To What Extent Does Gender and Ethnicity Impact Engineering Students' Career Outcomes? An Exploratory Analysis Comparing Biomedical to Three Other Undergraduate Engineering Majors

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Introduction

Understanding and addressing the diversity gap in engineering is of critical importance to the current and rapidly growing U.S. workforce needs [1]–[3]. This is particularly true within Biomedical Engineering (BME), a field that is amid a 10-year estimated 23% employment growth (2014-2024) [4]. Gender and ethnic diversity in particular have been studied to develop interventions aimed to support, graduate, and retain a larger and more diverse population into the engineering workforce [1]. Despite these efforts, diversity in both the biomedical and the general engineering workforce as a whole has remained low [2]. This paper aims to further the knowledge of the diversity gap by exploring the relationship between diversity and career outcomes for undergraduate engineering students upon graduation. More specifically, we aim to gain insight on the extent of the impact gender or ethnic identity have on the career outcomes of Biomedical Engineering undergraduate students at a large Midwestern research university, compared to three other engineering majors. Identifying potential diversity- and major-based inequities could provide further insight for how to improve retention and maintain appropriate pathways into the growing engineering workforce.

Challenges with Diversity in Engineering

The engineering field is challenged with a lack in gender and ethnic diversity, both at the academic and workforce levels. Although a higher percentage of women than men are pursuing bachelor's degrees in the U.S. today, only 19% of undergraduate engineering students are female [5]. Additionally, those who are considered underrepresented ethnic minorities (URMs) in engineering account for 23% of the total U.S. population, but only comprise of 6% of the engineering workforce [6]. These discrepancies are compounded when an individual belongs to multiple minority groups, i.e. only 0.6% of Black and 0.4% of Hispanic women are represented in the science, technology, engineering, and mathematics (STEM) workforce [6].

Of the female and URM students who do pursue engineering degrees, many prefer to enroll in certain engineering majors more than others. This discrepancy could be attributed to differences in how each engineering discipline traditionally presents and engages students with its technical content. For instance, Knight et al. found that female students preferred engineering fields that cultivate multidisciplinary approaches, engage in real-world activities, and emphasize systems thinking [5]. This may explain why majors like Biomedical Engineering (BME) often enroll higher percentages of female students, while traditionally fundamental and theory-based disciplines like mechanical or computer engineering remain male-dominated [6].

Even though Biomedical Engineering is among the top engineering disciplines in enrollment diversity [7], there is still room and critical need for broadening the participation of female and URM groups. Studying differences in interest, participation, and career attainment of underrepresented groups across different engineering fields provides an opportunity for creating interventions that support broader inclusion. For instance, studies have led to recent incorporation of more inclusive K-12 and undergraduate engineering curriculums that are focused on real world applications and team work, while still maintaining technical STEM content and rigor [6].

This exploratory study aims to further understand gender and ethnic diversity differences between BME and other engineering majors, namely, Mechanical (ME), Chemical (ChE), and Materials Science Engineering (MSE), as they pertain to undergraduate students' career attainment. As typical with many BME programs, the BME major at a large Midwestern research university within which this study is conducted has attracted a higher enrollment of female students (32.4%), compared to its college of engineering (22.5%) and across U.S. undergraduate engineering programs as a whole (22.8%) [7]–[10]. Similarly, this BME program has enrolled more than twice the percentage of under-represented ethnic minorities (URMs) than the university's entire college of engineering

(15.0% and 6.5%, respectively), and is just shy of the U.S. engineering enrollment or URMs (17.3%). Herein we analyze factors such as pursuit of industry vs. graduate school, and reported industry salary offers, across gender and ethnic groups between BME and the three other, less diverse engineering majors. This work builds upon a previous case study that evaluated the industry potential of engineering students progressing through and graduating from undergraduate engineering programs [11]. This current investigation seeks to address the following research questions:

1. To what extent does the relationship between undergraduate career outcomes and gender/ethnic groups differ between BME and other engineering majors at a large Midwestern research university?
2. What are the differences in undergraduate engineering career outcomes across gender/ethnic groups at a large Midwestern research university?

