

## **Investigating the Participation and Belongingness of Women in Engineering through Cultural Comparisons**

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## **Abstract**

The severe under-representation of women in the engineering profession observed in the United States is not consistent around the world. Significant variations in women's participation in engineering among countries imply a cultural effect. This study demonstrates an inverse relationship between a culture's Hofstede's Cultural Dimension of Masculinity and women's participation in engineering. Hofstede's Cultural Dimension of Masculinity was applied to US subcultures to better understand the role of US subcultures on women's representation in engineering degree programs. This study also compared perceptions held by engineering and health and human services students regarding relative suitability of people of their gender for careers in their fields, relative difficulty associated with working in their profession for people of their gender, and gender biases in their discipline as well as student's sense of belonging in their discipline. The analysis used survey data collected from 613 students in the college of engineering and the college of health and human services at California State University, Fresno, a Hispanic Serving Institution. Differences in perceptions of gender-based suitability and levels of belongingness were observed between ethnic groups. A relationship between perceiving women to be less suitable for engineering and perceptions of increased difficulty for women in engineering was also observed.

## **Introduction and Background**

Although the number of engineering bachelor's degrees awarded to women in the United States increased noticeably in the 2010s [1] after decades of lackluster growth, women, especially Black and American Indian / Alaska Native women, remain under-represented in engineering relative to their proportion of the US population. To improve the representation of women in engineering from under-represented minority (URM) backgrounds, it is important to expand the body of literature investigating this topic from an intersectional identity perspective. This paper presents two related studies conducted by the authors, which seek to provide insight into the relationship between culture and women's participation and belongingness in engineering. The first study analyzes the relationship between national levels of women's participation in engineering and nations' Hofstede's Cultural Dimension of Masculinity vs. Femininity Index. The second study is a case study at California State University, Fresno, regarding gender-related perceptions held by undergraduate students.

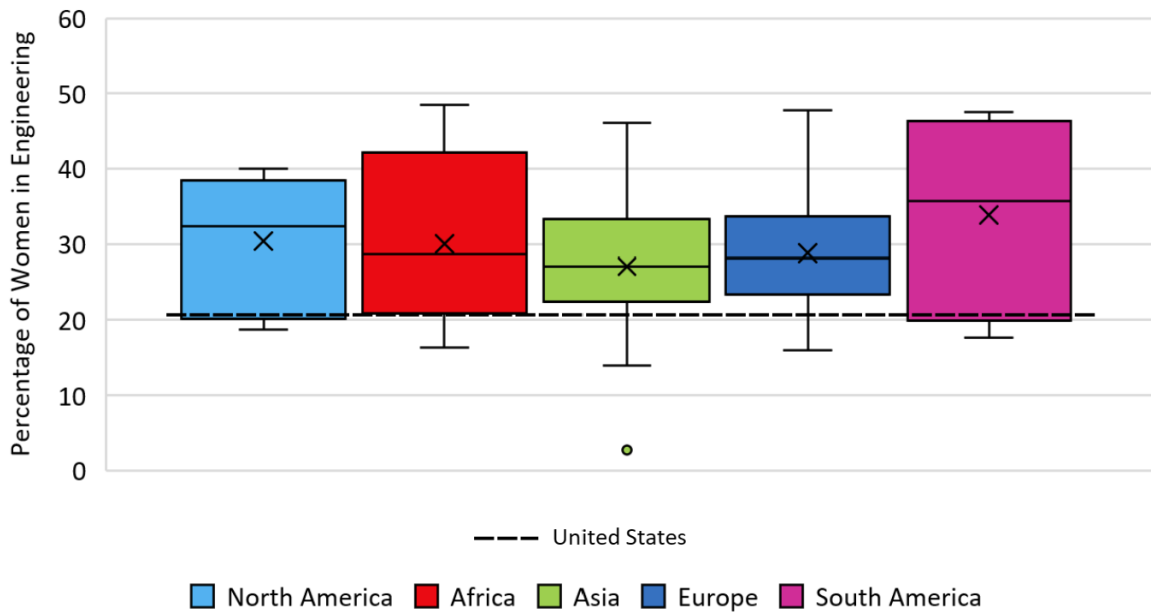
As of 2019, women earned 23.0% of engineering bachelor's degrees awarded to US citizens and permanent residents. The majority of these women (59.6%) were White, which corresponds to 13.7% of the overall engineering bachelor's degree recipients. Black, Hispanic, and American

