration of a subset of data from a larger study aimed at measuring engineering self-efficacy, math preparedness, and extracurricular involvement in students in addition to risk and resiliency factors. This study explored data related to students' initial contact with the survey (T1) during the first two years of data collection (2018-2020 pre-pandemic) from students in a small engineering program at a private liberal arts university.

Procedure

Measures used for the study were reviewed and approved by the Human Subjects Review Board (HSRB). All engineering students received the survey by email through the engineering student listserv during the first time point. At subsequent timepoints students were contacted by the listserv and previous participants were also contacted, in the event that any of the participants had changed majors or left the university. The email contained a link to a Qualtrics survey. Engineering instructors were also encouraged to remind students to participate in the study, and that their participation was voluntary and anonymous. Surveys were administered during the 2018-2019 and 2019-2020 (prior to COVID shutdown) academic years. The survey was left open for approximately 2 weeks to allow for student responses and once closed, the survey results were de-identified for further analysis. Students received a gift card to Amazon for their participation in the survey ranging from $20 to $30, with an extra incentive given to those who repeated the survey at multiple timepoints.

Data from each participant's initial baseline response was cleaned and any participant with missing data was removed from the dataset. For the purposes of the current analyses, data were included only from the first time point a participant engaged with the study. Initially, T1 responses from this data yielded 295 participants. However, 68 participants were removed due to incomplete data. As possible, between group analysis was conducted on completers versus non-completers (n=57) and there were no significant differences on demographic variables. Between group differences on other study variables could not be explored as this data was not available. An additional 5 were removed because gender was either not identified (n=3) or non-binary (n=2). As such, the final dataset used in this study included 227 participants (56 women).

Participants

All students, identified as engineering majors and over the age of 18, were eligible for participation. The survey was administered at a liberal arts university in the US with a small engineering program. The program awards Bachelor of Science degrees in Engineering, where students can select from an array of specialization areas including civil, computer, electrical, environmental, mechanical, or a custom area. (Environmental engineering was recently added as a specialization area, but it was not listed as an option in these surveys when administered, so students specializing selected “custom” if this was their specialization.) Students in the engineering program therefore take most of the same courses together throughout their undergraduate career, no matter their chosen specialization, until they get to the upper-level courses. Specializations are typically chosen by the spring of a student’s second year.

Program enrollment during this period was between 250 and 300 students, consisting of approximately 25% women identified students, compared to approximately 50% women identified at the whole university. The university census data categorizes gender into only two categories, women and men. The majority of declared specializations were mechanical, followed by civil, electrical, computer and finally custom. Class standing had a slightly larger number of first-year students as respondents which is expected due to this data being their initial contact with the survey. It is worth noting that five of the ten full-time tenure-track engineering faculty members at the time of the study identified as women.

A summary of the program and study demographics for the years when the survey was administered (academic years 2018-19 and 2019-20) are provided in Table 1.

Table 1. Engineering program demographics from this study compared with survey participation data.

	Program Census AY 2018-19		**Program Census AY 2019-20**		**Survey Data (2018-2020, T1)**	
	n	%	n	%	n	%
Gender						
Total	273		269		227	
Women	58	21%	50	19%	56	25%
Men	215	79%	219	81%	171	75%
Year in School						
First-year	82	30%	93	35%	90	40%
Sophomore	76	28%	66	25%	39	17%
Junior	51	19%	49	18%	61	27%
Senior	64	23%	61	23%	37	1%
Engineering Specialization						
Undeclared	179	66%	167	62%	–	-
Civil	23	8%	26	10%	54	22%
Electrical	10	4%	10	4%	28	12%
Mechanical	54	20%	54	20%	108	48%
Computer	5	2%	7	3%	13	6%
Custom	2	1%	5	2%	24	10%

Measures
The larger study included several different measures of self-efficacy and other risk and resilience factors related to the larger study. For this study, the following measures were included for analysis.

Demographics: Participants were asked a variety of demographic questions as part of this study.

Gender. Study participants were asked to report on gender on their self-identified gender. Respondents were given male, female, transmale, transfemale, non-binary, and other as options. Due to the low number of respondents in transmale, transfemale, non-binary, and other (n=5), these participants were removed from the study as they represent a specific and unique subset of individuals. Thus, for this study, gender was coded as dichotomous (male, female).

Race/Ethnicity. Participants were asked to report their race/ethnic identity and were provided with options including: White, Black/African American, Hispanic/Latinx, Asian/Asian American, Native American and other. This study's sample contained a high number of individuals who identified as White (n=212, 93%). As such, this variable was also dichotomously coded as white and non-white for the purposes of analysis.

Age and High School GPA. Participants were asked to self-report their current age and GPA in high school. These variables remained continuous for analysis. A dichotomous GPA and age score were computed using a median split to use in the final analytic model.

Pre-College Math Preparation. Study respondents were asked to report the highest math course taken prior to college. This variable was coded into calculus (n=147, 65%) and other non-calculus classes that included algebra, pre-calculus, trigonometry and statistics.