Methods

This paper includes an exploratory analysis of aggregated undergraduate engineering student data collected by the college of engineering and Engineering Career Services (ECS) at The Ohio State University. The majors selected for this investigation include Biomedical Engineering (**BME**) and three comparison majors, namely Chemical Engineering (**ChE**), Material Science Engineering (**MSE**), and Mechanical Engineering (**ME**). These majors were purposefully selected for their categorization as emerging (i.e. BME, MSE) and traditional (i.e. ME and ChE) disciplines. Additionally, these majors were shown to be preferred transfer alternatives for BME undergraduate students at this university [11].

The data herein was collected with the approval of the Institutional Review Board (IRB) of the university studied. The dataset includes enrollment, degrees acquired, career outcomes, and reported salary upon graduation by gender and URM status for each selected major. Academic enrollment data from the autumn 2013 to autumn 2018 terms is used, while career outcomes data is from the autumn 2013 to autumn 2017 terms.

To perform the analyses, each major was further divided by either gender or underrepresented minority (URM) status. Gender only includes male (**M**) and female (**F**) categories, as collected and reported by the university. Due to the low enrollment of ethnic groups in the university, and to avoid potential risks of individual student identification, this paper will focus only on two ethnic statuses: non-URM (**N- URM**) and **URM** students. URM students include Black or African Americans, Hispanics, and American Indian/Alaska Native, as defined, collected, and reported by the university.

Student Population

To provide a better understanding of the size of the student population investigated, some categorical statistics are presented. The total enrollment (N_e) of students across the six years of data within these four majors is N_e = 9381 (BME = 1367, ChE = 3678, MSE = 791, ME = 3545). The total degrees granted (N_d) across these four majors is N_d = 3228 (BME = 418, ChE = 1113, MSE = 329, ME = 1368). The analyses and results in this paper are based on these populations.

Career Outcomes and Salary

Within the data set, students have the option to report four possible outcomes upon graduation. These include: career employment, further education, looking for job, and other plans. Career employment (**Industry**) includes students that have accepted a career offer, are considering an offer, or have made military commitments. Further education (**F. Edu.**) includes students that have opted to attend graduate or professional school, or other forms of continued education. Looking for job (**Looking**) includes students that reported a lack of offer and at the moment were actively pursuing a job. In this analysis, other plans were not included as they represented fewer than 3% of the students, and could not be related to a specific activity or action by the student. Students who opted for career employment also reported accepted/offered job salaries (**Salary**), N_s = 879 salary offers (BME = 48, ChE = 292, MSE = 77, ME = 462).

Statistical Analysis

For the statistical analyses in this paper, each of the four majors (**BME, ChE, ME, MSE**) were separated into the four target groups (**F, M, URM, non-URM**). Each major and target group combination were then separated into the three career outcomes (**Industry, F. Edu., Looking**). These resulting outcomes were normalized by the total number of degrees awarded for each target group (*i.e. Total BME Female with Industry Outcome / Total BME Female Degrees Awarded*), and then averaged across the five available academic years (**2013 – 2017)**. The **Salary** outcomes were calculated as simple averages across the same five academic years and four target groups for each of the four majors.

Two non-parametric hypothesis tests ($\alpha = 0.05$) were used to address the two research questions (**Figure 1**). These tests were chosen because of the low number of samples for each analysis performed. The first analysis was performed using the Kruskal – Wallis non-parametric test; this test is conceptually comparable to an ANOVA test, and identifies significant differences in a group (*multiple medians*). This test attempts to answer the first research question: *To what extent does the relationship between undergraduate career outcomes and gender/ethnic groups differ between BME and other engineering majors at a large Midwestern research University?* The second test conducts a comparison between conditions (gender and URM status) for all outcomes (Industry, F. Edu., Looking, Salary) in each major. This second analysis was performed using the Mann – Whitney non-parametric test, which is conceptually similar to a t-test; it identifies significant differences in two samples (*two medians*). This test attempts to answer the second research question: *What are the differences in undergraduate engineering career outcomes across gender/ethnic groups at a large Midwestern research University?*

Eta-squared was selected as the effect size measure of data variance for both the Kruskal-Wallis test and the Mann-Whitney test [12]–[14]. Effect size allows for the comparison of studies with different sample sizes, and provides a quantitative measure for the strength of the relationship between factors [13]. A value higher than 0.26 is used as the limit for a large or strong effect size.

