Critical Analyses of Representation and Success Rates of Marginalized Undergraduate Students in Aerospace Engineering

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Abstract

The field of aerospace engineering is collectively grappling with the problem of disproportionate underrepresentation of women and people of color both within educational programs and within the aerospace industry. Identifying the problems is a vital preliminary step towards building equitable systems, and the underrepresentation and inequitable outcomes of women and students of color is indeed a well-documented problem. However, building on the theoretical foundation of critical theory, we argue that there exists another substantial sector of the population that is currently marginalized within aerospace engineering: the working class. As income inequality continues to grow both nationally and globally, the population of students who are not coming from highly affluent backgrounds are at a continually growing disadvantage within educational spaces.

This quantitative study takes place at a large, highly selective public research university. Working class Americans account for the vast majority of the national population but are a minority amongst the students studying engineering at this institution. Marginalization processes on the bases of ethnicity and social class have a compounding effect, as is recognized by the theory of intersectionality. Nationally, people of color are more likely than people who are white to be members of the working class, and the same is true at this institution. The aerospace field is also known to have even lower rates of representation of women than other engineering disciplines. Thus, this study seeks to examine how systemically oppressed identities affect outcomes for the undergraduate student population. To do so, we evaluate representation rates and the effects of student identity on the measured outcomes of graduation rate, time to graduation, and cumulative grade point average using critical quantitative methodology. The results offer insights into how systems of oppression are perpetuated within aerospace academia and what specific goals must retain our focus as we build collectively toward systemic change.

Introduction

Broadening participation and success in aerospace engineering, generally speaking, is clearly the goal of every aerospace engineering educator. We desire for students to both choose to enter and successfully finish our programs, as well as to do so in a reasonable amount of time and with significant academic success. Quantitative analyses are commonly used at various levels, from classroom to institution, to ensure that this is the case.

This study takes place at a highly selective public research university in the Midwestern United

States. As can be seen in Figure 1, the aerospace engineering department at this institution does not seem to have a significant retention problem. The common pathway also appears to be quite traditional; the vast majority of the students enter the department with their cohort (not as transfer students), initially declare aerospace engineering as their major within the engineering college, and successfully finish their aerospace engineering degrees. However, these results do not answer questions about *who* is joining and *who* is succeeding in the aerospace engineering program.

This study follows the authors' previous investigation of marginalized students in the engineering college, which consists of 12 disciplinary departments [1]. Our previous quantitative study found that students marginalized on the bases of gender, race/ethnicity, and/or household income level experienced both disproportionately low representation rates and diminished outcomes. We are interested in determining how the quantitative results are impacted by a focus specifically on aerospace engineering students.

Existing research on retention of diverse students in aerospace engineering undergraduate programs is scarce. General reports of demographical representation are published annually by the American Society of Engineering Education [2]. Orr et al.'s 2015 study [3] was effectively the first study to quantitatively investigate gender and ethnic persistent in aerospace engineering programs specifically. Their study utilized data from the MIDFIELD database and included 6 of the 20 largest aerospace-engineering-degree-granting institutions in the U.S., but the insti-

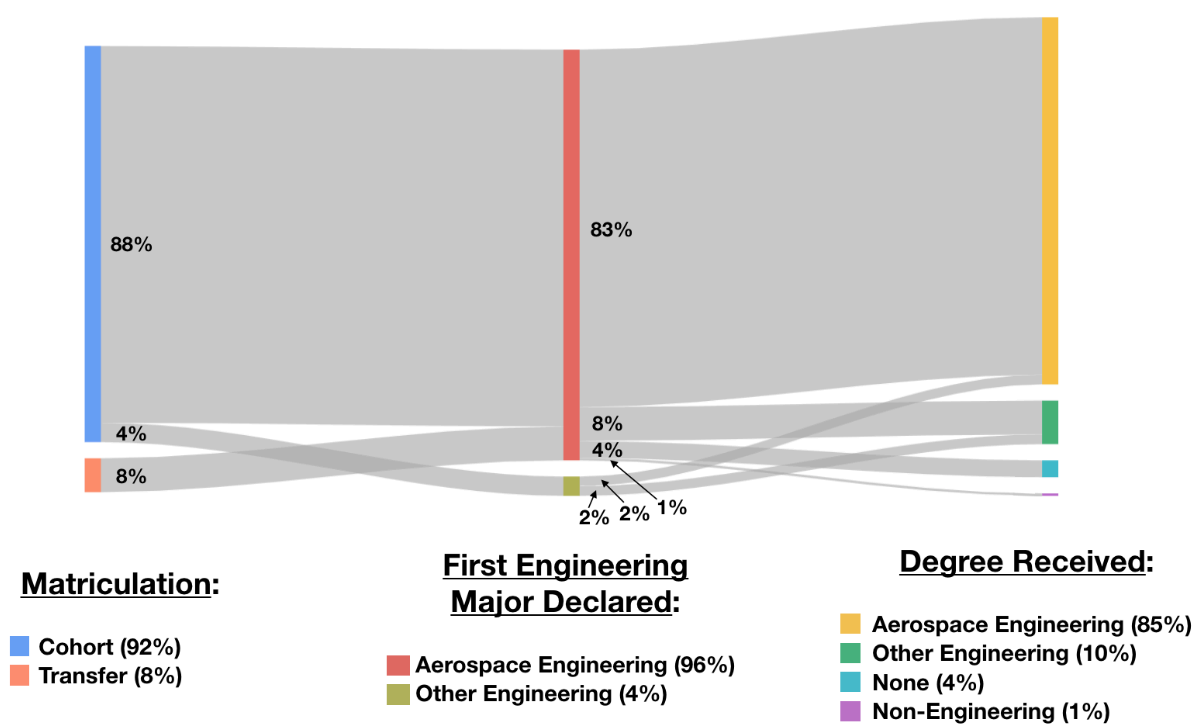

Figure 1: Matriculation method, first major declared in the engineering college, and degree received for students who entered the engineering college between Fall 2011 and Fall 2017 and ever declared a major in aerospace engineering.

tution under study in this paper was not included in their data. Bir and Ahn's 2019 study included an exploration of the effects of various identity factors, such as gender, ethnic-minority status, and self-reported financial confidence, at a large university also located in the Midwestern U.S [4]. Bir and Ahn investigated the impact of these factors on aerospace engineering undergraduate students' likelihood of receiving GPAs under 2.0 in their first semester and persisting in the aerospace engineering department beyond the first year of study. A 2019 Master's thesis by Sara Oliveira Pedro dos Santos investigated primary motivations for undergraduate students at Iowa State University to join and complete the aerospace engineering program [5]. Results in this study are compared to those from these studies when applicable.

Conceptual Frameworks

This study utilizes critical and liberative frameworks, which recognize how structural and societal realities have been shaped by persons and groups with privilege for the purposeful goal of furthering their own interests [6–8]. Anti-oppressive feminist theory [9, 10], critical race theory [11, 12], and critical theory [6, 13] name and advocate for the deconstruction of systems of oppression on the bases of gender, race, and social class, respectively. Contrary to neoliberal perspectives on diversity and equality, critical and liberative theories do not approach these issues from the viewpoint of the privileged [14, 15]. Instead, they recognize that equity cannot be achieved while also maintaining the current comfort levels that privileged populations enjoy.

Typical approaches to quantitative educational analyses are one example of how systemic privilege has manifested itself. As Gillborn, Warmington, and Demack explain, "Numbers are no more obvious, neutral, and factual than any other form of data" [16, p.163]. An emerging approach to quantitative methodology, termed *QuantCrit* or *CritQuant*, seeks to re-center the interests of marginalized populations [16–18]. Gillborn et al. summarize the principles of the approach as follows, "(1) the centrality of racism; (2) numbers are not neutral; (3) categories are neither 'natural' nor given: for 'race' read 'racism'; (4) voice and insight: data cannot 'speak for itself'; (5) using numbers for social justice" [16, p.169]. While Gillborn et al. focus on the continued use of data and quantitative analyses to perpetuate structures of racism, we expand the premise to include structures that oppress women and members of the working class. Using this approach, we reverse the usual assumptions of quantitative educational analyses: we wholly recognize that existing educational structures are oppressive against marginalized populations, and statistically significant results are necessary in order to show that oppressive systems are *not* in operation in any given context. This approach is explained in more detail in the methods section in reference to the analysis of the data in this study.