Indian or Alaskan Native women (collectively classified by NSF as URM women) constituted just 4.1% of US citizens and permanent residents earning engineering bachelor's degrees [2]. Demographics of US citizens earning bachelor's degrees in engineering are summarized in Table 1 alongside corresponding U.S. population demographic data pertaining to ages 20 - 29, the age group most representative of bachelor's degree recipients [3]. Data for intersectional demographics (gender and ethnicity) is shown for women only. By comparing the percentage of engineering bachelor's degrees awarded to each demographic to that demographic's percentage of the US population ages 20 to 29, it is apparent that women of all ethnicities are underrepresented, with the exception of Asian women. Black / African American women and American Indian / Alaskan Native are the most acutely underrepresented, followed by Hispanic women.

**Table 1. 2019 demographics of engineering bachelor's degree recipients and US population ages 20 to 29 [2]**

Gender, Race/Ethnicity	Engineering BS degree recipients		US Population ages 20 to 29		Representation: Ratio % Engineering BS degrees to % US Population
	Number	%	Number	%	
All US citizens	115,439	100.0	45,141,956	100.0	1.0
All Men	88,872	77.0	23,069,322	51.1	1.51
All Women	26,567	23.0	22,072,634	48.9	0.47
Hispanic	3,374	2.9	4,733,443	10.5	0.28
American Indian / Alaskan Native	83	0.1	187,837	0.4	0.17
Asian	3,907	3.3	1,415,265	3.1	1.07
Black / African American	1,323	1.1	3,242,522	7.2	0.16
Native Hawaiian / Pacific Islander	37	0.03	45,662	0.1	0.32
White	15,839	13.7	11,822,005	26.2	0.52
More than 1 race	1,231	1.1	625,900	1.4	0.77
Other / Unknown	773	0.67	-	-	-

While women remain significantly under-represented in engineering programs in the United States, the participation of women in engineering varies throughout the world, with countries such as Algeria, North Macedonia, and Peru nearing gender parity in engineering bachelor's degree programs [4]. In recent years, women constituted between 47.5 and 48.5% of bachelor's degree recipients in these countries. Figure 1 shows the percentage of women earning bachelor's degrees in engineering across the five largest continents. Data on the percentage of women in engineering pertaining to individual countries was obtained from the report by UNESCO [4] and combined based on their continents. Furthermore, the median percentage of women in engineering in North America is 32.35%, compared to 28.6% in Africa, 27.12% in Asia, 28.2% in Europe, and 35.65% in South America. This indicates that Asia has the lowest median percentage of women in engineering, and South America has the highest median percentage of women in engineering. This is in contrast with engineering participation between ethnicities in the US, where Table 1 shows that Asian Americans are the only ethnicity to surpass gender parity in favor of Women.

