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Impact of Stereotype Threat on Engineering Undergraduates*

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Efforts to increase diversity and inclusivity in engineering have had limited success in the United States where the percentage of women enrolling in engineering remains around 20%. One theory as to why women and minorities enroll in engineering at lower rates is stereotype threat which is the fear of fulfilling a negative stereotype about a group to which one belongs. In our study, we utilized Picho and Brown's Social Identities and Attitudes Scale (SIAS), which we adapted for engineering students, to measure stereotype threat vulnerability in engineering undergraduates in the southern United States. With 179 survey responses, we answered the following research questions: (1) Is the Social Attitudes and Identities Scale psychometrically sound when modified for engineering students? (2) What populations are most vulnerable to stereotype threat? (3) How does stereotype threat impact students in terms of the six constructs laid out within the Social Identities and Attitudes Scale? Our results show that the SIAS scale can be effective in measuring stereotype threat vulnerability in engineering students and that women are significantly more impacted by stereotype threat than any other group.

Keywords: diversity; inclusivity; stereotype threat; undergraduates

1. Introduction

Diversity and inclusivity have long been concerns within engineering. Within the United States, varying progress has been made in the admittance and retention of underrepresented groups; the national average enrollment rate for undergraduate women in engineering has remained around 20%, and 75% of professional engineers are still White/Caucasian [1]. These numbers indicate that in spite of efforts to make engineering more diverse and inclusive (e.g., recruitment programs, women in STEM movements), the engineering field continues to have persistent issues with diversity and inclusivity. One theory about why these issues may be ongoing is stereotype threat, which is the fear certain groups have of fulfilling a negative stereotype. Stereotype threat has a direct impact on student motivation and performance [2, 3]. In this paper, we report on our efforts to investigate a way to measure stereotype threat for undergraduate engineering students. Additionally, our study examines how stereotype threat may still exist in a college that has undergone measures to increase diverse student enrollment. By using a previously-validated survey instrument designed to measure stereotype threat across race and gender lines, we pinpoint which groups of students may still feel disenfranchised despite increased recruitment and retention measures.

1.1 Theoretical Approach: Stereotype Threat

Stereotype threat refers to an individual's fear of conforming to a negative stereotype [3]. The term *stereotype threat* was first coined by Steele and Aronson in 1995, but the idea of negative stereotypes impacting individuals was not a new concept. Researchers had long acknowledged that stigma can negatively impact the formation of identity [4] and harm individuals socially and psychologically [5]. Steele and Aronson's novel study showed that stereotype threat could be induced and directly impact student performance [3]. Fig. 1 provides an overview of stereotype threat and highlights the conditions that result in performance interference (i.e., both knowledge of a stereotype and application to one's self within an assessment situation). The figure emphasizes that an individual must have a knowledge of a negative stereotype plus an awareness of how it applies to themselves within a diagnostic situation (i.e. a testing environment, for women it would be a STEM test where women are expected to underperform) in order to experience stereotype threat.

Once it was understood that stereotype threat had measurable consequences on performance, researchers began attempting better understand its mechanics. Through repeated experimental tests, researchers were able to show that stereotype

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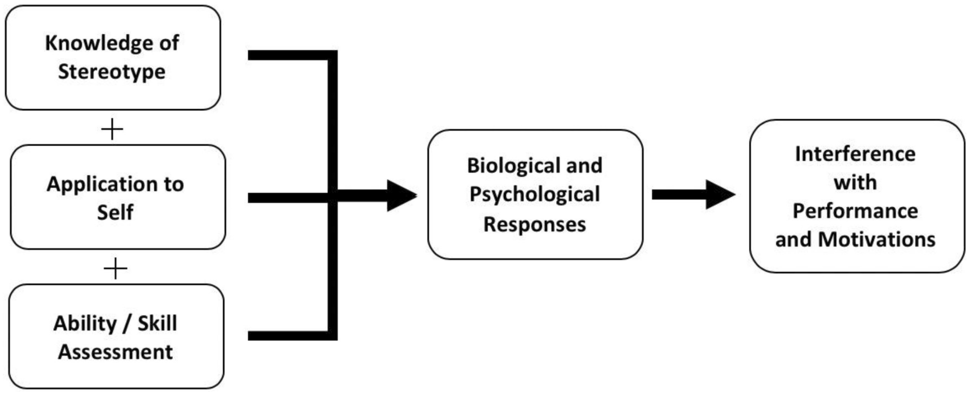