Methods

Data

Data for this study are provided by the engineering college directly and consists of the self-reported gender, race/ethnicity, annual household income level, enrollment information, and semester-by-semester cumulative grade point averages of all students who entered the college between the Fall 2011 and Fall 2017 semesters. Gender, race/ethnicity, and annual household income level are treated as independent variables in this study, whereas rate of graduation, time to graduation, and fourth-semester cumulative grade point average are considered dependent variables. While all students in the engineering college are represented in the original dataset, not all students chose to report their gender, race/ethnicity, and annual household income level.

In the dataset, gender is recorded as either man or woman, as these, problematically, were the only options made available to students for selection. The race/ethnicity categories, based on the selections made available to the students, are "Asian," "Black / African American," "Hispanic / Latino," "Native American / Pacific Islander," and "White." Students who selected more than one option are instead moved into a separate multi-racial/ethnic category. Students who selected solely "Native American / Pacific Islander" are excluded from this study due to their extremely low numbers. The students' estimated annual household incomes are consolidated into three groups: less than \$50,000, \$50,000 to \$100,000, and greater than \$100,000. As the median household income in the U.S. in 2016 was \$67,871 and 69% of households made less than \$100,000 per year [19], it is reasonable to think of the three income levels as low-, middle-, and high-income, respectively. Critical theory recognizes the reality of extremely income inequality in which 80% of the global income is controlled by a mere 20% of the global population [20]. Thus, students from households with annual incomes less than \$100,000 will be referred to as working class, whereas students from households with annual incomes greater than \$100,000 will be referred to as ruling class.

One purpose of this study is to quantitatively compare the representation rates and outcomes of undergraduate students studying aerospace engineering to those of the undergraduate student body in the engineering college as a whole, which were previously published in [1]. To do so, we generate subsets of this dataset that consist of students who declared majors in aerospace engineering.

The populations of students for whom aerospace engineering was their first declared major and students who graduated with a degree in aerospace engineering are analyzed for their representation rates of women, people of color, and working class individuals. 717 students who entered the engineering college between Fall 2011 and Fall 2017 *initially* declared an aerospace engineering major, and 70.6 % of those students are included in the analyses. The 506 students who are included are those who disclosed their gender, race/ethnicity, and estimated annual household income to the college. The frequency counts of gender, race/ethnicity, and annual household income level among the 506 students included in these analyses are shown in Table 1 in the appendix. 433 of the students who entered the engineering college between Fall 2011 and Fall 2017 graduated with a major in aerospace engineering. 297 of these students (68.6 %) are included in the representation rate analyses. Again, this group consists of the students who disclosed their gender, race/ethnicity, and estimated annual household income to the college. Table 2 in the appendix shows the frequency counts by identity group of these 297 aerospace engineering graduates.

For analyses of cross-representation and student outcomes, we use the group of students who *ever* declared a major in aerospace engineering, regardless of whether it was their first declared major or of whether they successfully completed the major. 750 students who entered the college between Fall 2011 and Fall 2017 ever declared an aerospace engineering major, and we use the 531 students (70.8 %) for whom we have record of their gender, race/ethnicity, and household income. The frequency counts for this group are shown in Table 3 in the appendix. Within this group, we consider 254 students for our graduation rate analyses. These students entered the college in Fall 2014 or earlier, in order to give the students at least 5 years to graduate, and were no longer enrolled at in the college in Fall 2019 when the data was collected (2 students who would have been included otherwise were still enrolled). The frequency counts for graduation rate analyses are shown in Table 4 in the appendix. Of these 254 students, those who entered with a cohort (not as a transfer) and successfully graduated with a degree in aerospace engineering are included in analyses of time to graduation. These analyses include 197 students, who are profiled in Table 5 in the appendix. Finally, of the 531 students shown in Table 3, 513 recorded fourth-semester cumulative grade point averages and are profiled in Table 6 in the appendix. GPAs are analyzed in the fourth semester of study in order to strike a balance between ensuring that students will have taken classes offered by the aerospace engineering department (as opposed to only taking courses that fulfill general education requirements) and including students in the analyses who drop out of the college before completing their degrees.

Analysis

Numerical analysis techniques are used to determine the statistical significance of representation rates and outcomes of marginalized aerospace engineering undergraduate students. Chi-squared analyses are used to determine the significance of the discrepancies in representation rates of marginalized students. Logistical regression is applied to predict graduation rates on the bases of gender, race/ethnicity, and income level. Analysis of Variance, or ANOVA, tests are used to test the dependence of time to graduation and grade point average on these identity factors. All results are compared to those for the aggregated engineering undergraduate student body, which were presented in [1]. The significance of discrepancies in these comparisons are again tested using chi-squared analyses. However, the effects of interactions between gender, race/ethnicity, and income on student outcomes for aerospace students are not tested, in order to protect the privacy of the marginalized students, for whom sample sizes are small. P-values below 0.1 are considered statistically significant for this study; particularly given the small numbers of marginalized students in the aerospace engineering student body, we interpret a 90 % probability of non-random occurrence to be sufficiently high to justify confidence in a corresponding conclusion.

Given that this work uses a critical quantitative framework, there exists an assumption of a system being oppressive unless quantitatively proven otherwise with statistically significant data. This assumption is a perfectly reasonable one, as existing research very well documents systemic structures that discriminate against students of marginalized backgrounds within the engineering educational space [3, 21–36]. Figure 2 uses a flow-chart to demonstrate how this assumption enables the interpretation of our quantitative results.

This interpretive model necessitates that, in order to demonstrate the lack of oppression, a marginalized population must actually exhibit *better* representation rates or quantitative outcomes than non-marginalized populations to a statistically significant degree. Once this has been achieved, the system can be stated to be *liberative*. This defies the common neoliberal goal of "equality," recognizing that neutrality benefits the oppressor, not the oppressed [37, 38]. Rather than aiming for *equal*, systems must instead become *equitable*. As an example of the application of this principle to our study, in order to correct the problem of the historical as well as current oppression of the Black / African American population in the U.S., they will require representation in engineering education that is not only equal to but actually *greater than* their percentage of representation within the national population. Allowing this community to have proportional representation is insufficient, because we must also overcome the effects of hundreds of years of oppression that