Engineering Extracurricular Involvement. Participants were asked to report their extracurricular involvement in engineering focused clubs. Survey items corresponded to the engineering student organizations including the American Society of Mechanical Engineers (ASME), American Society of Civil Engineers (ASCE), Institute of Electrical and Electronics Engineers (IEEE), Society of Women Engineers (SWE) and Engineers Without Borders (EWB). The Engineering Extracurricular Involvement variable was coded as yes/no regarding participation.

Mentor in High School. Student respondents were asked to report if they had a mentor in high school that helped foster their interest in engineering. This variable is coded yes/no.

Longitudinal Assessment of Engineering Self-Efficacy (LAESE). This assessment is a measure of engineering specific self-efficacy of undergraduate and graduate students (Marra & Bogue, 2006; AWE, 2020). This measure has been normed and validated with undergraduate and graduate engineering students (Marra & Bogue, 2006). It has been used by researchers seeking to better understand the self-efficacy of engineering students in a wide variety of programs at large public and private universities (Marra et al., 2009; Gaikwad & Kulkarni, 2016; Concannon & Barrow, 2010; Mamaril et al., 2016). Items address several aspects of self-efficacy including "barrier" situations, expected outcomes, expectation of workload, major selection, coping skills in difficult situations, career exploration and role models. The survey items address experiences inside and outside of the classroom, for example extracurricular activities and employment. The instrument consists of six-subscales which are determined through computing means of Likert-type responses to various prompts (where 1 = strongly disagree, 7 = strongly agree). Subscales include:

Engineering career success expectations. This subscale consists of 7 items that gauge respondents engineering career success expectations. It includes items such as "someone like me can succeed in an engineering career" and "a degree in engineering will allow me to obtain a well-paying job". The subscale has been shown to have acceptable internal consistency in other samples ($\alpha = 0.84$) (AWE, 2020) and in this sample ($\alpha = 0.76$).

Engineering self-efficacy 1. This subscale asks students about their perceptions of their future success in engineering. It includes 5 items such as "I will succeed (earn an A or B) in my engineering courses" and "I can succeed in an engineering curriculum while not having to give up participation in my outside interests (e.g., extracurricular activities, family, sports)". This subscale has been shown to have acceptable internal consistency in other samples ($\alpha = 0.82$) (AWE, 2020) and in this sample ($\alpha = 0.74$).

Engineering self-efficacy 2. This subscale gauges student confidence about completing required portions of an engineering degree and it includes items such as "I can complete the math requirements for more engineering majors" and "I can excel in an engineering major during the current academic year." It contains 6 items and has acceptable internal consistency in other samples ($\alpha = 0.82$) (AWE, 2020); however, in this sample acceptable internal consistency was not achieved ($\alpha = 0.68$). Due to unacceptable internal consistency, this scale was not included in the analysis for this study.

Feelings of inclusion. Questions on this subscale evaluate student feelings of inclusion in the field of engineering. It includes 4 items that ask questions such as "I can relate to the people around me in class" and "I have a lot in common with the other students in my classes". Internal consistency has been found to be acceptable ($\alpha = 0.73$) in other studies (AWE, 2020) and also in this sample ($\alpha = 0.81$).

Coping self-efficacy. This subscale contains 6 items and focuses on student coping strategies in difficult situations. Questions such as "I can cope with not doing well on a test" and "I can make friends with people from different backgrounds and/or values" are included. The scale has acceptable internal consistency (α = 0.78) (AWE, 2020) and also in this sample (α = 0.81).

Math outcome expectations. This subscale focuses on students' math outcome expectations and includes 3 questions such as "Doing well at math will enhance my career/job opportunities" and "Taking math courses will help me to keep my career options open". Internal consistency has been demonstrated to be acceptable (α = 0.84) (AWE, 2020) and also in this sample (α = 0.75).

Data Analysis

Data from the T1 surveys were included in this analysis and represents the student's baseline as part of the larger longitudinal study. Data from T1 was merged into a single dataset that included the variables of interest for this study. SPSS 27 was used to clean data, LAESE subscales were computed and analyzed for internal consistency. Demographics variables were re-coded to be dichotomous in nature and the analysis was conducted. As noted above, several students' data were removed due to incomplete responses (n=57) and no data imputation was done. Differences between completers and non-completers were explored on study demographic variables and no differences were found. The following analysis was conducted on the remaining complete 227 T1 responses.

After data cleaning, initial correlations were conducted to explore associations between study demographic variables and the LAESE subscales (Table 2). Pearson correlation coefficient was used to compute correlation between the study's continuous variables. Kendall's Tau was used to compute correlation coefficients between dichotomous and continuous study variables and chi-square tests were used to explore bi-variate associations between all dichotomous study variables (Table 3).

Finally, to test the primary hypothesis, a multivariate analysis of variance (MANOVA) was conducted to explore gender differences on the LAESE subscales while controlling for other study variables including any interactions. MANOVA is the appropriate statistical test due to the continuous nature of the study's dependent variables, which are moderately correlated and the dichotomous nature of the independent variables.