Fig. 1. Illustration of the Stereotype Threat Model.

threat created biological responses that directly impacted working memory [6] and caused a disruptive mental workload [7] that directly impacted a student's ability to perform during testing [8]. Researchers found that they could also alter the impact of stereotype threat through its inducement and mitigation [9, 10]. Through these experiments, they discovered that stereotype threat had two requirements in order to occur: (1) the individual must have a situated identity that can be impacted by the stereotype; and (2) the individual must have knowledge of, and partially believe in, the negative stereotype [9–11]. For these reasons, stereotype threat is dependent on the beliefs already held within a culture and can be utilized to reveal hidden barriers to minority populations.

Examinations of gender and cultural stereotypes in engineering have shown negative performance impacts during stereotype threat conditions. For example, an examination of introducing the Fundamentals of Engineering Exam as either diagnostic (thus introducing stereotype threat), non-diagnostic (which mitigated stereotype threat), or gender-fair (which highly mitigated stereotype threat) found that stereotype threat could significantly and negatively impact women's performance on the challenging examination [12]. Another performance-based study investigated how engineering students evaluate gender-typical speech acts, and found that students greatly undervalue "feminine" speech patterns and believe that feminine speech indicated a lowered ability to present technical work [13]. This view of gendered speech acts could explain why a recent study found undergraduate engineering teams tend to have female members present less technical portions of group presentations and answer fewer technical questions [14]. Other stereotype threat investigations have considered gendered stereotypes in combination with ethnic and cultural stereotypes. For example, Villa and colleagues interviewed undergraduate engineering students in Mexico and found that cultural stereotypes cast engineering as a profession unsuitable for women [15]. Marsden and colleagues investigated barriers to first generation, immigrant, and female students to an industrial engineering program in southern Germany [16]. They concluded that being a member of minority group (female or immigrant) resulted in negative impacts; however, membership in a minority group in the majority (first-generation) mitigated impacts resulting in higher satisfaction with the program. For a more detailed review of stereotype threat literature, the reader is referred to [17, 18].

With both gender and cultural stereotypes consistently producing negative performance impacts, the need to support underrepresented minorities in engineering is an issue of international concern. Our investigation focuses on the validation and application of a survey instrument designed to measure stereotype threat across race and gender lines in engineering within the context of the rural southern United States. Following psychometric validation, the survey instrument can be used in other engineering contexts worldwide.

1.2 Rural Southern United States Study Site

Our study was conducted at a university with total enrollment of over 22,000 students and an engineering total enrollment of nearly 5,000 students. Majority of students are local (64% in-state, 33% out-of-state, 3% international). Undergraduate engineering programs are ABET-accredited and both the undergraduate and graduate engineering programs in the top 100 nationwide [19]. The college of engineering has been consistently ranked as a top research university [20].

The study site was located in the rural southern United States, the "deep-south", which is known for being entrenched in stereotypes regarding women and minorities (for examples see [21–23]). Due to its rural location, there is a lack of access to science education, especially in poorer communities that lack the ability to travel [24]. The more conservative nature of the area can also impede women