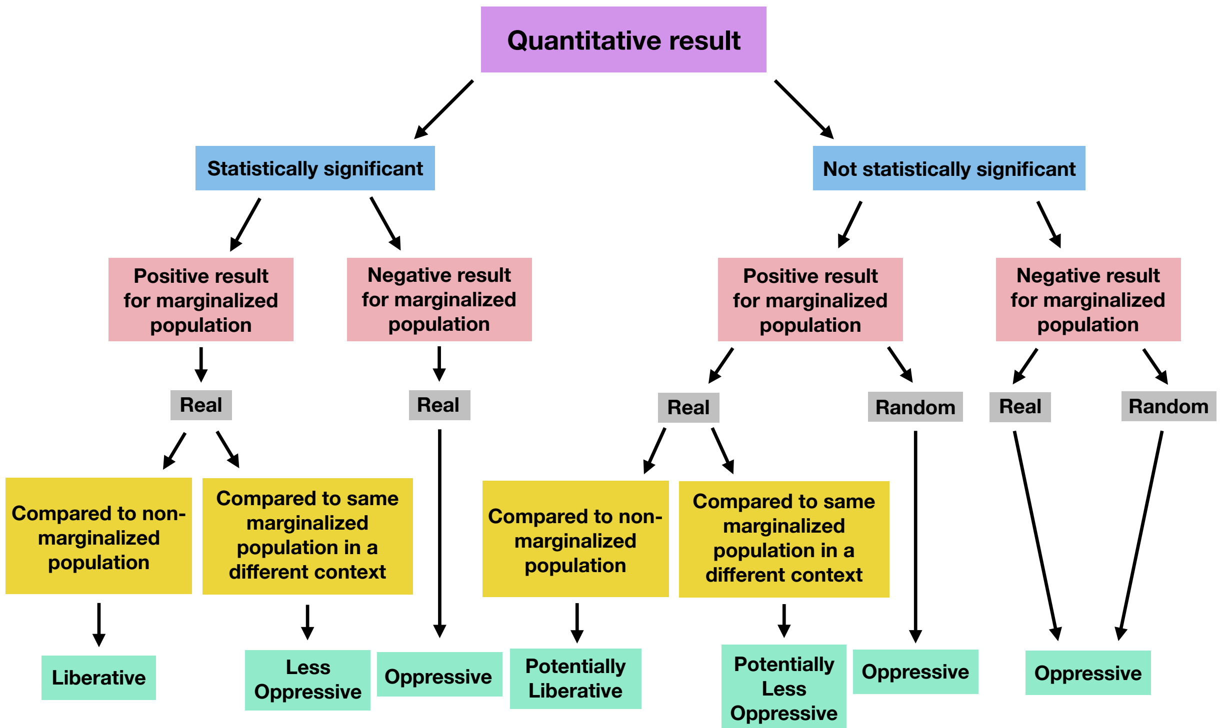

Figure 2: Critical quantitative model for interpretation of numerical results.

have caused today's Black / African American community to lack sufficient resources. Thus, marginalized communities must be *disproportionately* supported in order to be liberated.

When presented with positive results for marginalized populations, especially ones that are shown to be statistically significant, it can be tempting to view them as evidence that disproves the existence of oppression. However, this is not necessarily the the case. In Figure 2, we see that positive statistically significant results can only be determined to be *less oppressive* if the comparison is being made to another educational population. This is due to the critical assumption that educational systems currently operative in structurally oppressive ways. *Potentially less oppressive* results also fit into the *less oppressive* category described previously - *if* they are, in fact, real trends. Because these results are statistically insignificant, a *less oppressive* conclusion cannot be verified with this dataset. If these results are actually random, then there may be no difference between the levels of oppression present in the department and the educational population to which it is being compared.

Alternatively, if a positive result for a marginalized population is not statistically significant, the trend can only be said to be *potentially liberative*. If this is the case, data should continue to be collected in future years to allow numerical analyses of larger datasets. The department may then be able to show that the finding is statistically significant, demonstrating that targeted efforts are dismantling systems of oppression and beginning to achieve positive results. If, however, sufficiently large datasets do not yield statistically significant liberative results, then it must be concluded that these findings are, in fact, random, and oppressive systems continue to remain in existence.

Results and Discussion

Representation

Chi-squared analyses are used to determine the significance of the discrepancies in representation rates on the bases of gender, race/ethnicity, and income level individually for both students who first declared majors in aerospace engineering and students who graduated with degrees in aerospace engineering. These discrepancies are measured in relation to the national and state populations, the population of all students at public universities in the U.S., the population of all students in engineering undergraduate programs in the U.S., and the starters and graduates of this engineering college. The representation rates are shown in Figure 3 and the resulting chi-squared values and statistical significance levels are shown in Figure 4.

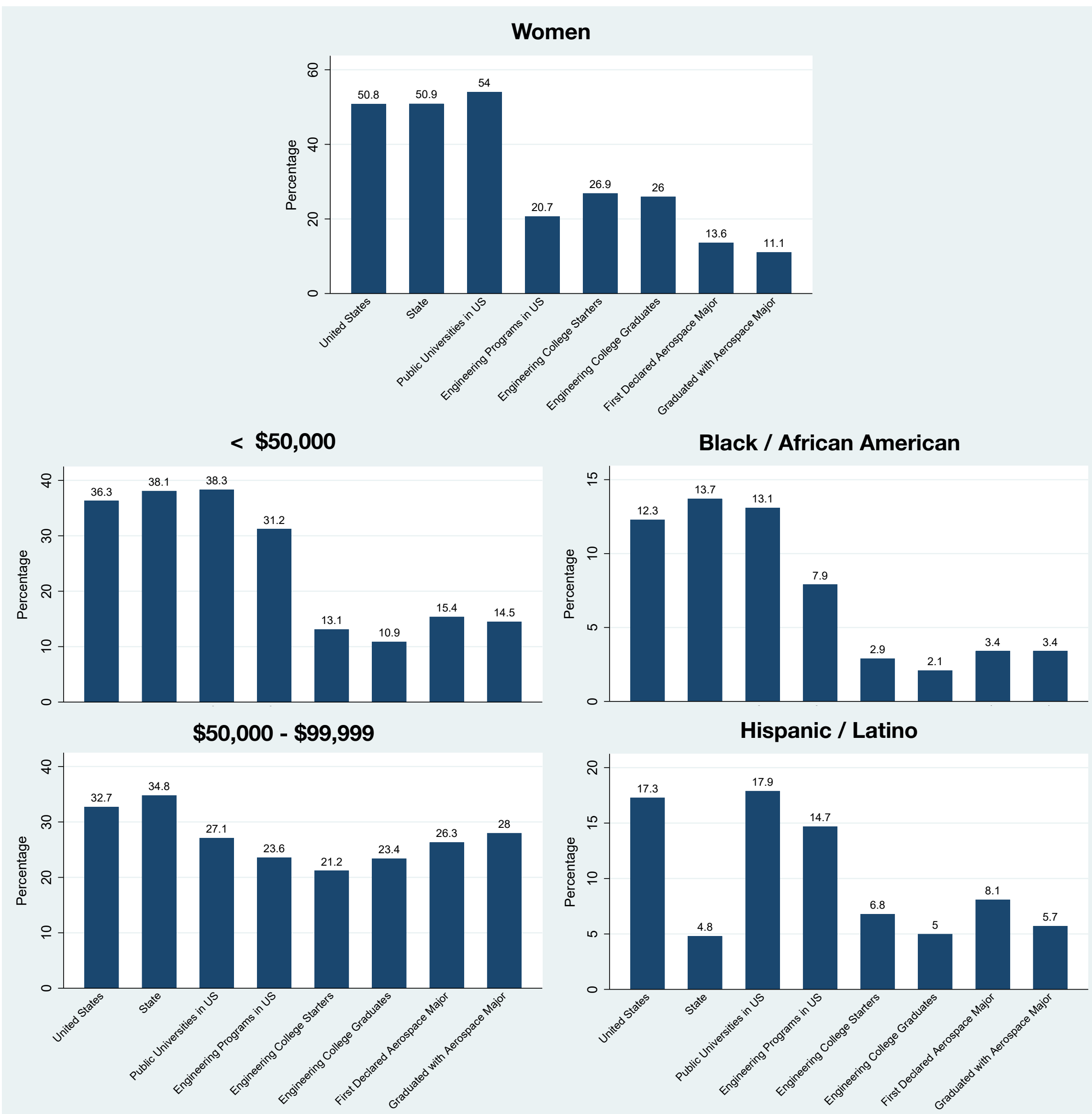

Figure 3: Percentage of marginalized people in populations. [19, 39].