Table 2. Correlations between study variables

All participants	LAESE: Career	LAESE: Self-efficacy 1	LAESE: Inclusion	LAESE: Coping	LAESE: Math
Gender	0.01	-0.14	-0.03	-0.01	-0.07
Age (≥ 19.44)	-0.2	0.02	0.19*	0.01	-0.13*
Race (white)	0.01	0.08	0.04	0.05	0.02
Year in School (1st)	-0.04	-0.09	-0.07	0.01	-0.09
Specialization (Mechanical)	0.14	0.06	0.01	-0.03	0.05
HS GPA (≥ 3.55)	-0.04	0.18	0.04	0.01	0.06
Engineering Extracurricular (yes)	0.02	0.11	0.06	0.03	0.04
Math Preparation (calculus)	0.03	-0.28*	-0.03	0.04	-0.04
HS Mentor (yes)	-0.09	-0.07	-0.09*	-0.06	0.07
LAESE: Career	-	0.37*	0.46*	0.72*	0.59*
LAESE: SE1	-	-	0.42*	0.29*	0.21*
LAESE: Inclusion	-	-	-	0.32*	0.28*
LAESE: Coping	-	-	-	-	0.54*
Women					
Age (≥ 19.44)	0.01	0.42*	0.24*	-0.03	-0.21
Race (white)	0.05	-0.24	-0.15	-.16	-0.11
Year in School (1st)	0.02	0.26	0.18	-0.03	-0.17
Specialization (Mechanical)	-0.15	0.45*	0.15	-0.21	0.02
HS GPA (≥ 3.55)	0.14	0.19	-0.15	0.04	0.01
Engineering Extracurricular (yes)	-0.13	0.32	0.08	-0.14	-0.1
Math Preparation (calculus)	-0.08	-0.34	0.03	0.17	-0.05
HS Mentor (yes)	-0.04	-0.23	-0.11	0.01	0.02
LAESE: Career	-	0.21	0.09	0.59*	0.51*
LAESE: SE1	-	-	0.51*	-0.25	0.14
LAESE: Inclusion	-	-	-	0.01	-0.05
LAESE: Coping	-	-	-	-	0.52*
Men					
Age (≥ 19.44)	-0.02	-0.10	0.07	0.03	-0.09
Race (white)	-0.06	-0.06	-0.03	-0.05	0.05
Year in School (1st)	-0.05	-0.19*	-0.03	0.01	-0.09
Specialization (Mechanical)	0.11	0.06	0.05	-0.05	0.08
HS GPA (≥ 3.55)	-0.08	0.09	0.04	0.01	0.02
Engineering Extracurricular (yes)	0.04	0.14	0.12	-0.05	0.11
Math Preparation (calculus)	0.05	-0.25*	-0.04	0.02	-0.03
HS Mentor (yes)	-0.11	-0.06	-0.08	-0.09	-0.17*
LAESE: Career	-	0.34*	0.68*	0.68*	-0.09
LAESE: SE1	-	-	0.05	0.32*	0.15
LAESE: Inclusion	-	-	-	0.31*	0.46*
LAESE: Coping	-	-	-	-	0.48*

* Correlation is significant at the 0.05 level
Note: correlation coefficients presented for continuous and dichotomous using Kendall's Tau and Pearson for continuous variables

Table 3. Chi-square between dichotomous study variables by gender

	Total % (N=227)	**Women % (N=56)**	**Men % (N=171)**	χ^2	***p*-value**
Age (≥ 19.44)	48% (109)	51% (29)	46% (80)	0.42	0.51
Race (white)	91% (207)	92% (52)	91% (155)	0.25	0.78
Year in School (1st)	40% (90)	36% (20)	41% (70)	0.48	0.48
Specialization (Mechanical)	52% (119)	69% (39)	47% (80)	8.84	0.01*
HS GPA (≥ 3.55)	50% (108)	80% (42)	40% (66)	25.93	0.01*
Engineering Extracurricular (yes)	68% (155)	76% (43)	65% (112)	2.48	0.14
Math Preparation (calculus)	62% (141)	73% (41)	58% (100)	3.72	0.05*
HS Mentor (yes)	27% (62)	26% (15)	27% (47)	0.01	0.94

RESULTS

Descriptive Statistics

Demographics

Gender. Women comprised approximately 25% (n=56) of this study's sample and the remainder of the participants identified as Men (n=171).

Race/Ethnicity. This study's sample is largely white (91%, n=200). The remaining 9% (n=27) identified as African-American/Black (n=2), Asian/Asian-America (n=5), Hispanic/Latinx (n=10) and Prefer Not to Answer (n=9). Once recoded to dichotomous, this variable included White (91%, n=200) and Non-White (n=27, 9%)

Age. This sample included students ages 17-25. The mean age was 19.44 (SD 1.33). A dichotomous variable was created for those who were below 19.44 (n=118) and those above (n=109).

Year in School. This sample was largely first year students (40%, n=90), followed by third year students (27%, n=61), second year students (17%, n=39) and fourth year (15%, n=37). Once re-coded to a dichotomous variable, first-year students represented 40% (n=90) and non-first year students comprised the remaining 60% (n=137).