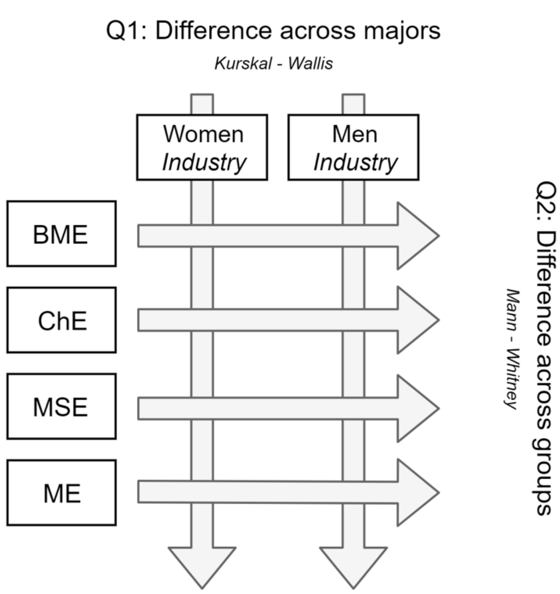

Figure 1: Overview of the statistical approaches. Research question 1 (Q1) Kurskal-Wallis analysis compares differences across each of the four majors, by target group (either gender, as shown, or by ethnic status). Research question 2 (Q2) Mann – Whitney analysis compares differences across target groups (either gender, as shown, or by ethnic status) by major and career outcome (either industry, as shown, or by further education or looking).

Results and Discussion

Enrollment and Bachelor's Degree Obtainment of Women

On average, between the years 2013 and 2018, approximately 22% (std. dev. of 10% for enrollment and 13% for degree attainment) of the population enrolled in the college of engineering investigated was female. This same percentage also matches the number of engineering bachelor's degrees obtained by women nationally [8]–[10]. Of the 14 engineering majors offered within this college, the major with the third highest enrollment of women was BME (34.2%). ChE was the fifth highest (31.3%), MSE was the sixth highest (28.7%), and ME was in the ninth position (15%). **Figure 2** shows the summary of enrollment and degrees obtained for the four selected majors. Here, it is visible that BME, ChE and MSE are above the college's overall average percentage line (22%), while ME is well below. Additionally, these values are in congruence with other reports that show heterogeneous distribution of gender diversity across engineering majors [5], [6].