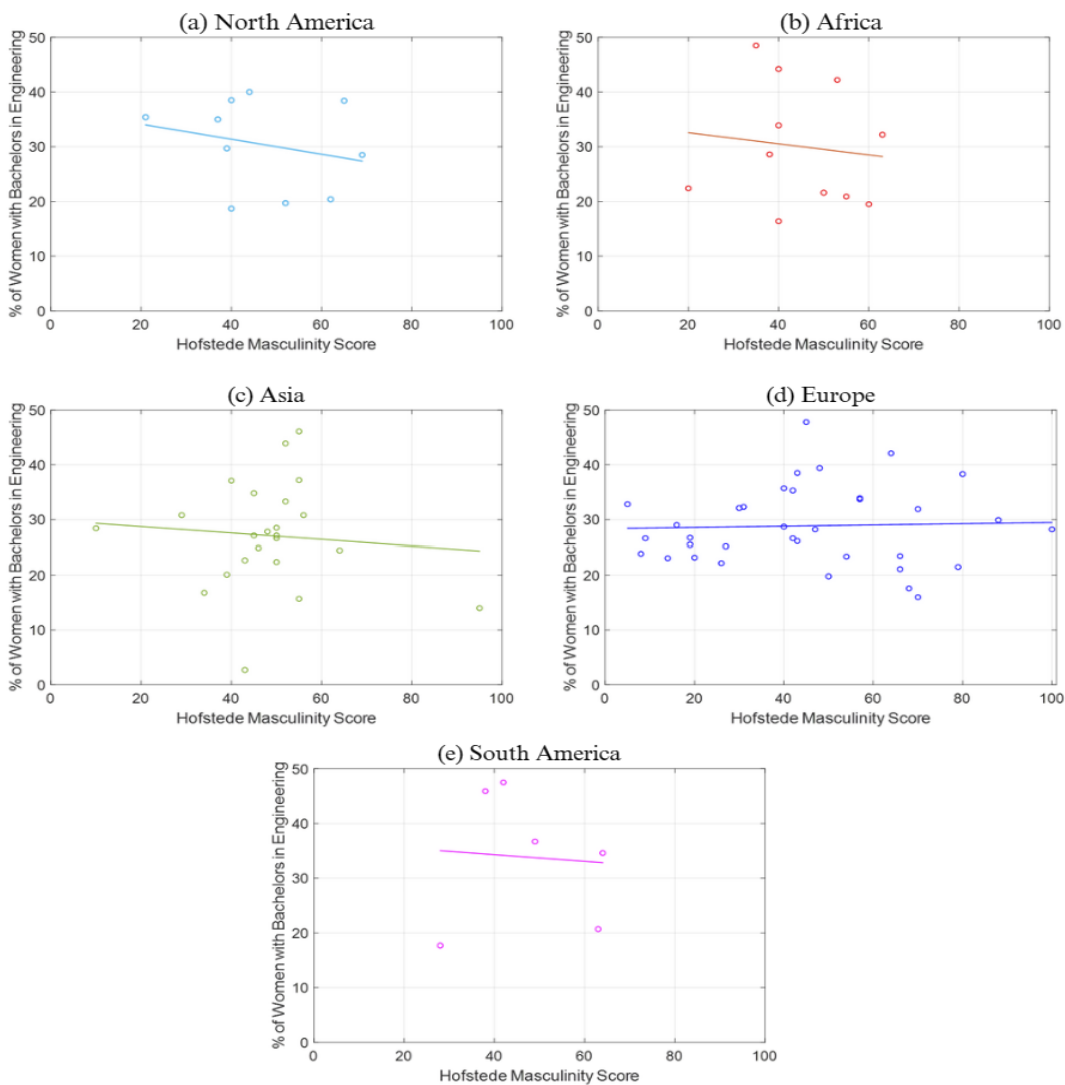


**Figure 1. Proportion of engineering bachelor's degrees awarded to women in the world vs. the United States [4].**

Figure 1 shows the percentage of women earning engineering bachelor's degrees in the United States (20.4%) is near or below the 25th quartile of each of the continents displayed. This is paradoxical considering that the United States ranks in the top 1/3 of countries in terms of national gender equality [5]. However, studies have shown that women's attainment of STEM degrees is inversely proportional to national gender equality [6, 7].

## Study 1: Women's Participation in Engineering vs Hofstede's Masculinity Index

The authors of the presented study sought to determine whether Hofstede's Cultural dimension of Masculinity vs. Femininity could provide a more intuitive explanation of variations in women's participation in engineering between countries. Hofstede's Cultural dimensions set forth a framework by which national cultures can be characterized and compared using four indexes: Power Distance Index, Individualism versus Collectivism, Masculinity vs. Femininity, Uncertainty Avoidance Index [8]. The Masculinity vs Femininity index (MAS), is a measure of the degree to which men are expected to exhibit more assertive, success focused traits as opposed to being tender and concerned with the quality of life [9]. Higher MAS scores are indicative of more pronounced gender role expectations. Figure 2 displays the relationship between Hofstede's masculinity score [10] and the percentage of women in engineering by country [4].



**Figure 2. Relationship between national Hofstede Masculinity Scores and proportion of engineering bachelor's degrees awarded to women in engineering for a) North America, b) Africa, c) Asia, d) European countries, and e) South America [4, 10].**

Figure 2 shows that for all continents except Europe, higher Hofstede's masculinity is inversely proportional to the percentage of Women in engineering with North America showing the greatest representation of this trend. Given this relationship, the United States' relatively high MAS score could be a contributing factor to the United States' relatively low proportion of women earning engineering degrees.