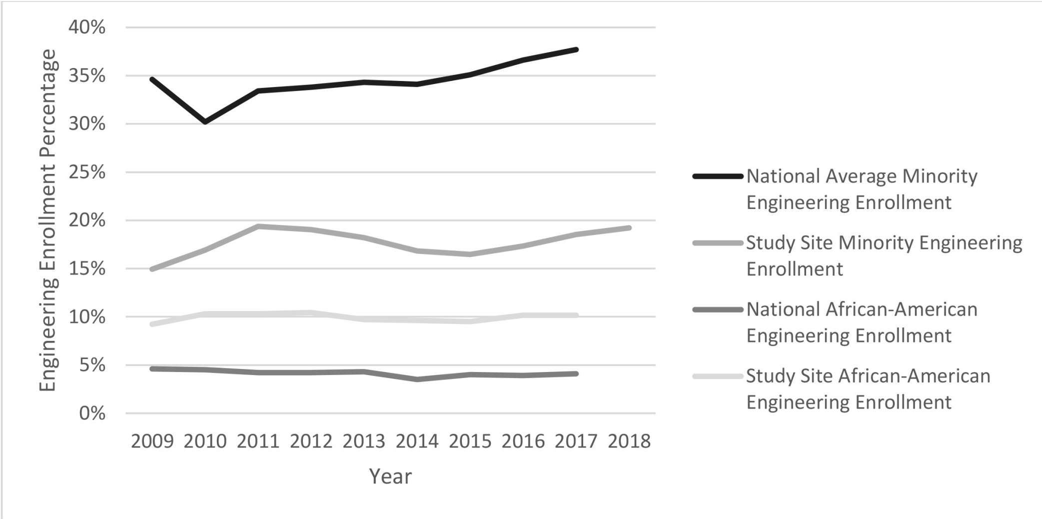

Fig. 2. Minority and African-American student enrollment rates as compared to national averages; data from [30, 31].

from pursuing degrees in stereotypically more "masculine" fields and there is increased pressure to obey gender roles [25].

The study site was founded after the Morrill Act of 1862, was segregated until 1965, and did not allow the regular admittance of women until 1932 [26, 27]. Despite having a historical barrier to women and minorities, the university now boasts a nearly equivalent male and female enrollment rate and a slightly higher than average African-American enrollment (19% as compared to a national average of 15%) [28], [29]. The high African-American enrollment is most likely partially due to the university's location in a State that has higher than average percentage of African-American residents [29]. Despite the university boasting a higher than average African-American enrollment rate, the college of engineering has historically fallen below national averages in terms of minority student enrollment (Fig. 2). While the national average minority student enrollment has been increasing since 2010, the college of engineering had a negative trend until 2015 at which point the college's trend began to become positive.

In our examination of diversity, we also considered how the college compared to national averages in terms of female enrollment. We observed a slightly below average female enrollment in comparison to national averages from 2005–2015 (Fig. 3). From 2015 onward, the college boasted slightly above average female enrollment including 22.5% enrollment in Fall 2018 [32].

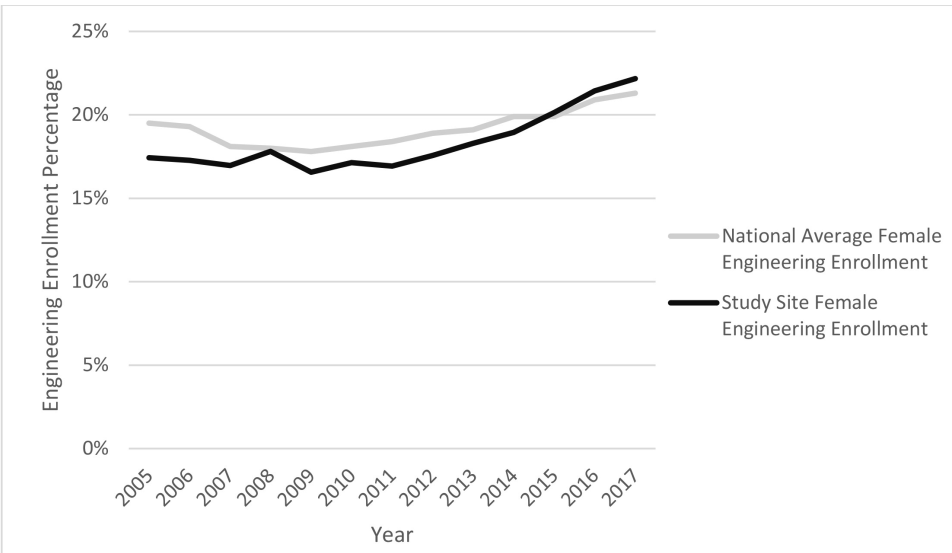

Fig. 3. Comparison of study site to national female engineering enrollment rate; data from [30, 31].