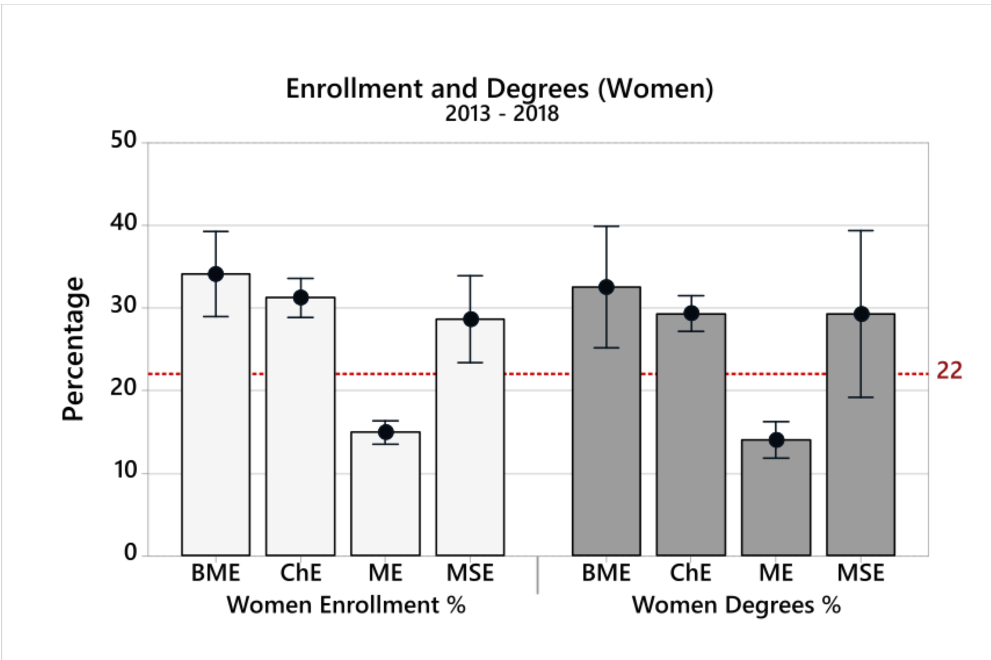

Figure 2: Average percentage of enrollment and bachelor's degrees awarded to women from 2013 to 2018 in each of four engineering majors (BME, ChE, ME and MSE). The dotted line indicates average enrollment and degrees awarded to women for the entire college of engineering at the university investigated (2013-2018).

On average, between the years 2013 and 2018, 6% (std. dev. of 3% for student enrollment and 4% for degree attainment) of the population in the college of engineering was from an underrepresented background. **Figure 3** summarizes the underrepresented enrollment across each of the four selected majors. ChE and MSE exhibit URM enrollment closest to the overall college average of 6%, followed by BME, and ME. Similar to gender, these results align with previous reports of heterogeneous URM student populations across engineering majors [9]

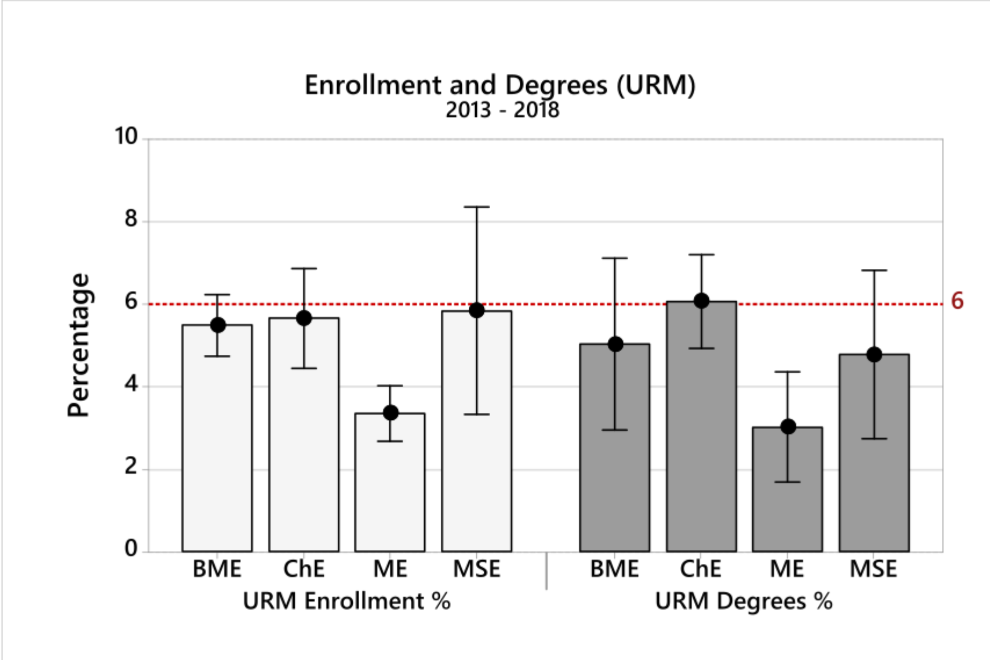

Figure 3: Average percentage of enrollment and degrees acquired by URM students from 2013 to 2018. The dotted line indicates average enrollment and degrees awarded to URM students for the entire college of engineering (2013-2018).