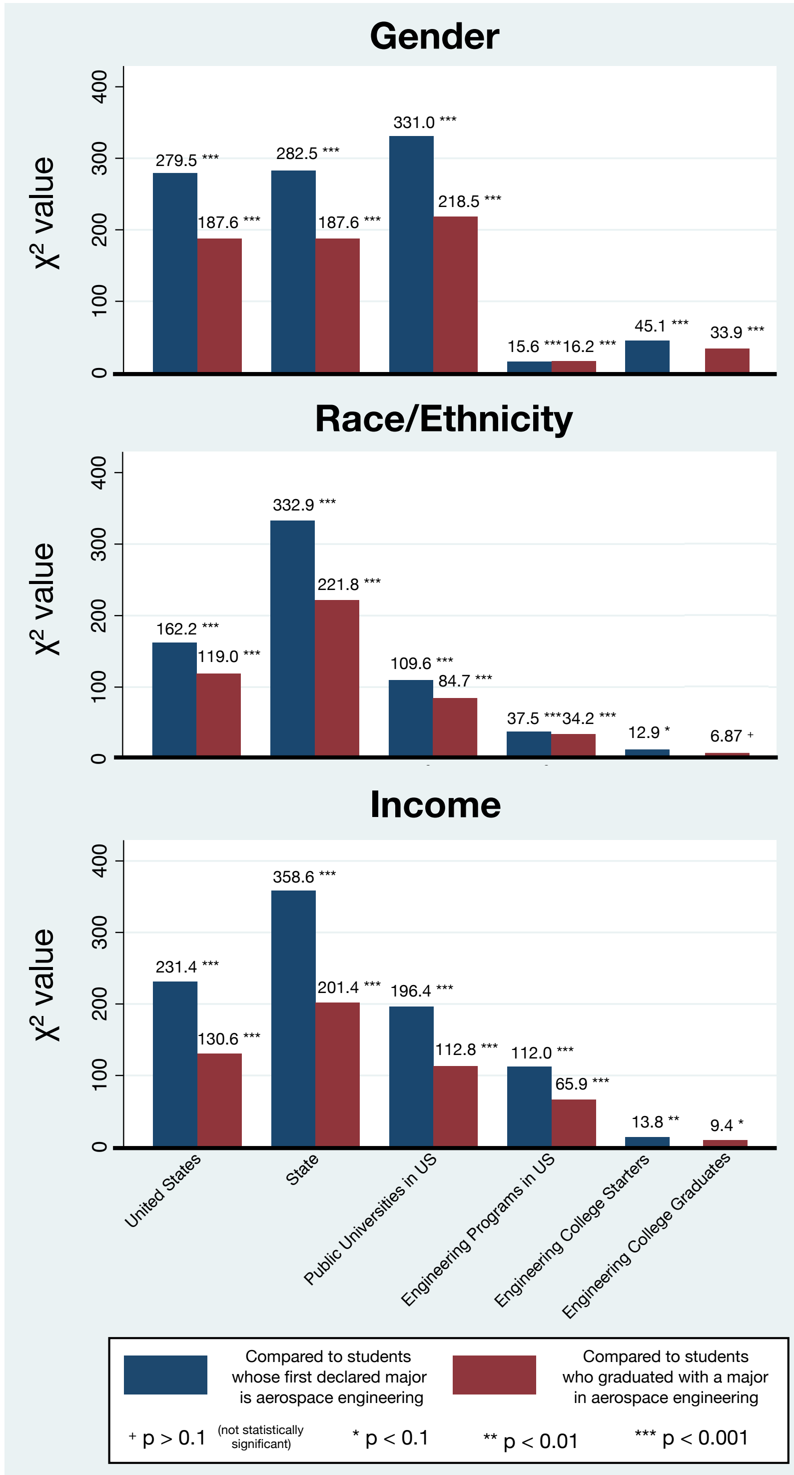

Figure 4: Chi-squared statistics of discrepancies in representation rates between aerospace engineering student populations and comparative populations [19, 39]. N=506 for students whose first declared major was aerospace engineering and N=297 for students who graduated in aerospace engineering.

While Figure 4 can be read horizontally to compare the representational discrepancies across various populations, it can also be read vertically to compare the discrepancies across identity factors for a given population. It can also be used to compare representational discrepancies in matriculating aerospace engineering students with those of graduating aerospace engineering students. Note that chi-squared values typically decrease for smaller populations, which is reasonable as the chi-squared statistic takes into account sample size. This explains the general decrease in chi-squared value between students who first declared majors in aerospace engineering (shown in blue in Figure 4) and students who graduated with degrees in aerospace engineering (shown in red), since the latter has a significantly smaller sample size (see Tables 1 and 2 in the Appendix).

To first compare the effects of gender, ethnicity, and income, we can see that the aerospace engineering department has discrepancies in both its matriculating and graduating students compared to the national and state populations, the student population at public universities in the U.S., and student population enrolled in engineering programs in the U.S., all with $p < 0.001$. In Figure 3, it can be seen that there are fewer women, working class, and Black / African American and Hispanic / Latino students than expected in each of these comparisons with the exception of Hispanic / Latino students based on the state population. As shown in Figure 4, the gender discrepancy in this aerospace engineering program is more significant than that of income and ethnicity in each of these comparisons except for that of the student population in engineering programs in the US, in which it is less significant than both income and ethnicity. The income discrepancy in this department is more significant than that of ethnicity in every comparison except one: aerospace engineering graduates compared to the state population. However, nearly all chi-squared results demonstrate statistically significant discrepancies between aerospace engineering student identity distributions and target distributions.

These results are not surprising given existing research. The American Society of Engineering Education (ASEE)'s 2018 "Engineering By The Numbers" report found that only 14.6 % of aerospace engineering Bachelor's degree recipients were women, showing aerospace to have amongst the lowest representation of women of all engineering disciplines [2]. At 11.1 %, this aerospace engineering department is doing even worse than the average. Oliveira Pedro dos Santos reported in 2019 that 11% of Iowa State University's aerospace engineering undergraduate students were women [5]. While the ASEE report also disaggregates degrees awarded by ethnicity, it does not disaggregate further by engineering discipline [2]. It does show greater representation of Black / African American and Hispanic / Latino students than is present in this aerospace engineering department, however. Bir and Ahn's results show that first-year aerospace engineering students between 2011 and 2016 at the university he studied were 8% women and 12% non-white [4], representation rates that are even worse than those of this department when Asian and multi-racial/ethnic students are included. Data from the U.S. Census shows that, in 2017, the aerospace engineering workforce was 12.5% women and 73.2% non-Hispanic white [40]. Thus, this department is not producing demographics of aerospace engineering graduates that will contribute to overcoming these gender and racial/ethnic chronic underrepresentation rates.

We next compare representational discrepancies in the aerospace engineering department to those in the engineering college aggregated. We find that the department has had fewer women students than the engineering college with $p < 0.001$ for both students whose first engineering major was in aerospace and students who graduated from the department. The aerospace engineering department also has more Black / African American and Hispanic / Latino students than the engineering college, with p = 0.01 for students whose first engineering major was in aerospace. This result is not found to be statistically significant for aerospace engineering graduates. Finally, the department has more working class students than the engineering college with p = 0.003 for students whose first engineering major was in aerospace and p = 0.03 for aerospace engineering graduates.

By examining the intersections of the three identity factors, we begin to see the overlapping and compounding effects of marginalization in terms of gender, ethnicity, and income. From this data, we can observe the ways in which the aerospace engineering department is participating - or not participating - in furthering educational trends of compounding marginalization [41, 42]. Figure 5 shows two-way cross-plots of gender, race/ethnicity, and annual household income for students who *ever* declared a major in aerospace engineering. Note that we do not present three-way intersections or analyze any intersections of identities in the discussions of outcomes due to the low numbers of marginalized people in this department and the need to protect their privacy.

The results show that Black / African American, Hispanic / Latino, and multi-racial/ethnic students are more likely to be working class, and Black / African American students have the lowest household incomes by far. The statistical significance of this relationship between race/ethnicity and income is p = 0.01. This finding is consistent with the national reality in which people of color have less access to financial resources [43, 44]. We also find that women have higher levels of representation amongst Black / African American and multi-racial/ethnic populations and that Hispanic / Latino students have the least representation of women of any ethnic group. Orr et al. had also found higher levels of representation amongst Black / African American aerospace Engineering students [3]. The relationship between gender and race/ethnicity in our study, however, is not found to be statistically significant. Finally, Figure 5 shows that women have higher levels of representation amongst low-income (< $50,000 per year) students, but this result is also not found to be statistically significant.