The upticks in African-American and female student enrollment around 2015 is partially attributable to a university-wide strategic diversity plan introduced in 2013. In the plan, the college of engineering claimed that they had "a mission to increase the participation of minorities and women in the field of engineering" [33]. The plan did not contain specific action details, but following the strategic plan, the college diversity office increased their minority focused recruitment. For instance, one such program is focused on the introduction of engineering to middle school girls with a mission to "demonstrate that girls can maintain their personal identity while pursuing technical majors and career paths" [34]. These programs are often free or offer scholarships in order to serve populations that may otherwise not be introduced to engineering due to its rurality and lower-income populace [24, 35]. The enrollment rate of women and minorities in engineering increasing since 2015 does indicate that the diversity movements are working to recruit a more diverse population, but we do not fully understand how these changes are impacting the students once they enroll in engineering in terms of stereotypes about women and minorities.

1.3 Purpose of Study

The purpose of this study was to understand the degree to which stereotypes are present in a college of engineering located in the rural south that recently completed a push for diversity. The instrument utilized collected data on both gender and ethnic stigmas, thus this was an intersectional investigation. Our research questions were as follows: (1) Is the Social Attitudes and Identities Scale psychometrically sound when modified for engineering students? (2) What populations are most vulnerable to stereotype threat? (3) How does stereotype threat impact students in terms of the six constructs laid out within the Social Identities and Attitudes Scale? We hypothesized that the Social Attitudes and Identities Scale, which was design to investigate stereotype threat vulnerability broadly, will be effective to measure stereotype threat vulnerability in engineering students. We also hypothesized that women and African American students will have significantly higher rates of stereotype threat vulnerability.

2. Methods

2.1 Instrument

For our study, we utilized a previously validated Likert-scale instrument, the Social Identities and Attitudes Scale (SIAS) [11], which measures stereotype threat with six subscales: Math Identity, Gender Identity (GI), Gender Stigma Consciousness (GSC), Ethnic Identity (EI), Ethnic Stigma Consciousness (ESC), and Negative Affect (NA). As defined by Steele, stereotype threat requires that the individual have a high personal value within the affected domain (i.e., race, gender, or the field itself) as well as a knowledge and belief that negative stereotypes impact them [36]. The identity related constructs (Math Identity, GI, EI), therefore, all measure the degree to which the participants value their gender, race, and participation in math in order to establish that the participants have value in those domains. GSC and ESC measured the degree to which participants believe that their gender and ethnicity impact their interactions with other people, including professors and other students. The NA subscale was developed to measure negative feelings experienced during testing that could negatively impact math identity. These six subscales together form a multidimensional, intersectional measure of stereotype threat that measures identity and stigma consciousness across race, gender, and math.

The SIAS is the only survey instrument that has been developed to measure stereotype threat directly. Other than our work presented in this paper, the only other study to examine stereotype threat with the SIAS was a pilot study examining criterion validity [17]. The pilot study found low correlation between math emotions (boredom and anxiety) and GSC, which was discussed as evidence that the SIAS scale may not reliability measure stereotype threat. However, the pilot finding is situated within multiple limitations and produces the recommendation to examine the SIAS scale in future studies with a more diverse participant pool and domain specific questions.