Engineering Specialization Area. Most students taking the survey reported an intent to specialize in Mechanical Engineering (48%, n=108). Additionally, students reported intent to specialize in Civil Engineering (22%, n=54), Electrical Engineering (12%, n=28), Custom Specialization (10%, n=24) and Computer Engineering (6%, n= 13). This was re-coded into Mechanical (48%, n=108) and Other (52%, n=119).

Grade Point Averages. Students were asked to self-report high school GPA. Respondents reported an average high school GPA of 3.55 (SD=0.43) and this was used to create a dichotomous variable at the mean split. This resulted in an even split below (n=108) and above (n=108) the mean. Eleven participants did not report their high school GPA.

Math Preparedness. A majority of students reported taking calculus in high school (63%, n=146). The remainder reported precalculus (27%, n=61), statistics (5%, n=11), algebra (3%, n=5) and trigonometry (2%, n=4). This variable was recoded to calculus (63%, n=146) and not calculus (37%, n=86).

Engineering Extracurricular Involvement. Most students reported being involved in general extracurricular activities (98%, n=227) and more than half reported involvement in an engineering specific extracurricular activity (70%, n=158).

High School Mentor. About half of students (54%, n=123) reported having a mentor in high school who supported their desire to become an engineer.

LAESE

The mean (x), standard deviation (SD), and range for the scores on the five scales on the LAESE were: career success expectations (x=43.83, SD=4.38, range=15 to 52), self-efficacy 1 (x=29.51, SD=4.38, range=5 to 35), inclusion (x=14.51, SD=2.67, range=4 to 20), coping self-efficacy (x=36.74, SD=4.25, range=11 to 47) and math outcome expectations (x=18.21, SD=2.58, range=5 to 23).

For women, scores on the five scales on the LAESE included career success expectations (x=44.05, SD=3.35), self-efficacy 1 (x=30.25, SD=5.76), inclusion (x=14.83, SD=2.27), coping self-efficacy (x=37.03, SD=3.71) and math outcome expectations (x=18.67, SD=2.19).

For men, scores on the five scales on the LAESE included career success expectations (x=43.76, SD=4.68), self-efficacy 1 (x=29.31, SD=3.95), inclusion (x=14.42, SD=2.79), coping self-efficacy (x=36.64, SD=4.42) and math outcome expectations (x=18.06, SD=2.69).

Exploration of Association Between Study Variables.

Correlations and Chi-square. To explore associations between study variables, tests of association were run. Pearson and Kendall's Tau correlations are presented in Table 2. These correlations indicate that a MANOVA is the appropriate analysis to explore between group differences and to control for the interrelatedness between these dependent variables. Additionally, it is noteworthy that there was only a weak association between gender and any of the LAESE subscales.

A series of chi-square tests were run to explore associations between the study's dichotomous variables. Female gender was associated with a specialization of mechanical engineering ($\chi^2(1, N=231)=8.84$, $p=0.01$) having a higher GPA in high school ($\chi^2(1, N=231)=25.93$, $p=0.01$) and taken calculus in high school ($\chi^2(1, N=231)=3.72$, $p=0.05$). No other demographics variables contained significant differences between groups (Table 3).

Multivariate Analysis of Variance (MANOVA)

Prior to conducting the MANOVA aimed at exploring gender differences on the LAESE subscales, a series of Pearson correlations was run on the dependent variables (LAESE subscales). While gender was not correlated with the LAESE subscales, the subscales were moderately correlated with each other (Table 2). Additionally, a series of Kendall's Tau correlations was conducted on study variables and the LAESE subscales for the whole sample as well as for women and men (Table 2). As no correlation existed for race, high school GPA and engineering extracurriculars, these variables were not included in the model. G*power was also used to compute power for this analysis and with the inclusion of over 171 respondents it was deemed that the MANOVA was sufficiently powered.

A MANOVA was run to test the primary hypothesis that there would be one or more mean differences on the LAESE subscales between men and women when accounting for age, year in school, math preparedness, high school mentor, and subspeciality (major) of engineering. Statistically significant MANOVA effects were obtained related to gender and math preparedness on the LAESE subscale scores in this model.

The homogeneity of variance assumption was tested for all subscales and yielded non-significant results. Based on a series of Levene's F tests, the homogeneity of variance assumption was considered met as none were statistically significant.

The math preparation (having taken calculus) and gender were both significant in the overall model (Table 4.) The math preparation was significant with a Pillai's Trace=.16 $F(5, 104)=3.93$, $p=.03$. The multivariate effect size was estimated at 0.16, which indicates that 16% of the variance in the dependent variables (LAESE subscales) was accounted for by math preparation. Gender was also significant with a Pillai's Trace=.10 $F(5, 104)=2.42$, $p=.02$. The multivariate effect size was estimated at 0.10, which indicates that 10% of the variance in the dependent variables (LAESE subscales) was accounted for by gender.

As the omnibus MANOVA was significant for gender and math preparation, the test of between subjects post-hoc tests were reviewed to determine the specific significant differences on the LAESE scales.

Table 4. Pillai's Trace results for math preparedness and gender.