Career Outcomes and Salary – by Gender

Figure 4 shows the average percentage, with standard deviation, of each major's career outcomes (**Industry**, **Looking**, **F. Edu.**) subdivided by gender. The Kruskal-Wallis test indicated significant differences in the industry career outcome across majors for both male ($\chi^2(3) = 16.55$, p-value = 0.001) and female ($\chi^2(3) = 10.73$, p-value = 0.013) students, each with large effect sizes (male - 0.85 and female – 0.48). This difference is in congruence with BME students entering industry at lower rates than their peers in other engineering disciplines. A significant difference was also observed in both male ($\chi^2(3) = 15.27$, p-value = 0.002) and female ($\chi^2(3) = 12.40$, p-value = 0.006) students who pursued further education, with large effect sizes (male – 0.77 and female – 0.59). This difference again is in congruence with BME students selecting further education at higher rates than their peers. Lastly, comparisons pertaining to students looking for a job or other opportunities did not yield significance for either male ($\chi^2(3) = 1.97$, p-value = 0.578) or female ($\chi^2(3) = 7.05$, p-value = 0.07) students. However, it is important to note that there was more variability in the *Looking* career outcome for female students across each major, compared to male students.

This study also explored potential differences between genders for each career outcome in each engineering major. For BME in particular, the Mann – Whitney test indicated a significantly larger proportion of female students (44.4%) who pursued industry careers compared to male students (22.0%, p-value 0.037), with a large effect size of 0.44. Additionally, the median percentage for female (7.7%) and male (24.0%) students who were looking for jobs were significantly different (p-value = 0.037), with a large effect size of 0.44. These results indicate that female BME students have better industry placement than their male counterparts. No statistically significant difference was found between male and female students in BME pursuing further education.

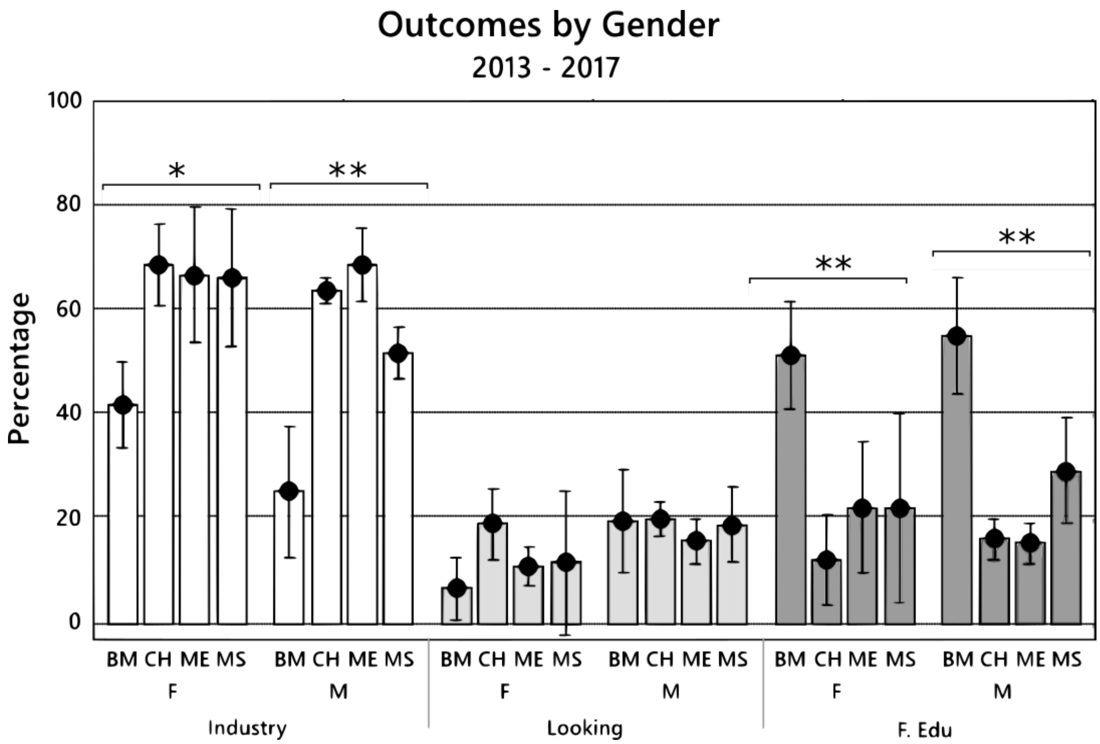

Figure 4: Average percentage and standard deviation, by gender, for each career outcome (*p < 0.05 and **p < 0.01).