Further understanding of the under-representation of women in engineering considering intersectional identities of gender and ethnicity was investigated. Limited studies have attempted to apply Hofstede's Cultural Dimensions to sub-cultures within the United States. In particular, Duncanson et al. [11] determined that African American subculture has a lower MAS score than the average US MAS score and Fadil [12] was not able to show that the MAS score of Hispanic Americans was significantly different from either US or Hispanic MAS scores. Given that Mexican-Americans are the largest Hispanic population group in the United States, it is reasonable to assume Hispanic Americans would have a MAS score in the range between the US MAS score (62) and Mexico's (69). Based on these scores for African Americans and Hispanic Americans, the proposed relationship between Hofstede's masculinity vs. femininity index and women's attainment of degrees in engineering would indicate that Black women would be represented in engineering degree recipients at higher proportions than women overall and Hispanic women would be represented at similar proportions as women overall. However, these are contrary to the data presented in Table 1 in which both Black and Hispanic women earn engineering degrees at noticeably lower rates than US women overall.

## **Study 2: Gender-related Perceptions Survey of Undergraduate Students at CSU Fresno**

The presented study sought to investigate whether gender related perceptions held by students from US subcultures were correlated with differences in intersectional gender and ethnic demographics of collegiate programs with significant gender disproportionality. The study was conducted at California State University, Fresno, a Hispanic-Serving Institution (HSI) and Asian American Native American Pacific Islander Serving Institution (AANAPISI). This study stems from a portion of a larger voluntary survey that was conducted at California State University, Fresno in Spring 2018 with IRB approval, garnering responses from 1119 undergraduate students from four colleges (engineering, science and math, business, and health and human services). The composition of the survey and the institutional context are fully discussed in Oka and Stillmaker [13], and the demographics of the survey respondents are presented in Stillmaker, et al. [1]. Because the current study seeks to investigate disciplines with gender under-representation, only responses from students of the Lyles College of Engineering (LCOE) and the College of Health and Human Services (CHHS) were analyzed. Departments surveyed within the LCOE include Civil and Geomatics Engineering, Construction Management, Electrical and Computer Engineering, and Mechanical Engineering. Departments surveyed within the CHHS include Communication Disorders, Nursing, Public Health, and Social Work. At the time of the

survey, the departments surveyed within these colleges contained an average of 14% women for the LCOE and 82% women for the CHHS. The other two colleges in the survey were considered gender balanced. The analysis presented herein used survey data collected from 272 students in the LCOE (88 women, 180 men, and 4 non-binary individuals) and 341 students from the College of Health and Human Services (307 women, 31 men, and 3 non-binary individuals) for a total of 613 respondents [1].

The presented study analyzes the responses to the following key survey questions:

1. People of my gender are more, less, or equally suited for this field relative to other genders.
2. It is more, less, or equally difficult for people of all genders to work in the industry related to my major.
3. A gender bias exists towards my gender in my major that is unfavorable, favorable, or no bias.
4. I feel like I belong in my major.

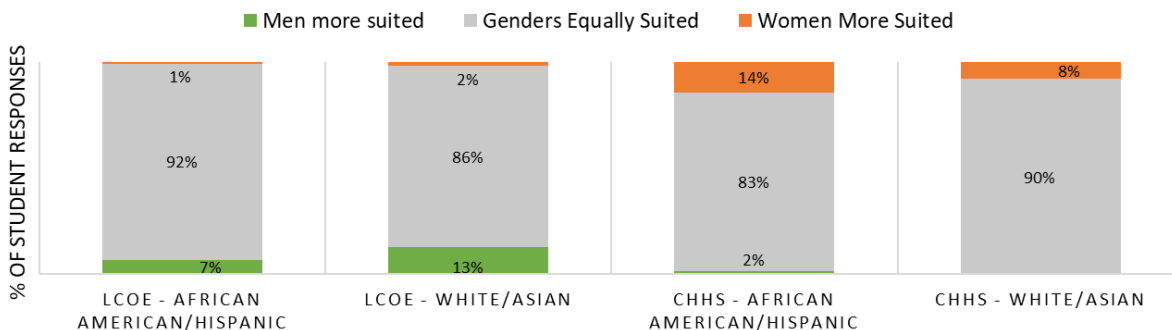
Question 1 aims to investigate internalized gender bias held by the respondent, while questions 2 and 3 investigate perceptions respondents hold regarding gender-based obstacles in their academic and professional environments (i.e. factors external to individuals). Question 4 investigates students' sense of belonging within their major. Questions 1 through 3 were intentionally phrased to avoid a binary perspective of gender, which would be alienating to non-binary respondents. Given the small number of non-binary responses, these responses are omitted from the presentation of analysis. Men's and women's responses were aggregated such that the aggregated responses had the same sentiment, e.g. women who selected "my gender is less suited for my field" were aggregated with men who selected "my gender is more suited for my field."