Two-way representational results are also compared with those of the engineering college. While women in the aerospace engineering department have higher representation amongst low-income students, women have higher representation amongst ruling class students in the engineering college aggregated. This discrepancy in representation of women by income level is statistically significant with p = 0.02.

Outcomes

Graduation Rates

Turning to analyses of student outcomes, we consider the issue of graduation rate. Figure 6 shows the rate of success in graduating with a degree in aerospace engineering based on gender, race/ethnicity, and annual household income. The results show that women are less likely to graduate than men. On the other hand, Black / African American and low-income (< $50,000 per year) students are actually the *most* likely to graduate of all racial/ethnic and household income groups, respectively. Modeling these results using logistic regression, however, we find that the likelihood of

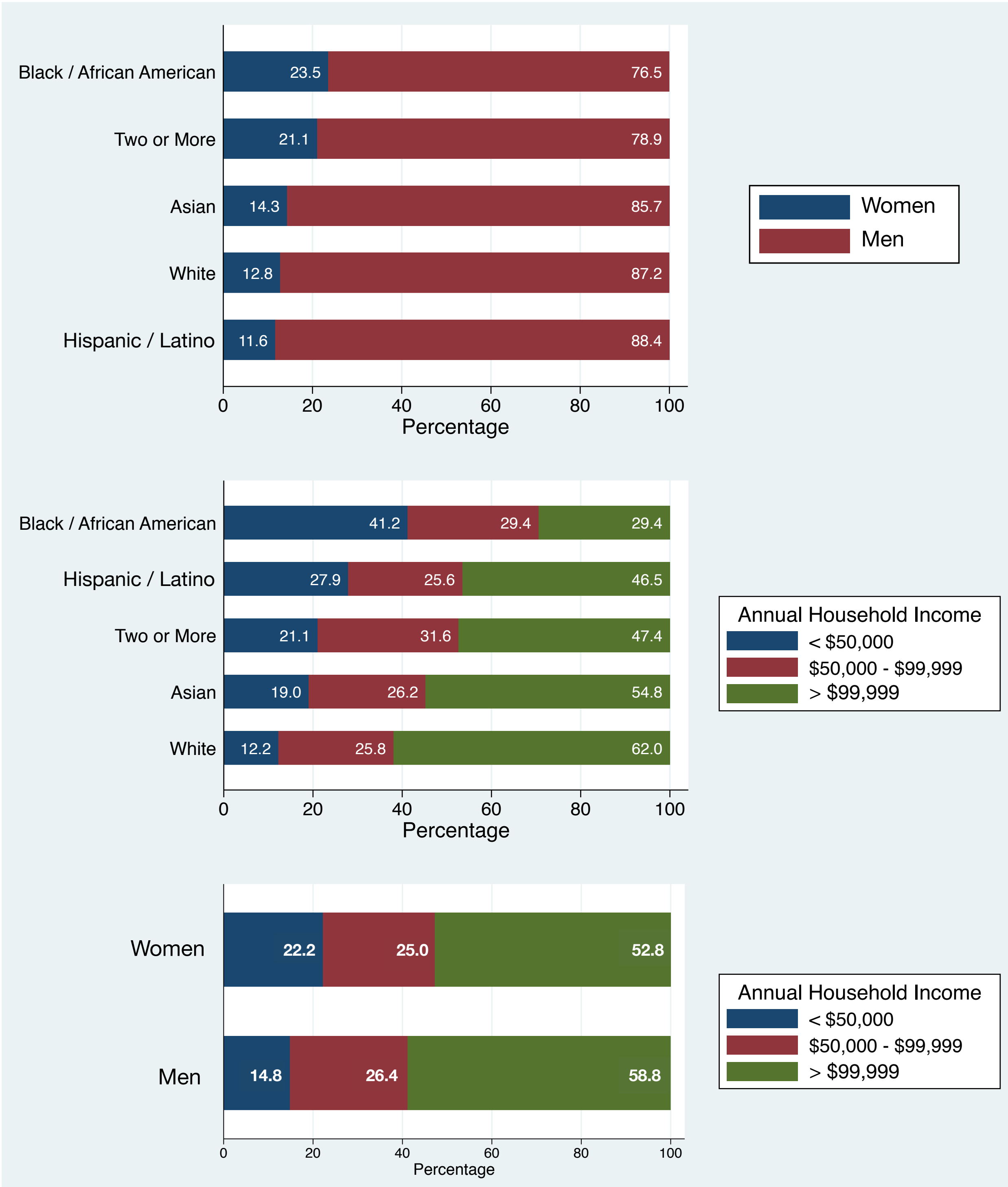

Figure 5: Cross-plotting the gender, ethnicity, and annual household income of students who ever declared a major in aerospace engineering.

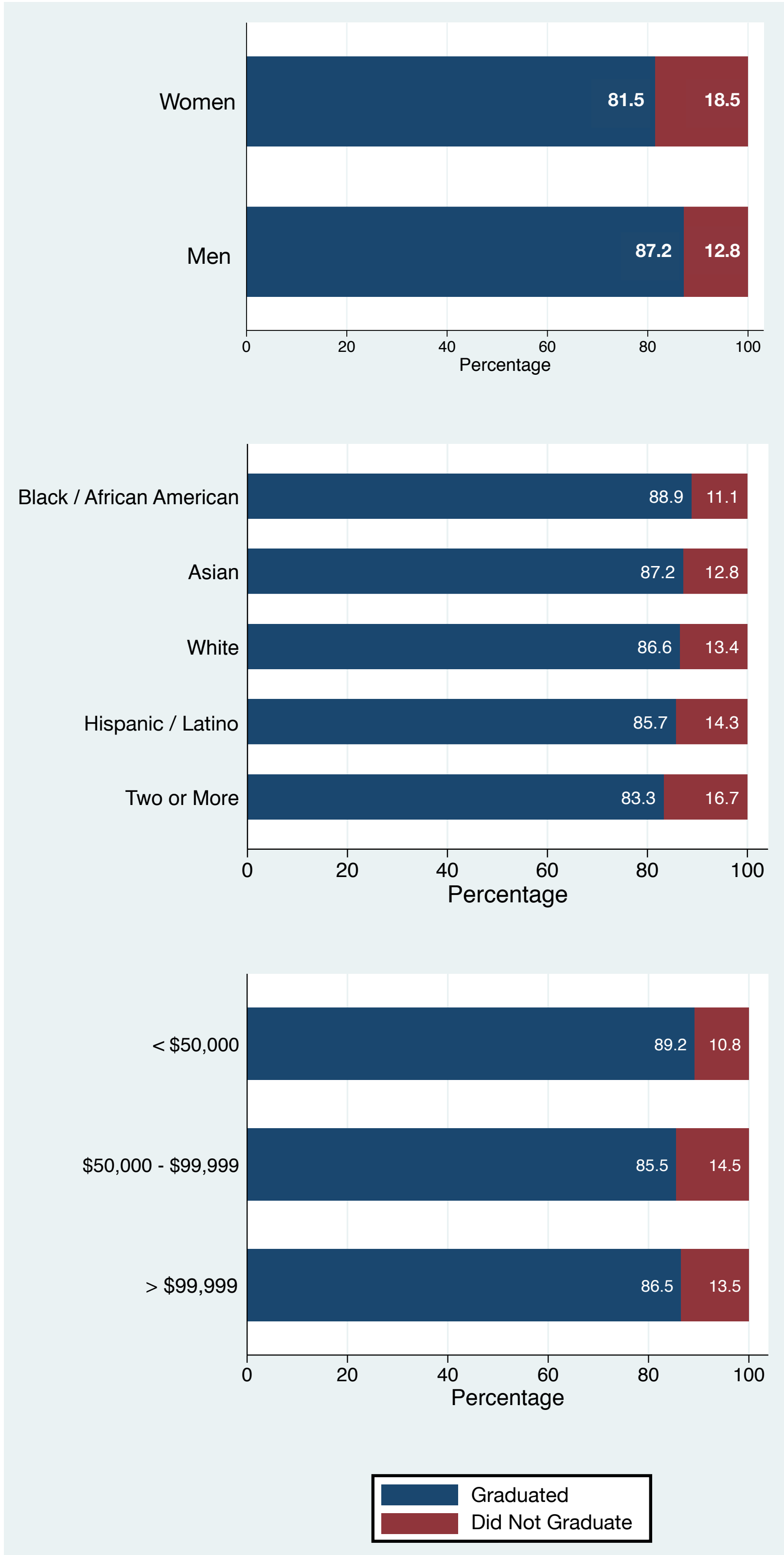

Figure 6: Aerospace graduation rates by gender, ethnicity, and annual household income.

graduation is not dependent on gender, race/ethnicity, or household income to a statistically significant degree.