	Multivariate Effect Size	F	Hypothesis df	Error df	Significance
Math preparedness	0.16	3.93	5	104	0.03
Gender	0.11	2.42	5	104	0.02
Post-hoc Analysis for Gender					
LAESE: Coping	0.03	2.3	23	202	0.05
LAESE: Math	0.09	10.26	23	202	0.01
Post-hoc Analysis for Math preparation (calculus)					
LAESE: SE1	0.13	17.04	23	202	0.01

Coping self-efficacy. Significant differences in gender were found on the Coping subscale (F (23, 202)=2.30, p=.05). This accounted for approximately 3% of the variance. Women in the sample reported scores on this subscale (x=37.01, SD=3.70) when compared with their male counterparts (x=36.65, SD=4.42).

Math outcome expectations. Women reported higher scores on the Math subscale of the LAESE (F (23, 202)=10.26, p=.01). This accounted for 9% of the variance. Women reported a mean score on this scale of 18.76 (SD=2.6) compared with their male counterparts who reported a mean score of 18.06 (SD=2.69).

Engineering self-efficacy 1. Those who had taken calculus in high school reported scores on the LAESE higher self-efficacy 1 (F (23, 202)=17.04, p=.01). This accounted for 13% of the variance. Those who took calculus in high school had a mean score on this scale of 30.84 (SD=2.67) compared with those students who had not taken calculus who reported a mean score of 27.52 (SD=5.61).

Interactions between these variables and gender did not yield significant findings.

A second MANOVA was conducted to explore this study's second question about factors that were associated with LAESE subscales for women. This model included age, race, year in school, high school GPA, high school mentor, engineering extracurriculars, math preparation and engineering specialization (major). There were no significant findings for the omnibus tests and therefore the test of between subjects post-hoc tests were not explored for this model.

DISCUSSION

This study's aim was to explore between gender differences in experiences and education as a means of understanding engineering self-efficacy as measured by LAESE. Women reported statistically greater high school GPAs and overall math preparedness (reported highest level of math classes taken before college), as demonstrated by Chi-square associations. Women also reported higher levels of involvement in engineering clubs, though not at a statistically significant level. The number of women who reported taking calculus prior to entering college was 73% compared with 58% of men which was statistically significant. Only weak correlations were found between gender and the LAESE subscales. A post-hoc analysis showed significant differences between genders on two of the LAESE subscales – math outcome expectations and coping self-efficacy – where women scored significantly higher than their male counterparts. There were insignificant gender differences on LAESE subscales of perceived self-efficacy, career expectations, and inclusion. These results are largely consistent with some studies that find no gender differences in self-efficacy (Hackett & Betz, 1992; Marra et al, 2007; Marra et al, 2012; Meinholdt & Murray, 1999) and inconsistent with others that found gender differences (Besterfield-Sacre et al, 2001; Malicky, 2003; Schaefers et al, 1997; Vogt et al, 2007).

The preparation and performance data, compared alongside the LAESE, indicate that academic preparation is correlated with self-efficacy. Students – both male and female – in the population who had taken calculus in high school reported greater self-efficacy. Women students began the program with statistically higher high school GPA and were more likely to have taken calculus in high school. With their better preparation, women reported higher feelings of math outcome expectations than their male peers who had lower high school GPA and less math preparation.

Women also reported a higher ability to cope with engineering education specific stressors as measured by the coping self-efficacy subscale. This subscale focuses on an individual's ability to cope with different college-focused situations. Research has demonstrated that women may have differential classroom based and academic experiences, such that understanding factors associated with improved stress tolerance may be important. Additionally, it is possible that as women learned to succeed in high school math and science that they also learned skills to cope with stress that allow them to be successful in college environments. This could be an important intervention factor with high school women and men to promote resilience in the college environment.

One might expect, based on their greater academic preparation and involvement, women students would have greater engineering self-efficacy specific subscale scores than the male students. However, no differences were found in self-efficacy between the genders. This may be related to different sociocognitive constructs of self-efficacy for women and men. Self-efficacy has been defined as mastery experiences and other sources of self-efficacy include social persuasion, vicarious experiences, and physiological states (Bandura, 1986). Previous studies have observed that women self-report lower competency on mastery skills related to engineering but show that women's actual skill levels do not differ from men (Besterfield-Sacre et al, 2001). Studies also suggest that men's self-efficacy beliefs are based on their ability to complete a course, while women's beliefs are based on getting an 'A' or a 'B' in a difficult course (Concannon and Barrow, 2010). In this study, male students with the same level of math preparedness (or lower) had greater feelings of engineering self-efficacy compared to the women students.

Interestingly, there was no significant difference between women and men in this study regarding reported feelings of inclusion measured by the LAESE subscale. It is important to note that at the time of this study, five of the ten full-time engineering faculty members in this program were women, which is much higher than the national average of about 18 percent in 2018 (Roy, 2018). The presence of such role models can serve as important "social vaccines" that mitigate the effects of negative stereotypes and increase feelings of inclusion (Dasgupta, 2011). However, this higher-than-average women/men faculty ratio may be important for offsetting differences in self-efficacy across the genders due to physiological states, particularly stereotype threat. Even just seeing other women as faculty members and as successful engineers has been shown to statistically eliminate gender differences in self-efficacy and in attrition rates (Bradburn, 1995). In fact, most of the first-year students at this university are introduced to at least one female faculty member early on in their engineering courses, since three of the five women faculty members teach at least one of the introductory engineering courses in the first-year curriculum.