Responses were analyzed based on respondents' ethnicity. While ethnicity is not necessarily synonymous with culture, it is assumed in this study that ethnicity-based observations are indicative of the associated culture. In analyzing student responses, the surveyed participants were separated by college. Within each college, respondents were pooled into either a Black/African American and/or Hispanic group (both identified as under-represented minorities by NSF) or a White and/or Asian group (not identified as under-represented minorities by NSF). For participants identifying as having more than one race, if at least one of the ethnicities identified was Black/African American or Hispanic, they were placed into that group. Because this study was conducted at an HSI, the Black/African American and/or Hispanic group is largely dominated by Hispanic respondents. Data labeled "All Ethnicities" includes respondents not contained in the Black/African American and/or Hispanic Group nor the White and/or Asian group, e.g. those who indicated non-resident alien or "Do not wish to disclose" as their ethnicity.

The ethnic groups used are disaggregated in some analyses to try to avoid masking in-group differences, however, this leads to small sample sizes, which should be considered when interpreting these results.

### California State University, Fresno Survey Results and Analysis

*Question 1:* Figure 3 summarizes student responses to question 1 by college and ethnic grouping. While the majority of respondents from each of these categories indicated that all genders are equally suited, in the LCOE, a *higher* proportion of students in the Black/African American and/or Hispanic group held this perspective while in the CHHS, a *lower* proportion of students in the Black/African American and/or Hispanic group held this perspective. Among those who indicated one gender was better suited, the vast majority of respondents from each demographic category indicated the gender that constitutes the majority in that field was better suited, i.e. men in engineering and women in health and human services. In LCOE, White and/or Asian group expressed this majority-favoring bias at nearly double the proportion of the Black/African American or Hispanic group. In the CHHS, the White and/or Asian group expressed this majority-favoring bias at nearly half the rate of Black/African American and/or Hispanic group.

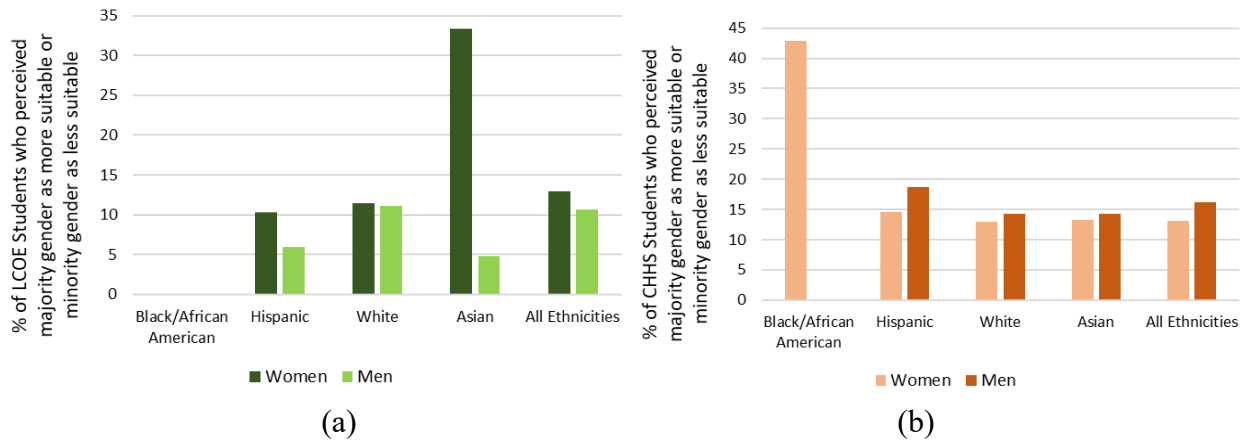


**Figure 3. Student perceptions of gender suitability for engineering related (LCOE) and health and human services related careers (CHHS).**