The original scale was designed to measure stereotype threat in STEM fields broadly, which all require a background in Mathematics. Thus, Mathematics Identification was included in the original scale. However, our study was limited to engineering students specifically. Thus, the inclusion of *mathematics identity* rather than *engineering identity* did not fit. Therefore, we modified the scale by replacing the word "math" with "engineering" throughout the instrument. This modification changed the six Math Identity questions to Engineering Identity (EngID) and modified the section for NA. In order to ensure that these changes did not overly impact the instrument, we conducted Confirmatory Factor Analysis (CFA) to revalidate the SIAS model fit for the engineering field. See Table 1 for the constructs, their acronyms, and what they mean. The questions in the revised instrument were on a 7-point Likert-scale from Strongly Disagree to Strongly Agree, which followed the original instrument design.

Table 1. SIAS Scale constructs and meaning

Construct	Acronym	Meaning
Engineering Identity	EngID	Measures the degree to which the students value engineering and see a future within it.
Gender Identification	GI	Measures the degree to which the students value their gender and relate it to their identity.
Gender Stigma Consciousness	GSC	Measures the degree to which students are aware of stigmas attached to their gender.
Ethnic Identification	EI	Measures the degree to which the students value their ethnicity and relate it to their identity.
Ethnicity Stigma Consciousness	ESC	Measures the degree to which students are aware of stigmas attached to their ethnicity.
Negative Affect	NA	Negative feelings experienced during testing.

2.2 Participants and Recruitment

We emailed the electronic survey to all undergraduate students in engineering. Additionally, we forwarded the survey through email lists to student groups for underrepresented students to ensure that we collected enough minority and female student responses for statistical testing. Participant recruitment for this study happened through three different rounds of email recruitment over a six-week period, which included a one-week university holiday. The first distribution was through an email listserv of all undergraduate engineering students at the university as well as by contacting select student groups. The groups that were contacted during the first round were student chapters of the Society of Women Engineers, Women in Computing, the Society of Hispanic Professional Engineers, and the National Society of Black Engineers. The first round of recruitment resulted in 126 responses with 60 women, 62 men, 1 non-binary, and 3 preferring not to answer. The first-round racial demographics did not reflect college averages with 101 Caucasian responses, 10 Black/African American, 4 Hispanic/Latinx, 4 Asian, 4 mixed race, and 2 preferring not to answer. Based on these numbers, we decided to conduct additional rounds of recruitment.

Subsequent recruitment was targeted and occurred two weeks after our initial recruitment. For the second round of data collection, we used diversity data for engineering majors and recruited through specific departments in attempts to rectify the racial imbalance. We found that the lowest responses in majors came from aerospace, computer, electrical, petroleum, and software engineering and computer science. Computer, electrical, and software engineering and computer science also both have higher enrollment rates of Black/African American and Asian students. Students in all four of the identified majors were contacted to encourage their students to participate. After the second data collection, we netted 177 complete responses but still had a low response rate from Black/African American students and Asian students. The low response rate did not reflect the study site's college of engineering racial profile. Due to no on-campus group for Asian students, we chose to only contact the National Society of Black Engineers once more for participants. We sent the final recruitment to the National Society of Black Engineers five-weeks after our original email, which was immediately following a one-week university holiday. After waiting one-week, at which point the survey had been open for six-weeks, the survey had 179 complete responses. At this point, we ended data collection.

3. Results

3.1 Confirmatory Factor Analysis

Due to our survey alteration, we conducted statistical analysis to revalidate the model fit for engineering. We first conducted a confirmatory factor analysis (CFA) in order to ensure that the model maintained good fit with the modification. Using SPSS AMOS, we conducted the model fit analysis and found that there was only a moderate model fit, $\chi^2(390) = 793.39$, $p < 0.001$, CFI = 0.894, TLI = 0.884, RMSEA = 0.076, 90% [0.069, 0.084], SRMR = 0.065. In an effort to create a better model fit, we consulted the modification indices (M.I.) for items that reported higher levels of error covariance. After examining the modification indices, we found that the highest covariance (M.I. = 52.21) existed between the first and third questions in the Negative Affect section (questions 25 and 27). The questions were extremely similar in nature which was likely causing the conflation. Negative Affect question 3 (question item 27) was therefore removed from the model, which did improve the model fit but still did not create a satisfactory fit, $\chi^2(362) = 677.893$, $p < 0.001$, CFI = 0.908, TLI = 0.897, RMSEA = 0.070, 90% [0.062, 0.078], SRMR = 0.067. For a better model fit, we found that two of