One of the major limitations of this study was the lack of racial and ethnic diversity of the population in this engineering program, which was 93% white. This percentage was greater than the university undergraduate population which is about 80% white. The homogeneity of this sample population is a limit of this study, as the results cannot be mapped onto groups with greater racial and/or ethnic diversity, as these factors may play an important role in a respondent's feelings of belongingness and self-efficacy. The student population was also mostly traditional students who entered college immediately after high school, ranging in ages from 18-22, and therefore the results may not be generalizable to a population with an older student population. Additionally, the female students in the survey results are over-represented compared to the actual engineering student demographics, with 25% of the respondents self-identifying as women compared to the 20% in the engineering program. That being said, the expanded collection of LAESE survey responses across a variety of institutions and student populations can ultimately strengthen our national, or perhaps global, understanding of undergraduate engineering self-efficacy across time and institutional settings.

CONCLUSIONS

In the engineering program at this institution, about one in five students identify as female, with a predominantly white student-body. This study was a baseline assessment of gender differences in engineering self-efficacy at this university. Data from the first timepoint of the survey was used for the analysis and represents the students' baseline as part of the longitudinal study of many years of subsequent data collection and analysis.

MANOVA results were significant for math preparedness and gender. Post-hoc tests revealed significantly higher coping and math subscales for women. Women in the study entered college with higher levels of math preparedness and significantly larger high school GPAs. The women had stronger preparation, stronger academic performance (in high school), and higher engagement in engineering clubs, however, their engineering self-efficacy and sense of inclusion, as measured by the LAESE subscales, were no different than the men's. This data suggests that better preparation and stronger engagement may be necessary for women to feel the same level of self-efficacy as their male counterparts.

Though the number of undergraduate engineering degrees continues to rise in the United States, the proportion of women recipients remains static at 20% (NCSES, 2019). This statistic holds true for the engineering program in this study. And while there is evidence that women's interest in engineering wanes as early as middle school (Dasgupta & Stout, 2014; Maltese & Tai, 2011; Sontgerath & Demetry, 2019), improvements to recruitment and retention can still be impactful at the university-level. The results of this survey are useful for universities in two ways. First, the data highlight where gender differences exist in engineering students' experiences. Second, the results inform areas that require more data collection that will help to improve feelings of engineering self-efficacy for women identified students, especially during the first year of college. Given the well documented gender disparity in engineering majors, this early time point seems important, since this is when interventions known to increase student retention can be implemented.

Based on this study, in this engineering program, women reported greater levels of coping self-efficacy, as well as their math outcome expectations, compared to the men. Higher scores on the coping self-efficacy scale indicate that the women students feel more able to handle stressful situations – perhaps one of the reasons that they have persisted in the engineering pipeline that has many off-ramps for women. Women's stronger scores for the math outcome expectations suggest that they expect strong math skills to be a key requisite to excel in engineering. The data also showed that women began the program with higher math preparedness, suggesting women with lesser math preparation veered away from pursuing engineering because of their belief in its importance to the major. Significant differences in engineering self-efficacy, inclusion, and career expectations, as measured by LAESE, were not found between men and women, despite women's better pre-college preparedness and performance. However, future research should investigate which combinations of factors may help support and retain students in the program. Such factors include student age, year in school, engineering specialization area, mentoring experiences, and club involvement.

There was a significant correlation between women who studied mechanical engineering and self-efficacy that could be further explored. The mechanical engineering specialization is the most popular engineering specialization at this school and nationally, however, the proportion of women to men in this specialization is one the smallest (less than 15%). In comparison, the environmental engineering specialization has the largest percentage of women at this school and nationally, typically over 50% (Roy, 2018). Women who select the mechanical specialization may already feel confident in their ability to succeed in this typically male dominated field and have higher self-efficacy than their peers in other specializations with greater populations of women.

Active participation in student engineering clubs has been shown to increase a student's sense of commitment to the field and as a result increase their sense of belonging in a community (Holland et al, 2011). In this study, women students report more involvement in engineering clubs than their peers, with 76% of women students participating in engineering clubs while 65% of men participating in engineering clubs. One might expect, given the greater involvement of women in engineering clubs over their time as a student in the program, that it would increase their feelings of self-efficacy. Results from this study indicate that being a woman over 19 years of age is correlated with greater feelings of self-efficacy and inclusion. This may indicate that the farther along they were in their program the greater their feelings of self-efficacy and inclusion were. Those who had low self-efficacy and low feelings of inclusions may have left the program after age 19, typically their sophomore year. In future studies, it will be important to explore how engagement in extracurricular clubs may continue to support the feeling of inclusion for both women and men throughout their time in the engineering program.