Overall, 12.9% of women in LCOE perceived women to be less suited for their field of study, and 10.6% of men in LCOE perceived men to be more suited for their field of study. Similarly, in CHHS, 16.1% of men perceived men to be less suited for their field of students and 13.1% of women perceived women to be more suited for their study. Thus, in both colleges, the minority gender expressed a slightly higher perception towards favoring the majority gender as more suited or regarding the minority gender as less suited. Figure 4 further disaggregates the engineering students who held these perceptions by ethnicity. It is interesting to note that none of the Black/African American respondents from LCOE expressed a majority favoring bias. Yet in CHHS, black women expressed the highest proportion of majority favoring responses. It also stands out that while proportions of white men and women in LCOE were very similar, the proportion of Hispanic women respondents was slightly higher than Hispanic men and the

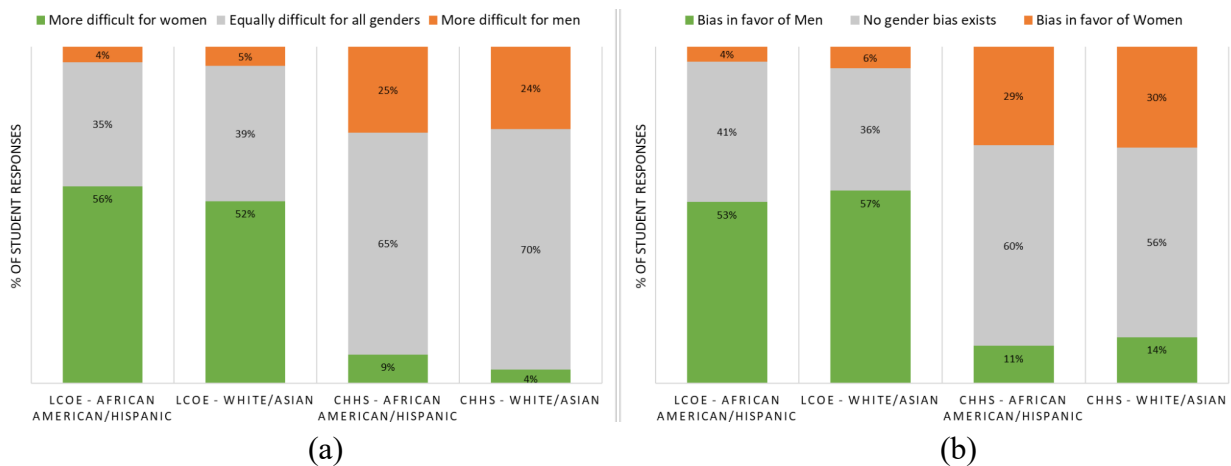


proportion of Asian women was much higher than Asian men. Across all ethnic groups and both colleges, the minority gender reported perceiving their own gender as less suited for the field at equal or higher rates than the majority gender reported perceiving their gender as more suited.



**Figure 4. Proportion of students perceiving the minority gender to be less suited for engineering or the majority gender to be more suited for a) engineering related and b) health and human services related majors disaggregated by gender and ethnicity.**

*Questions 2 and 3:* The responses questions 2 and 3 are summarized in Figures 5a and 5b, respectively. There were no statistically significant differences observed between the Black/African American and/or Hispanic respondents and the White and/or Asian respondents in either college. However, differences *between* colleges were observed. Significantly higher proportions of students in LCOE perceived it to be harder for the minority gender in their field compared to students in CHHS. Similarly, significantly higher proportions of LCOE students perceived a bias exists in their field in favor of the majority gender compared to HHS students.