Figure 5 shows the average starting salaries reported by each major for both male and female students. A Kruskal-Wallis test across majors for each gender showed no significant difference for both average female salaries ($\chi^2(3) = 7.14$, p-value = 0.068) and average male salaries ($\chi^2(3) = 6.04$, p-value = 0.11). Additionally, a Mann-Whitney test between male and female salaries for each major resulted in no significant differences (BME p-value = 0.095, ChE p-value = 0.296, ME p-value = 0.835, and MSE p-value = 0.531). It should be noted, however, that the average salary is comparably lower for female students; more data should be collected and monitored closely. Overall, these results are encouraging, as there does not appear to be statistically significant gender bias in starting salary offers.

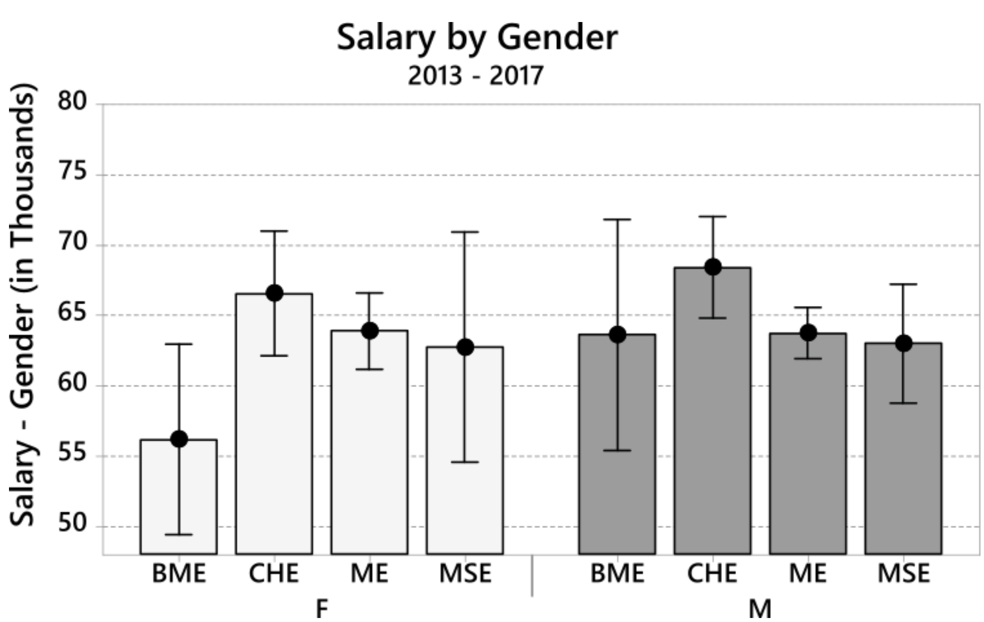

Figure 5: Average salaries, by gender, reported for each major from 2013 to 2017. Confidence intervals were constructed using the standard deviation.

Career Outcomes and Salary – by URM Status

Career outcomes for URM and N-URM students are presented in **Figure 6.** The Kruskal-Wallis test indicated significant differences only in the cases for N-URM students who pursued industry ($\chi^2(3) = 16.55$, p-value = 0.001) and further education ($\chi^2(3) = 15.94$, p-value = 0.001), both with large effect size (industry – 0.85 and further education – 0.81). The industry and further education outcomes of the N-URM students are similar to previously reported analyses [11], in which BME demonstrated a statistically significant difference on the average percentage for industry and further education student outcomes compared to the other three majors. It should be noted that the low total number of URM engineering graduates created high data variability. For example, the largest number of graduates from one of the analyzed engineering programs was $N_d = 13$, thus 13 becoming the denominator for normalizing percentages of URM students who pursued industry, further education, or were looking for a job. In some cases, a major had no URM graduates for a particular outcome, which significantly increased the percentages observed for the other outcomes. Therefore, due to the high level of data variability, the authors chose not to pursue the Mann-Whitney test to compare specific career outcomes between N-URM students and URM students in each major. Overall, the main (and concerning) observation within this data set is the low number of URM enrollment and degree attainment among the four engineering programs of interest.