Additionally, high school mentorship was not associated with greater self-efficacy, inclusion, coping, or math outcome expectations. While this study's sample of minoritized groups was too small to explore differences, the literature in this area suggest that women and minorities often do not have the same early experiences as their white-male counterparts. Furthermore, the literature argues that presence of female faculty may prevent women from feeling lower inclusion, self-efficacy, and belonging than men in their programs (Bradburn, 1995; Dasgupta, 2011; Hoyt, 2013). The high representation of women in the engineering faculty in this program (50%) may be another reason for the similar LAESE scores in self-efficacy among women and men. In this study, mentorship was analyzed as a dichotomous variable, and therefore no information was gleaned from the quality of mentorship students received. In future studies, the role of mentorship in combination with other factors (such as math preparation) should be explored as well as the quality of mentorship.

While the representation of female faculty members in this program far exceeds the national average, the percentage of women students does not. It will be important to explore the data further to understand the impacts of mentoring and student involvement, with the aim of providing insight on how to design interventions to improve recruitment and retention. Additionally, recruitment could be enhanced through expanding upon and advertising existing academic and social support systems deemed impactful. For example, peer and faculty mentorship programs could strengthen the appeal of the program and potentially increase feelings of self-efficacy and inclusion. Highlighting the strong representation of female faculty in the program, as well as the research and industry contributions of women and other minoritized individuals, could also serve as methods for attracting female students and fostering their sense of inclusion in the field of engineering.

The survey continues to be administered once per semester, such that future work will explore longitudinal trends over many years beyond this baseline analysis. Additionally, the survey results will be examined cross-sectionally by class year, to identify any changes in self-efficacy and feelings of inclusion over time. Finally, focus groups may provide different or enhanced insight into understanding gender differences of feelings of inclusion and may guide the design and study of interventions such as mentoring programs. Continued data collection and analysis will improve the understanding of engineering student recruitment and retention of underrepresented students in the field of engineering. Despite this study's limits, it provides additional information about the differential experience of women in engineering. Further, it reaffirms the need for academic engineering programs to continue efforts to design curriculum and experiences that are inclusive. Inclusive education supports the development of a diverse pool of future engineers upon which the field can continue to incorporate varied perspectives and grow in creative directions.

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REFERENCES

AWE: Assessing Women and Men in Engineering. (2020). http://aweonline.org/efficacy.html Accessed 23 June 2020.

Backer, P. R., & Halualani, R. T. (2012). Impact of self-efficacy on interest and choice in engineering study and careers for undergraduate women engineering students. Proceedings of the 119th American Society for Engineering Education Annual Conference and Exposition, San Antonio, TX.

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall.

Besterfield-Sacre, M.B., Moreno, M., Shuman, L.J., & Atman, C.J. (2001). Gender and ethnicity differences in freshman engineering student attitudes: A cross-institutional study. Journal of Engineering Education, 90, 477-490. https://doi.org/10.1002/j.2168-9830.2001.tb00629.x

Brainard, S., & L. Carlin. (1998). A six-year longitudinal study of undergraduate women in engineering and science. Journal of Engineering Education 87 (4): 369–75. https://doi.org/10.1002/j.2168-9830.1998.tb00367.x

Bradburn, E.M. (1995). Engineering gender roles: A self-efficacy model of occupational choice and persistence. Dissertation Abstracts International Section A: The Humanities and Social Sciences 55(7), 2146A.

Concannon, J. P., & Barrow, L. H. (2010). Men’s and women’s intentions to persist in undergraduate engineering degree programs. Journal of Science Education and Technology, 19(2), 133-145. https://doi.org/10.1007/s10956-009-9187-x

Dasgupta, N. (2011). In group experts and peers as social vaccines who inoculate the self-concept: The stereotype inoculation model. Psychological Inquiry, 22(4), 231-246. https://doi.org/10.1080/1047840X.2011.607313

Dasgupta, N., & Stout, J. G. (2014). Girls and women in science, technology, engineering, and mathematics: STEMing the tide and broadening participation in STEM careers. Policy Insights from the Behavioral and Brain Sciences, 1(1), 21-29. https://doi.org/10.1177%2F2372732214549471

Fisher, A.J., Mendoza-Denton, R., Patt, C., Young, I., Eppig, A., Garrell, R.L., Rees, D.C., Nelson, T.W., & Richards, M.A. (2019). Structure and belonging: Pathways to success for underrepresented minority and women PhD students in STEM fields. PloS one, 14(1). https://doi.org/10.1371/journal.pone.0209279

Fowler, R., & Meadows L. (2013). Assessing Gender Differences in First-Year Student Motivation. 120th ASEE Annual Conference and Exhibition, June 23–26, 2013, Atlanta, American Society for Engineering Education.

Gaikwad, H., & Kulkarni S.S. (2016). Self-Efficacy In Undergraduate Women In Engineering – A Case Study. Journal of Engineering Education Transformations, 30(1), 82-86.

Hackett, G., & Betz, N. E. (1992). Self-efficacy perceptions and the career-related choices of college students. Student perceptions in the classroom, 229-246.