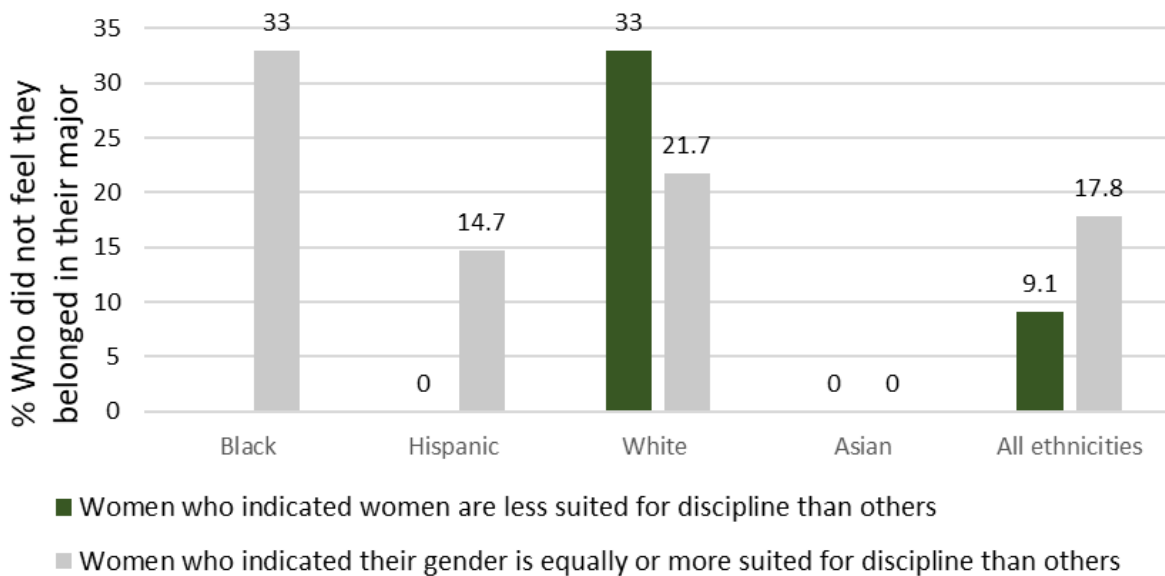
**Figure 5. Student perceptions of a) relative gender-based difficulty to work in engineering related (LCOE) and health and human services (HHS) related careers and b) gender biases in these fields.**

Despite the student perspectives indicating a significantly grimmer environment for women in engineering than men in nursing, the women constituted a similar proportion of LCOE enrollment as men constituted in CHHS. This difference in perception between colleges could indicate that these perceptions disproportionately discourage women from pursuing engineering related careers relative to men pursuing health and human services careers, which could explain the relative low participation of women in engineering compared to other countries. Considering that these responses are only from students who are already pursuing degrees in these colleges, it is possible that these perspectives were developed while in the degree programs and may not accurately reflect perspectives held by individuals at the time of selecting a major.

Because differences exist between the proportion of Black/African American and/or Hispanic students and White and/or Asian students who view their discipline's minority gender as being less suitable for their field of study in spite of similar perspectives on gender related difficulties and biases (i.e. external factors) associated with their disciplines, these differences cannot be attributed to culturally held beliefs about the difficulties and bias. To investigate whether the difference between these two ethnicity groupings in LCOE could be attributed to individuals' perspectives on the external factors, student perceptions on gender suitability were analyzed again with consideration to whether the respondents perceived external factors to be adverse to the minority gender in their field. LCOE students who perceived their discipline to be more difficult for women were more likely to perceive women to be less suited for their discipline. No difference in perceptions of suitability of women was found between students who did or did not perceive there to be a bias against women in their discipline. Thus, the perception of others' biases did not appear to influence their own bias, whereas the perceptions of difficulty did. Analyzing the relationship between survey responses in the opposite direction found similar results. LCOE students who indicated women were less suited for their discipline were more likely to perceive the field to be more difficult for women, but were not any more likely to perceive a bias against women existed in their discipline.