Table 2. Demographic data of the participants

Gender	Number of Participants	Race	Number of Participants
Man	92	White/Caucasian	137
Woman	82	Black/African American	20
Other	5	Asian	8
		Hispanic	5
		Other	9

the Gender Identity questions that had the second highest covariance (M.I. = 35.55) and deleted the fourth gender ID question (question item 10). By deleting these two questions, we created satisfactory model fit, $\chi^2(335) = 606.163, p < 0.001$, CFI = 0.917, TLI = 0.906, RMSEA = 0.068, 90% [0.059, 0.076], SRMR = 0.066.

3.2 MANOVA

Before conducting our multivariate analysis of variance (MANOVA) we had to reduce the number of categories for gender and race due to lower response rates. In our survey, we allowed participants to answer outside of the gender binary with non-binary, prefer to self-describe, and other all listed as potential other options. Due to the low response rate for those categories, we sorted all non-binary responses into an "Other" category which reduced the amount of potential error. Race/Ethnicity was similar in that we allowed for self-identification and the selection of multiple options, but due to the wide variety of answers, we created an "Other" category in order to capture lower response results. The demographic data is in Table 2.

The questions related to each of the six constructs (GI, GSC, EI, ESC, EngID, and NA) were averaged together for each participant resulting in six subscale averages per participant. The average score for each construct and the participants' gender and ethnicity were then analyzed utilizing IBM SPSS 25. We ran a two-way between-subjects MANOVA with $p < 0.05$ with gender, ethnicity, and the interaction of race and gender as our independent variables and the six subscale scores as the dependent variables. The complete results are in Table 3 with the areas of significance bolded.

Our MANOVA found no significant differences across the constructs in ethnicity or the interaction of gender and ethnicity. However, there was a statistically significant difference in gender, $F(12, 322) = 2.82, p < 0.001$; Wilk's $\Lambda = 0.816$, partial $\eta^2 = 0.097$. A one-way ANOVA was then conducted with gender as the only independent variable in SPSS. The ANOVA found significant difference in GI, $F(2, 178) = 15.57, p < 0.001$; GSC, $F(2, 178) = 22.63, p < 0.001$; ESC, $F(2, 178) = 4.38, p = 0.014$; and NA, $F(2, 178) = 6.64, p = 0.002$. We then conducted a Bonferroni post hoc test, and found the significant differences were between men and women and not with the "Other" category. The

Table 3. Results of the MANOVA with *F* statistic and *p* values reported

	Construct	*F*	*p* Value
Gender	Engineering ID	2.284	0.105
	Gender ID	4.572	**0.012**
	Gender Stigma	12.036	**0.000**
	Ethnic ID	2.282	0.105
	Ethnic Stigma	7.125	**0.001**
	Negative Affect	2.656	0.073
Ethnicity	Engineering ID	0.315	0.868
	Gender ID	0.454	0.769
	Gender Stigma	1.652	0.164
	Ethnic ID	1.971	0.101
	Ethnic Stigma	1.855	0.121
	Negative Affect	1.867	0.118
Gender* Ethnicity	Engineering ID	0.903	0.494
	Gender ID	0.792	0.578
	Gender Stigma	1.828	0.096
	Ethnic ID	1.314	0.254
	Ethnic Stigma	1.792	0.104
	Negative Affect	1.499	0.181