Our results are in mixed agreement with those in existing literature. Oliveira Pedro dos Santos's and Bir and Ahn's studies also identify lower persistence rates for women students [4, 5]. Orr et al. found extremely lacking graduation rates for both women and students of color - and especially for women of color [3]. While our results appear extremely exciting for Black / African American students, we note that there were only 9 Black / African American students in the dataset (see Table 4 in the Appendix). Thus, this result may very well be random and not indicative of a true phenomenon. However, Bir and Ahn's persistence model also finds ethnic-minority students more likely to persist past the first year of study, albeit not to a statistically significant degree. Finally, our non-intuitive result of low-income students having the greatest likelihood of graduation is also in agreement with Bir and Ahn's (also not statistically significant) finding of an inverse relation between financial confidence and student persistence. These curious trends regarding the effects race/ethnicity and income on persistence in aerospace engineering certainly require further study.

In comparing graduation rates in this department to those in the engineering college aggregated, the aerospace engineering students are more likely to graduate than engineering students in general. Women, however, are even less likely to graduate in the aerospace engineering department than in the engineering aggregated. For every racial/ethnic category, aerospace engineering students are actually more likely to graduate than engineering students in general. In terms of income, working class students (< $100,000 per year) are more likely to graduate in the aerospace engineering department than in the engineering college students in general. Logistic regression, however, shows that majoring in aerospace engineering does not have a statistically significant relationship with rate of graduation within the engineering college.

Time to Graduation

For students who did successfully graduate with an undergraduate degree in aerospace engineering, the mean and standard deviation of time to graduation from initial enrollment by gender, race/ethnicity, and annual household income are shown in Figure 7. Note that a student who joins the engineering college in the fall semester and graduates four years later would have a time to graduation of 3.7 years. The time to graduation is shorter for women students but longer for Black, Latinx, and multi-racial/ethnic students. Time to graduation is also longer for low-income students (< $50,000 per year). However, using ANOVA, the time to graduation is not determined to be dependent on gender, ethnicity, or income to a statistically significant degree.

Time to graduation is, overall, shorter in the aerospace engineering department than in the engineering college. While women have a shorter time to graduation in the engineering college aggregated, it is even shorter for women in the aerospace engineering department. The increase in time to graduation for students who are low-income (< $50,000 per year) in the aerospace engineering department is also less than it is for low-income students in the engineering college aggregated. Hispanic / Latino and multi-racial/ethnic students, however, take longer to graduate in the aerospace engineering department than they do in the engineering college in general. Chi-squared analyses show that none of the time to graduation results comparing the aerospace engineering students to engineering students in general are statistically significant.

Grade Point Average

The final dependent variable of our analyses is fourth-semester cumulative grade point average. The means and standard deviations by gender, race/ethnicity, and annual household income are shown in Figure 8. These results show that GPA is lower for women, Black / African American, and multi-racial/ethnic students. GPA is also lowest for low-income increases with increasing income (< $50k per year) students and jumps significantly for ruling class (> $100,000) students.

Upon performing a three-way ANOVA, fourth-semester cumulative grade point average is not dependent on race/ethnicity to a statistically significant degree, but *is* statistically significant for gender and income, with $p = 0.02$ and $p = 0.08$, respectively. Performing a two-way ANOVA over just gender and income, we find that $p = 0.02$ for gender and $p = 0.06$ for income. The results of a two-way ANOVA are shown in Figure 9.

The gender-based result, especially given only a 2% chance of random association, is especially disturbing compared to Bir and Ahn's finding that women were *less* likely to receive first-semester GPAs under 2.0 than men [4]. Bir and Ahn's result, though not statistically significant, is consistent with typical research findings that women have higher GPAs than men, even in STEM fields [21, 45]. Bir and Ahn also found that non-white students and those with less confidence in financial security were more likely to receive first-semester GPAs under 2.0. Although these results were also not statistically significant, they seem to be relatively consistent with our findings.

Comparing these results to those of the engineering college, the fourth semester cumulative GPA is higher for students in the aerospace engineering department than in the engineering college, though not to a statistically significant degree according to a chi-squared analysis. Women's GPAs, however, are lower in the aerospace engineering department than in the engineering college aggregated, and that result is statistically significant with $p = 0.03$. Black / African American and Hispanic / Latino GPAs are higher in the aerospace engineering department than in the engineering college, and Asian and multi-racial/ethnic GPAs are lower. A chi-squared analysis shows the racial/ethnic discrepancy between aerospace engineering students and engineering students in general to barely meet out cutoff for statistical significance, with $p = 0.098$. Finally, the decrease in GPA for low-income students (< $50,000 per year) is not as large in the aerospace engineering department than it is in the engineering college aggregated, though this is not shown to be statistically significant.

Interpretation

As explained by QuantCrit approaches, "numbers have no objective reality beyond the frameworks of meaning and politics that create them" [16, p.169]. To assign meaning to our results, we apply the critical quantitative model shown in Figure 2 to all our numerical results, even if they are not found to be statistically significant. The detailed results of this process are shown in Table 7 in the Appendix, in which they are grouped by topic. Each numerical trend identified in the quantitative analyses has five possible resulting interpretations as determined by the flow chart: oppressive, less oppressive, potentially less oppressive, potentially liberative, and liberative. In this section, we group the quantitative results by interpretation and describe the implications of these findings.

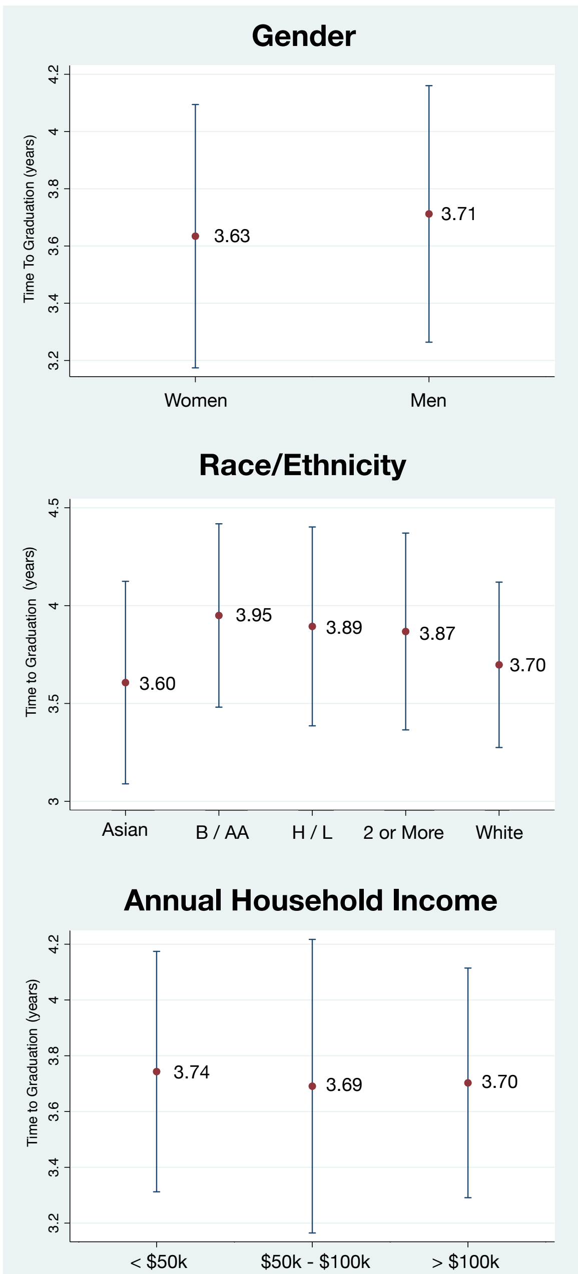

Figure 7: Mean and standard deviation of time to graduation by gender, ethnicity, and annual household income.