*Question 4:* Overall, 24.4% of women (n = 102) and 50% of non-binary (n = 4) students in LCOE reported not feeling that they belong in their major, compared to only 10.5% of men. The data indicated that Black women in LCOE most frequently expressed not feeling like they belonged (33%), followed by White women (23%), then Hispanic women (15%), and finally Asian Women (0%). The higher rate of belonging among Hispanic women, relative to White women is contrary to findings by others [14], but may be attributed to the fact that Hispanic is the largest ethnic group in LCOE. Note that the feeling of not belonging expressed by Black, White, and Hispanic women is inversely proportional to their representation in the LCOE [13]. Asian women's responses stood out as an anomaly to this trend in that Asian women constitute a similar proportion of the college's population as Black women, yet none of the Asian women respondents from LCOE indicated not feeling like they belonged in their major.

Given the importance of a sense of belonging for retention of women in engineering [15], this study sought to understand the inter-relationship between the women’s perceptions regarding the suitability of women in engineering related fields and students’ sense of belonging. Figure 6 displays the percentage of LCOE women respondents who did not feel they belonged in their major compared based on whether they perceived women to be less suited for their discipline. Note that zero Black women indicated women are less suited for their discipline, so there is only one bar shown for Black women. Also note that zero Asian women reported not feeling like they belonged, despite that demographic having the highest proportion of responses indicating women were less suited for engineering. While caution should be used in making inferences from these small data sets, these results appear to indicate overall and for Hispanic women in particular, women who perceived women to be less suited for engineering were *less* likely to feel as though they didn’t belong. This is unexpected, but could be interpreted as some of these women feeling that they are different from typical women, meaning that while they perceive women in general to be less suited for engineering, they themselves feel they belong in that field. The opposite trend is seen in White women’s responses. Women who reported perceiving women to be less suited for engineering were more likely to not feel that they belonged in their field.



**Figure 6. Percentage of LCOE women who did not feel they belonged in their field of study.**

## Discussion and Conclusions

The Hofstede Masculinity score data presented in the first study implies that the United States’s high Hofstede’s masculinity score could explain the low rate of women’s pursuit of engineering degrees. Looking at ethnic groups within the United States, masculinity scores of US subcultures did not explain the varying levels of under-representation of women, which points to the presence of other impeding factors. Further investigation of cultural influences could lead to solutions that could increase women’s participation in engineering.

Survey results analyzed in the second study indicated differences between demographic groups in perceptions of gender suitability for gender-disproportionate fields of study, perceived gender-based difficulty and bias in these fields, and sense of belonging within these majors. A key observation was that the rate at which women reported perceiving women to be less suitable for engineering was inversely related to the National under-representation of the respondents' ethnicity. I.e., the most under-represented ethnic group of women in engineering degree recipients in the US (Black/African American) showed no gender bias, whereas the only ethnic group of women to be over-represented in engineering (Asian) reported the highest gender bias against women in engineering. The degree to which women engineering students internalized bias against their own gender is concerning, however, based on this inverse correlation with under-representation, it does not appear to explain varying levels of participation in engineering among US subcultures. A relationship between perceiving women to be less suitable for engineering and perceptions of increased difficulty for women in engineering was observed. Survey responses also indicated a positive correlation between the number of women from a particular culture within LCOE and the rate at which this demographic of women felt they belonged in their major for Black, Hispanic, and White women, underscoring the importance of better connecting and increasing the number of women from under-represented ethnic backgrounds to improve belongingness in engineering. Asian women were an exception to this trend, reporting the highest rate of belonging while being one of the smallest demographic groups in the LCOE and also reporting the highest rate of perceiving women to be less suitable for engineering. With the exception of White women, women who held a perception of women being less suited for engineering did not report lower rates of belonging relative to women who did not perceive women to be less suited. The analysis of belongingness based on perceptions of women's relative suitability for engineering related disciplines merit further research to better understand the phenomenon.

Given the limitations associated with small sample sizes in this study, particularly for Black women, further study on this topic with a larger sample would be ideal. To better understand the influence of US subcultures on women's participation in engineering and whether the perceptions analyzed in this paper are shared throughout the subculture or are unique to individuals who choose to study engineering, and whether they are developed as a result of studying in an engineering program, surveys should also be conducted including individuals outside of engineering. Similar investigations in the engineering industry may also be warranted to provide increased insight into improving women's belongingness in the engineering industry and reducing attrition rates of women from the engineering industry.

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