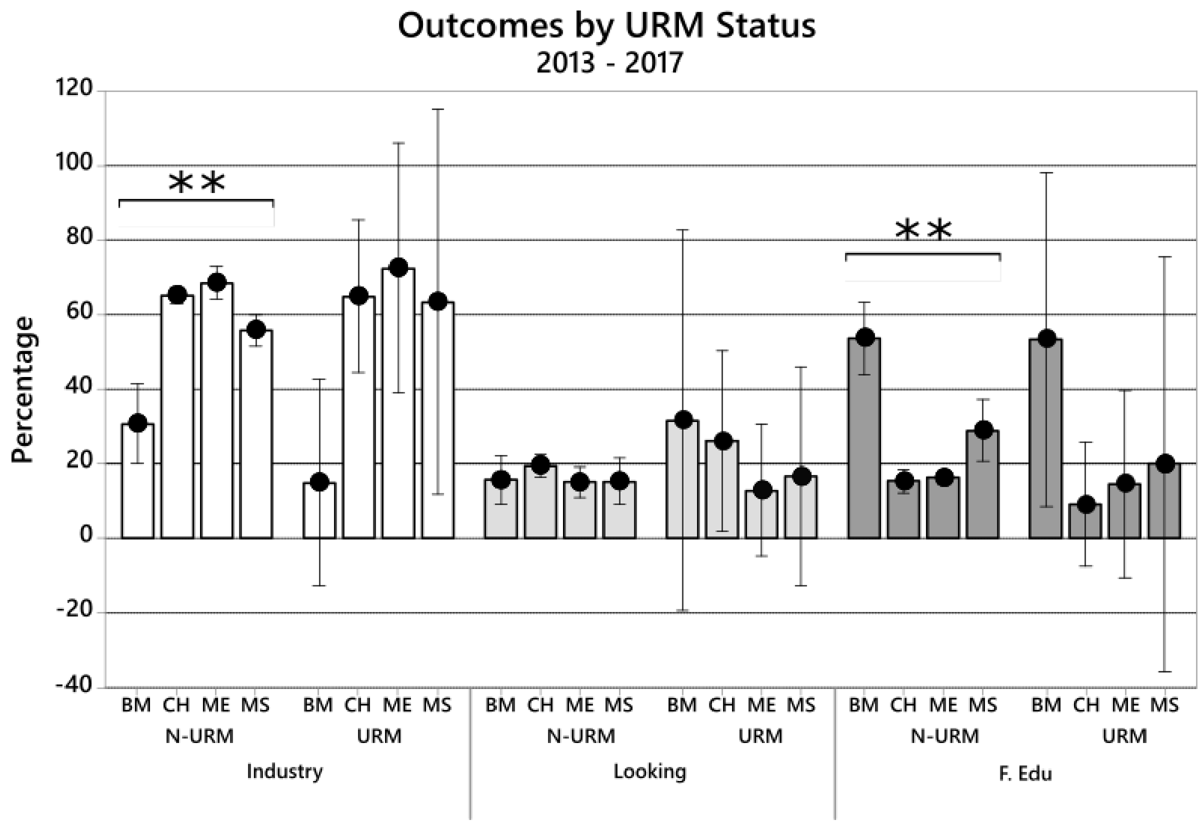

Figure 6*:* Average percentage, by URM status, for each career outcome. Confidence intervals were constructed using the standard deviation (*$p < 0.05$ and ** $p < 0.01$).