Hausmann, L. R., Ye, F., Schofield, J. W., & Woods, R. L. (2009). Sense of belonging and persistence in White and African American first-year students. Research in Higher Education, 50(7), 649-669. https://doi.org/ 10.1007/s11162-009-9137-8

Holland, J.M., D.A. Major, V.J. Morganson, & K.A. Orvis (2011). Capitalizing on Opportunity outside the Classroom: Exploring Supports and Barriers to the Professional Development Activities of Computer Science and Engineering Majors. Journal of Women and Minorities in Science and Engineering 17(2), 173-192. https://doi.org/10.1615/JWomenMinorScienEng.2011002913

Hoyt, C. L. (2013). Inspirational or self-deflating: The role of self-efficacy in elite role model effectiveness. Social Psychological and Personality Science, 4(3), 290-298. https://doi.org/10.1177/1948550612455066

Malicky, D. A. (2003). Literature review on the under-representation of women in undergraduate engineering: Ability, self-efficacy, and the “chilly climate”. Proceedings of the annual meeting of the American Society for Engineering Education Annual Conference, June 22-25, 2003.

Maltese, A.V., & R.H. Tai (2011). Pipeline Persistence: Examining the Association of Educational Experiences with Earned Degrees in STEM among U.S. Students. Science Education 95(5), 877-907. https://doi.org/10.1002/sce.20441

Mamaril, N.A., Usher, E.L., Caihong, R.L., Economy, D.R., & Kennedy, M.S. (2016). Measuring Undergraduate Students’ Engineering Self-Efficacy: A Validation Study. Journal of Engineering Education, 105(2), 366-395. https://doi.org/10.1002/jee.20121

Marra, R. M., & Bogue, B. (2006). Women engineering students' self-efficacy--a longitudinal multi-institution study. Proceedings of the 2006 Women in Engineering Programs and Advocates Network (WEPAN) Conference. June 11-14, Pittsburgh, Pennsylvania, 2006.

Marra, R., Bogue, B., Rodgers, K., & Shen, D. (2007). Self-efficacy of women engineering students? Three years of data at US institutions. In Proceedings of the 2007 ASEE Annual Conference and Exposition, Honolulu, HI.

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009). Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy. Journal of Engineering Education, 98(1), 27-38. https://doi.org/10.1002/j.2168-9830.2009.tb01003.x

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2012). Leaving engineering: A multi-year single institution study. Journal of Engineering Education, 101(1), 6-27. https://doi.org/10.1002/j.2168-9830.2012.tb00039.x

Meinholdt, C., & Murray, S. L. (1999). Why aren't there more women engineers? Journal of Women and Minorities in Science and Engineering, 5, 239-63. https://doi.org/10.1615/JWomenMinorScienEng.v5.i3.30

Morris, M., Hensel, R., & Dygert, J. (2019). Why do students leave? An investigation into why well-supported students leave a first-year engineering program. In Proceedings of the 2019 ASEE Annual Conference & Exposition, Tampa, FL.

Moses, L., Hall, C., Wuensch, K., De Urquidi,K., Kauffmann, P., Swart, W., Duncan, S., & Dixon, G.. (2011). Are Math Readiness and Personality Predictive of First-Year Retention in Engineering? The Journal of Psychology 145(3), 229-245. https://doi.org/10.1080/00223980.2011.557749

National Center for Science and Engineering Statistics (U.S.) (NCSES) (2019). Women, minorities, and persons with disabilities in science and engineering: Special Report NSF 19-340.

Nauta, M. M., Epperson, D. L., & Kahn, J. H. (1998). A multiple-groups analysis of predictors of higher level career aspirations among women in mathematics, science, and engineering majors. Journal of counseling Psychology, 45(4), 483. https://psycnet.apa.org/doi/10.1037/0022-0167.45.4.483

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. International Journal of STEM education, 5, 1-14.

Roy, J. (2018). Engineering by the Numbers, Engineering Statistics. American Society for Engineering Education. http://www.asee.org/documents/papers-and-publications/publications/college-profiles/2018-Engineering-by-Numbers-Engineering-Statistics-UPDATED-15-July-2019.pdf. Accessed July 2020.

Schaefers, K. G., Epperson, D.L., & Nauta, M. M. (1997). Women's career development: Can theoretically derived variables predict persistence in engineering majors. Journal of Counseling Psychology, 44, 173-183. https://psycnet.apa.org/doi/10.1037/0022-0167.44.2.173

Sontgerath, M. S., & Demetry, C. (2019). Offering multiple STEM outreach touchpoints to middle school girls is associated with engineering and university recruitment outcomes. Paper presented at 2019 CoCECD - The Collaborative

Network for Engineering and Computing Diversity, April 14-22, 2019, Crystal City, Virginia, American Society for Engineering Education. https://peer.asee.org/31779.

Strayhorn, T. L. (2018). College students' sense of belonging: A key to educational success for all students. Routledge. https://doi.org/10.4324.9781315297293

Vogt, C.M., Hocevar, D., & Hagedorn, L.S. (2007). A social cognitive construct validation: determining women’s and men’s success in engineering programs. The Journal of Higher Education 78(3), 337–64. https://doi.org/10.1080/00221546.2007.11772319