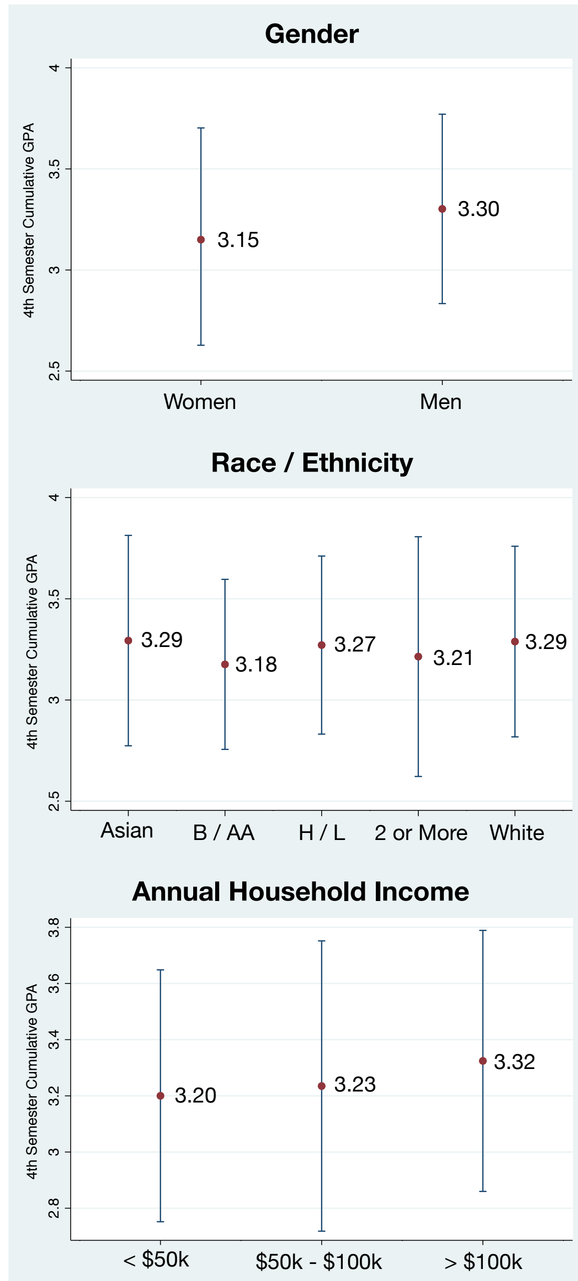

Figure 8: Mean and standard deviation of fourth semester cumulative GPA by gender, ethnicity, and annual household income.

Number of obs =	513	R-squared =	0.0224
Root MSE =	.474032	Adj R-squared =	0.0166

Source	Partial SS	df	MS	F	Prob>F
Model	2.6155972	3	.87186572	3.88	0.0092
Income	1.2524169	2	.62620844	2.79	0.0626
Gender	1.2536207	1	1.2536207	5.58	0.0186
Residual	114.37539	509	.22470607		
Total	116.99099	512	.22849803		

Figure 9: Two-way ANOVA results of fourth semester cumulative GPA by gender and annual household income.

Oppressive

Oppressive results show the perpetuation of structural systems of oppression in this aerospace engineering department. The following findings of this study demonstrate existing oppressive systems in practice in this aerospace engineering department:

- Discrepancies in the representation rates of people from marginalized gender, ethnicity, and income-based identities exist for both matriculating and graduating student populations. These discrepancies are in comparison to the populations of the U.S., the state, students at public universities in the U.S., and students in engineering programs in the U.S.
- The department has fewer women students than the engineering college aggregated.
- Women students are less likely to graduate. Women students are also less likely to graduate in the department than in the engineering college aggregated.
- Fourth semester cumulative GPA is lower for women students. Fourth semester cumulative GPA is also lower for women students in the department than in the engineering college aggregated.
- Hispanic / Latino students have the least representation of women of any ethnic group.
- Time to graduation is longer for Black / African American, Hispanic / Latino, and multi-racial/ethnic students. Hispanic / Latino and multi-racial/ethnic students also take longer to graduate in the department than in the engineering college aggregated.
- Fourth semester cumulative GPA is lower for Black / African American and multi-racial/ethnic students. Fourth semester cumulative GPA is also lower for Asian and multi-racial/ethnic students in the department than in the engineering college aggregated.
- Black / African American, Hispanic / Latino, and multi-racial/ethnic students are more likely to be working class than students of other ethnic groups, and Black / African Ameri-

can students have the lowest annual household incomes by far.

- Time to graduation is longer for low-income students (< $50,000 per year household income).
- Fourth semester cumulative GPA decreases with decreasing income.

Less Oppressive

The following results, while appearing to be positive in nature, do not present any evidence of liberation in action:

- The aerospace engineering department has more working class students (annual household income < $100,000) than the engineering college aggregated.
- The aerospace engineering department has more Black / African American and Hispanic / Latino starters than the engineering college aggregated.
- Women in the aerospace engineering department have higher representation amongst low income (< $50,000) students than they do in the engineering college aggregated.
- The GPAs of Black / African American and Hispanic / Latino students are higher in the aerospace engineering department than they are in the engineering college aggregated.

Potentially Less Oppressive

The following results, *if* documenting real trends, may fit into the *less oppressive* category above:

- The aerospace engineering department has more Black / African American and Hispanic / Latino graduates than the engineering college aggregated.
- Students in the aerospace engineering department are more likely to graduate than students in the engineering college in general for every racial/ethnic category.
- Working class students (annual household income < $100,000) are more likely to graduate in the aerospace engineering department than they are in the engineering college aggregated.
- Women students have a shorter time to graduation in the aerospace engineering department than they do in the engineering college aggregated.
- Time to graduation for low-income students (annual household income < $50,000) is less in the aerospace engineering department than it is in the engineering college aggregated.
- GPAs are higher for low-income students (annual household income < $50,000) in the aerospace engineering department than for those in the engineering college aggregated.

Potentially Liberative

A few of our findings do suggest the possibility of the existence of liberative results:

- Time to graduation is shorter for women students.
- Black / African American students are the most likely to graduate of all ethnic groups.

- Women have higher levels of representation amongst Black / African American and multi-racial/ethnic students.
- Women have higher levels of representation amongst low-income students (annual household incomes $< \$50,000$).
- Low-income students ($< \$50,000$ per year household income) are the most likely to graduate of all income groups.

Liberative

Following our critical quantitative model in Figure 2, no results from our study numerically prove liberative findings. Thus, there are no statistically significant examples of structural systems in this aerospace engineering department dismantling the systems of oppression that impede the successes of marginalized students.

Conclusions

Applying a basic assumption of oppressive systems, we find no statistically significant evidence of liberative processes occurring in the aerospace engineering department under study. Most findings conclude the existence of structurally oppressive systems in operation. These systems result in the women's lack of representation, lower rates of persistence, and decreased GPAs, although their time to degree is shorter. Students of color also experience underrepresentation in addition to increased time to graduation and decreased GPAs, although graduation rates vary between racial/ethnic groups. Low-income students, while also very underrepresented, are disadvantaged in terms of time to graduation, although they are the most likely to successfully graduate. Students' GPAs also increase with increasing household income level.