Figure 7 shows the average reported salaries of undergraduate students by URM status. This analysis did not indicate statistical significance from the Kruskal-Wallis test across majors. Additionally, the Mann-Whitney analysis could not be performed due to lack of BME URM observations, and the high variability of salaries reported by URM students in the other majors. For N-URM students in a previous publication [11], it was shown that BME salaries were statistically different to other engineering majors (specifically ChE), however in this data this difference is not observed. The authors attribute this change to a $10,000 increase in BME average salary in 2017 (not included in the previous works' analyses). As cautioned when discussing BME salaries by gender, this representation of overall BME salary must be closely monitored.

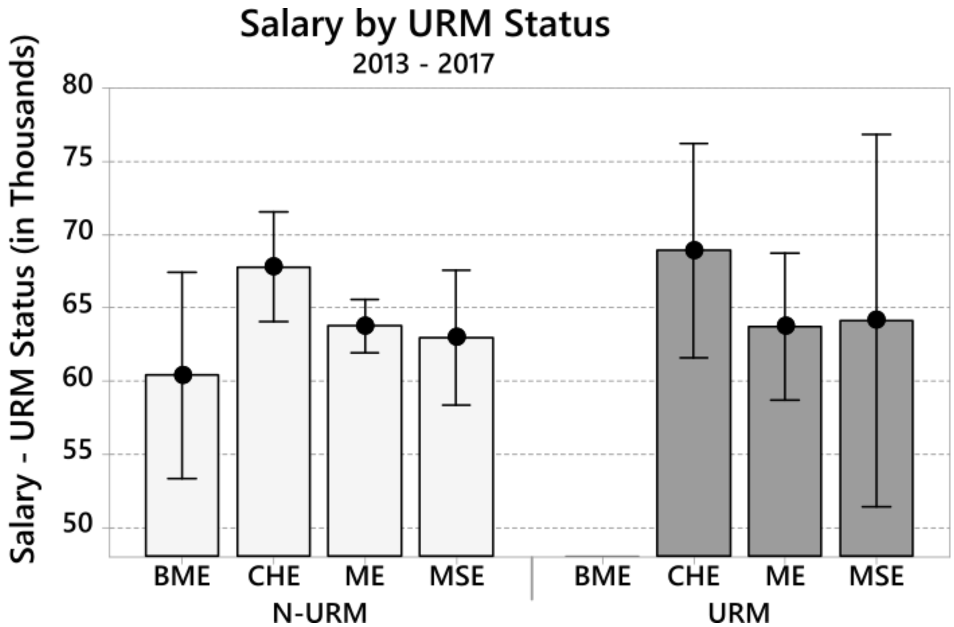

Figure 7: Average salaries reported by each major, separated by URM status (2013 to 2017). Confidence intervals were constructed using the standard deviation.

Conclusions and Future Direction

This exploratory study seeks to further understand the gap between BME undergraduate students and industry through a lens of those underrepresented within engineering. Understanding the similarities and differences in undergraduates not only across majors, but between genders and URM status, unveils new challenges and opportunities. This research confirms previous findings on heterogenous gender distribution across engineering majors [5], [6], and provides new insight into gender differences among three different career outcomes. Results particularly showed more female BME students pursuing industry careers compared to their male counterparts; this is especially encouraging for advancement towards a more diverse BME workforce. However, some caution should be noted regarding relatively lower starting salaries reported by female BME students. It was also observed that underrepresented minorities continue to comprise a small percentage in undergraduate engineering enrollment, with no visible sign for improvement. Future work will continue to probe for factors that explain *why* such a gap exists in the university and BME-to-industry pipeline, and identify *ways* in which this gap can be bridged.

Acknowledgments

The authors are grateful to The Ohio State University's Engineering Career Services, including Amy Thaci and Laura Pizoli, and the College of Engineering's Data Specialist, Jamie Paulson, for assistance with data access. Additionally, the authors thank OSU's Data Access and Analyses Core and Turhan Carroll for guidance that significantly strengthened this work.

This material is based upon work supported by the National Science Foundation under Grant No. 1830814. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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