Table 4. Bonferroni post hoc results with mean and standard deviations

		M	SD	*p* Value
Gender ID	Men	2.8693	1.64263	< 0.001
	Women	4.1138	1.24974	
Gender Stigma	Men	2.8103	1.44189	< 0.001
	Women	4.1927	1.31973	
Ethnic Stigma	Men	2.3348	1.41331	= 0.023
	Women	2.9024	1.36743	
Negative Affect	Men	2.6587	1.71189	= 0.001
	Women	3.5610	1.48787	

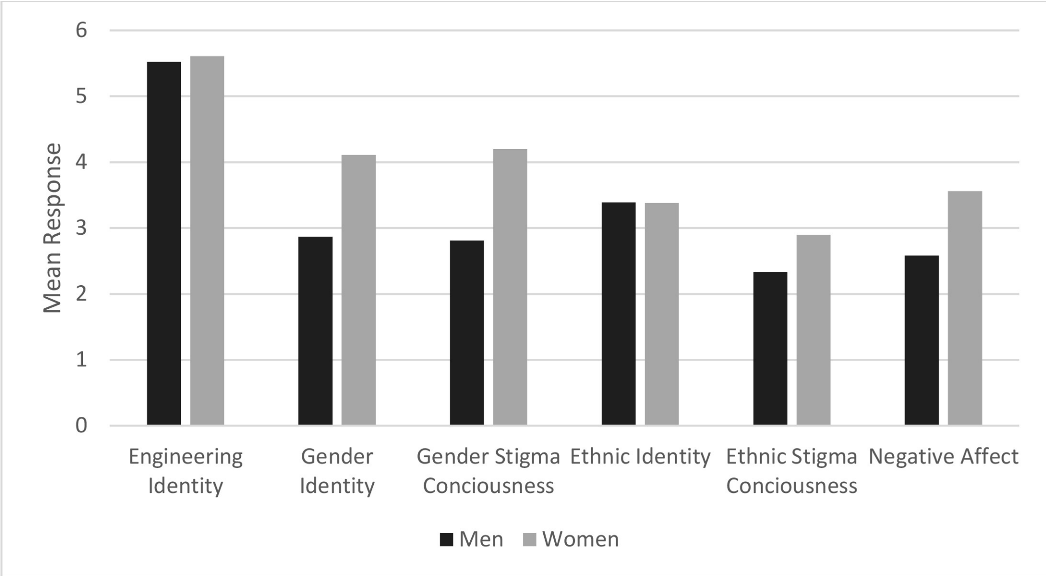

Fig. 4. Comparison of means between men and women across the constructs.

means, standard deviations, and Bonferroni *p* values are reported in Table 4. Fig. 4 displays the means for men and women across the 6 different constructs.

4. Discussion

After CFA, we found that the SIAS instrument can be effectively utilized to measure stereotype threat within engineering. While the instrument did initially have some model fit issues due to covariance, we were able to resolve these issues by modifying the survey and removing 2 questions that had higher covariance. Each construct therefore was addressed through 3–6 questions. We hope that our study motivates additional examinations of stereotype at the intersection of gender and race so that we can better understand the phenomena and design interventions to support underrepresented student groups. We suggest that future studies begin with the entire instrument as our covariance errors may have been due to our low response rate.

We acknowledge that a recent pilot study, the only other study to use the SIAS, was conducted independently and concurrently with our work presented in this paper. Leker's pilot study cast some doubt on the SIAS criterion validity due to low correlation between negative math emotions and stigma consciousness [17]. Our results do not add to Leker's discussion because we did not measure criterion validity. However, we note that Leker's pilot study did not reveal significant differences between men and women for gender stigma consciousness, whereas our study did. We encourage future investigators considering the SIAS to review the findings from both our work and Leker's pilot study before modifying the SIAS.

Our results indicate that stereotype threat impacts women in engineering significantly more than men, regardless of race. The low response rate of minorities in the survey could have been a reason that we were unable to find significance between ethnicities or the interaction of gender and ethnicity. However, ESC was significant at a $p = 0.05$ level at a gender level. This indicates that women encounter more stigma in engineering both in regards to their gender and ethnicity. The reasoning for this could be due to increased solo-status for women of color. However, due to our data having low minority participation, future research with a larger sample size should investigate further into why ESC was only significant for gender and not ethnicity nor the interaction of gender and ethnicity is warranted.