These findings must be aggressively addressed by the department under study. Given these results in conjunction with those in existing literature, aerospace engineering programs nationwide have good reason to suspect that they may also be functioning in a fundamentally oppressive manner. Utilizing critical quantitative methodology, other aerospace engineering departments, and indeed educational bodies at any level, can ascertain their own involvement in the perpetuation of structurally oppressive systems.

The aerospace engineering community must fulfill its obligation to build equitable academic environments as well as systems of practice. To do so, a combination of critical quantitative, qualitative, and theoretical research should support the enactment of change at levels ranging from interactional and pedagogical to institutional, national, and even global. Structural changes can then shape new approaches within aerospace engineering systems by which marginalized people can not only participate but also lead the field into a future of collaborative productivity. In this way, aerospace engineering can play a significant role in the creation of equitable engineering practice that contributes to the common good.

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Appendix

Table 1: Frequency counts of gender, race/ethnicity, and annual household income level amongst students whose first declared major in the engineering college was aerospace engineering.

Category		Count	Percentage
Gender	Women	69	13.64
	Men	437	86.36
Race/Ethnicity	Asian	77	15.22
	Black / African American	17	3.36
	Hispanic / Latino	41	8.10
	2 or More	18	3.56
	White	353	69.76
Annual Household Income	< $50,000	78	15.42
	$50,000 - $99,999	133	26.28
	$100,000 - $149,999	117	23.12
	> $150,000	178	35.18

Table 2: Frequency counts of gender, ethnicity, and annual household income level amongst students who graduated with a major in aerospace engineering.

Category		Count	Percentage
Gender	Women	33	11.11
	Men	264	88.89
Race/Ethnicity	Asian	49	16.50
	Black / African American	10	3.37
	Hispanic / Latino	17	5.72
	2 or More	7	2.36
	White	214	72.05
Annual Household Income	< $50,000	43	14.48
	$50,000 - $99,999	83	27.95
	$100,000 - $149,999	69	23.23
	> $150,000	102	34.34

Table 3: Frequency counts of gender, ethnicity, and annual household income level amongst students who ever declared a major in aerospace engineering.

Category		Count	Percentage
Gender	Women	72	13.56
	Men	459	86.44
Race/Ethnicity	Asian	84	15.82
	Black / African American	17	3.20
	Hispanic / Latino	43	8.10
	2 or More	19	3.58
	White	368	69.30
Annual Household Income	< $50,000	84	15.82
	$50,000 - $99,999	139	26.18
	> $99,999	308	58.00

Table 4: Frequency counts of gender, ethnicity, and annual household income level amongst students included in graduation rate analyses.

Category		Count	Percentage
Gender	Women	27	10.63
	Men	227	89.37
Race/Ethnicity	Asian	39	15.35
	Black / African American	9	3.54
	Hispanic / Latino	14	5.51
	2 or More	6	2.36
	White	186	73.23
Annual Household Income	< $50,000	37	14.57
	$50,000 - $99,999	76	29.92
	> $99,999	141	55.51

Table 5: Frequency counts of gender, ethnicity, and annual household income level amongst students included in analyses of time to graduation.

Category		Count	Percentage
Gender	Women	19	9.64
	Men	178	90.36
Race/Ethnicity	Asian	33	16.24
	Black / African American	5	2.54
	Hispanic / Latino	12	6.09
	2 or More	4	2.03
	White	144	73.10
Annual Household Income	< $50,000	26	13.20
	$50,000 - $99,999	58	29.44
	> $99,999	113	57.36

Table 6: Frequency counts of gender, ethnicity, and annual household income level amongst students included in analyses of fourth semester cumulative GPA.

Category		Count	Percentage
Gender	Women	68	13.26
	Men	445	86.74
Race/Ethnicity	Asian	78	15.20
	Black / African American	15	2.92
	Hispanic / Latino	42	8.19
	2 or More	18	3.51
	White	360	70.18
Annual Household Income	< $50,000	79	15.40
	$50,000 - $99,999	133	25.93
	> $99,999	301	58.67

Table 7: Quantitative results and their significance.

Metric	Result	Comparison	Statistical Significance	Interpretation
Representation Rates	Students of marginalized genders, race/ethnicities, and incomes are underrepresented in both matriculating and graduating student populations	Compared to the populations of the U.S. and the state	$p < 0.001$	Oppressive
		Compared to the populations of students at public universities in the U.S. and students in engineering programs in the U.S.	$p < 0.001$	Oppressive
	Black / African American, Hispanic / Latino, and multi-racial/ethnic students are more likely to be working class, and Black / African American students have the lowest annual household incomes by far	Within the student body	$p = 0.01$	Oppressive
	Women students have higher levels of representation amongst Black / African American and multi-racial/ethnic students	Within the student body	Not statistically significant	Potentially liberative (if real), otherwise oppressive
	Hispanic / Latino students have the least representation of women of any ethnic group	Within the student body	Not statistically significant	Oppressive

Metric	Result	Comparison	Statistical Significance	Interpretation
Representation Rates	Women students have higher levels of representation amongst students with annual household incomes of less than $50,000	Within the student body	Not statistically significant	Potentially liberative (if real), otherwise oppressive
		Compared to the engineering college	p = 0.02	Less oppressive
	Working class students have higher levels of representation	Compared to the engineering college	p = 0.003 (matriculating), p = 0.03 (graduating)	Less oppressive
	Black / African American and Hispanic / Latino students have higher levels of representation amongst matriculating students	Compared to the engineering college	p = 0.01	Less oppressive
	Black / African American and Hispanic / Latino students have higher levels of representation amongst graduating students	Compared to the engineering college	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive
	Women students are underrepresented in both matriculating and graduating student populations	Compared to the engineering college	$p < 0.001$	Oppressive

Metric	Result	Comparison	Statistical Significance	Interpretation
Graduation Rates	Black / African American students are the most likely to graduate of all ethnic groups	Within the student body	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive
	Students with annual household incomes less than $50,000 are the most likely to graduate	Within the student body	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive
	Women students are less likely to graduate	Within the student body	Not statistically significant	Oppressive
		Compared to the engineering college	Not statistically significant	Oppressive
	Students of every race/ethnicity are more likely to graduate	Compared to the engineering college	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive
	Working class students (annual household incomes less than $100,000) are more likely to graduate	Compared to the engineering college	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive

Metric	Result	Comparison	Statistical Significance	Interpretation
Time to Graduation	Time to graduation is longer for Black / African American, Hispanic / Latino, and multi-racial/ethnic students	Within the student body	Not statistically significant	Oppressive
	Time to graduation is longer for students with annual household incomes less than $50,000	Within the student body	Not statistically significant	Oppressive
	Time to graduation is shorter for women students	Within the student body	Not statistically significant	Potentially liberative (if real), otherwise oppressive
		Compared to the engineering college	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive
	Time to graduation is longer for Hispanic / Latino and multi-racial/ethnic students	Compared to the engineering college	Not statistically significant	Oppressive
	Time to graduation is shorter for students from households with annual incomes less than $50,000	Compared to the engineering college	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive

Metric	Result	Comparison	Statistical Significance	Interpretation
Fourth Semester Cumulative Grade Point Average	GPAs are lower for Black / African American and multi-racial/ethnic students	Within the student body	Not statistically significant	Oppressive
	GPA decreases with decreasing annual household income	Within the student body	$p = 0.08$	Oppressive
	GPAs are lower for women students	Within the student body	$p = 0.02$	Oppressive
		Compared to the engineering college	$p = 0.03$	Oppressive
	GPAs are higher for Black / African American and Hispanic / Latino students	Compared to the engineering college	$p = 0.098$	Less oppressive
	GPAs are lower for Asian and multi-racial/ethnic students	Compared to the engineering college	$p = 0.098$	oppressive
	GPAs are higher for students from households with annual incomes less than $50,000	Compared to the engineering college	Not statistically significant	Potentially less oppressive (if real), otherwise oppressive