By better understanding how stereotype threat impacts women, we can create better strategic plans for their recruitment and retention. Our survey results indicate that strong stereotypes about women in engineering still persist and interrupt their interactions with their peers and professors despite there being a growing number of women matriculating through the program. Based upon our results, the colleges of engineering should focus efforts to dispel stereotypes about women in engineering and work to create a more inclusive environment for women. Future research should be conducted to address the format, content, and timing of these interventions.

The location of this study is important as stereotypes and the threats they present can be impacted culturally. For this university, even after implementing a plan to create inclusive environments for women and minorities, it appears that gender stereotypes are still present and directly impacting the motivations of women in the college of engineering. This could be due to the rural south having more "traditional" cultural ties that can create bias against women in technical fields [24, 35]. Our result appears consistent with Villa and colleagues' qualitative investigation of undergraduate engineering students in Mexico [15], another study site described as a "traditional" culture. Since, the SIAS measures student perceptions rather than actual cases of stereotypes in action, further research should investigate how students' perceptions developed as well as investigate specific cases in which participants cited their gender/ethnicity being a barrier within engineering.

The last area that was significant in the survey was NA. NA was defined as negative feelings associated with engineering tests and is very similar to self-efficacy [11]. Researchers have long acknowledged that women in engineering have lower levels of self-efficacy than men [37, 38], but as of yet, researchers have failed to explain why this phenomena occurs. Our results indicate that stereotype threat could be a potential explanation into why women have significantly lower confidence in their own abilities. Stereotype threat builds within a context and causes there to be a mental overload that directly impacts performance. Because women are more aware of their gender and stigmas associated with their gender, they are then more susceptible to other threats to their identities and stereotype threat as a whole. In order to address NA and lowered self-efficacy for women, our results suggest that we must first address negative stigmas associated with women in engineering.

5. Conclusions

Research Question 1: Is the Social Attitudes and Identities Scale psychometrically sound when modified for engineering students?

Based on our results, the SIAS scale can be effectively used within engineering. The survey instrument had moderately good fit when modified. After the elimination of two of the questions that had the highest modification indices, the model had satisfactory fit. Future research should be conducted with a larger study population, to examine if the modifications described herein are necessary to ensure construct validity for using the instrument in engineering contexts.

Research Question 2: What populations are most vulnerable to stereotype threat?

Our results indicate that women, regardless of ethnicity, are impacted by stereotype threat across 4 of the six constructs. This means that women on average undergo stereotype threat to a significantly higher degree than men. Therefore, future recruitment and diversity efforts at this university should be focused more on gender diversity and inclusivity in order to rectify their lowered diversity levels. However, this result could be due to the lower response rate from ethnic minorities but relatively high response rate of women in engineering.

Research Question 3: How does stereotype threat impact students in terms of the six constructs?

Women overall had higher GI, GSC, ESC, and NA, meaning that they are significantly more vulnerable to stereotype threat in 4 of the 6 constructs measured. Women place more value in their gender than men while also perceiving that their gender and ethnicities negatively impact their interactions with peers and professors at higher rates. These factors together could also be contributing to the negative feelings that women report experiencing at higher degrees during difficult engineering tests.

6. Future Work

Our research contributes to the literature on stereotype threat in engineering by providing a first application of the SIAS instrument on engineering students and by allowing a first-look into how stereotype threat exists at an engineering college that has a diversity action plan ongoing. However, future researchers should continue to investigate how ethnicity impacts students in engineering as well as if the culture of their area impacts the significance of the different constructs. Additional quantitative investigations utilizing the SIAS will strengthen the external validity of the instrument as well as provide a more complete understanding of academic barriers for underrepresented groups. Qualitative studies should be conducted in order to better understand why women are reporting higher levels of stigma consciousness and negative feelings during testing.

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