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On the Relationship Between Race, Gender, and Student Success from First Year to Second Year in Engineering

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On the Relationship Between Race, Gender, and Student Success from Year 1 to Year 2 in Engineering

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Abstract

There is a need to identify where student success disparities are occurring in engineering, investigate why the differences are present, and propose institutional and pedagogical changes to address them. This work seeks to understand how the gap in student success amongst students in engineering is correlated to student identity and academic level. Built upon an anti-deficit framework, this study works to reframe the narrative around the achievement gap acknowledging the impact that climate and support have on students of color and women in engineering.

The authors hypothesize that there is a difference in academic performance by a student's gender and race and that this gap is not reliant solely upon academic preparedness. The work investigates 10 years of academic records for engineering students at a midwestern, predominantly White, Jesuit institution. The data shows that White women received higher grades than every other group of students. On the contrary, men of color, including Black, Latinx, and Asian students, earn grades below the population mean. To investigate how the curriculum structure affects student success, an analysis of performance by course level (1000, 2000, etc.) is detailed. This analysis finds that course level is a significant factor in student success and the gap amongst demographic groups. At the 1000 level in engineering courses, White men, Asian women, and Black men perform at the population mean; White women perform above the mean; and Latinx men and women perform below the mean. However, at the 2000 level in engineering courses, all men of color earn grades below the population mean, with Black men dropping to 0.5 GPA points below the population mean on a 4.0 scale. Additional exploration of students' academic preparedness, including standardized test scores, is conducted to identify the correlation of prior metrics on the gap in performance. Future work is focused on understanding what factors are influencing these disparities and how classroom and institutional design can mitigate the effects.

1 Introduction

There is a growing call to diversify the pipeline of engineering students to meet the need of technological development and to advance equity in Science, Technology, Engineering, and Math (STEM)**.** To achieve this goal, academic institutions are looking introspectively to understand how their campus environments are designed to foster student success and equity. This work seeks to identify gaps in engineering student success through a ten-year study of academic performance correlated to student identity and course attributes.

The work of Tinto [1], [2] has been built upon to show that a students' sense of belonging is related to their propensity to persist in higher education [1]–[3] and in engineering [4]. This is most notably important in students who are minoritized in engineering, specifically women and students of color, whose sense of belonging is influenced by the environment around them [4],

[5]. It has been shown that extracurricular engagement and faculty support have a positive effect on minoritized students' sense of belonging [5]. Furthermore, work has shown that instructor mindset has a significant factor on relative student success with minoritized students performing better in STEM courses in which the instructor has a growth mindset as compared to a fixed mindset [6]. In addition to belonging, systematic factors, such as minority stress and stereotype threat, affect minoritized students' overall success [7]. These contribute to a reduction in mental bandwidth as students are spending more energy and focus on combatting underlying systemic factors, leading to less bandwidth remaining for academic endeavors [8].

There is a documented observation of reduced performance from year 1 to year 2 in higher education across groups [9], [10]. Furthermore, recent work has shown that introductory courses affect students of colors' likelihood to persist in STEM education at a disproportionately higher rate compared to their White colleagues [11]. Additionally, second year students report a decline in course enjoyment and faculty engagement despite a positive trend in academic engagement and social integration when compared to first year [12], attributes which have been previously shown to improve belonging and persistence [4], [5]. Investigations of second year students showed significant differences between the experiences of students along racial groupings [13]. In this work, the first and second year are of focus due to the apparent difference in experience for students at these levels, detailed herein.

The authors are approaching the research questions posed herein with an anti-deficit achievement framework. Harper explains that this framework should be used to repose questions around minoritized students in STEM toward what students bring that is unique to their success, rather than what they lack [14]. Mejia, et al. argue that these frameworks provide a critical lens in which to view the systems that result in the observed academic inequities [15]. Often, Asian American and Pacific Islander (AAPI) students are assumed to be less affected by systemic inequities than their Black and Brown peers and characterized as a monolithic group of high-achieving individuals, coined the model minority myth [16]. The relationship between anti-deficit framing and the model minority misconception is reviewed by Poon, et al. [17]. They articulate the problematic relationship between the model minority myth and racist structures within higher education when Asian students are grouped with White peers, treated as a monolith, and characterized as a middle group between White students and Black and Latinx students [17]. There is a call to stop treating AAPI students as a monolith and include them in broader discussions on racial equity in higher education [18]. The data presented herein are disaggregated by six racial categories (Asian, Black, American Indian, Latinx, Pacific Islander and White) to avoid conflating the experiences of all students of color. The authors acknowledge the limitations of failing to disaggregate these groups further, however, these data are limited by the institutional data categorization. Additionally, the choice of American Indian as an identifier, as compared Indigenous, is made to remain consistent with the self-selected student options provided by the institution. The authors acknowledge future data collection should consider appropriate representation.

This work seeks to understand how the factors in a curriculum affect students and their success in engineering by answering two research questions (RQ). *(1) What, if any, demographics factors influence a student's engineering GPA? (2) How does the course level affect the performance of students in demographic groups shown to be significant in RQ1?* Herein, it is shown that the progression through an academic career affects students differently based on their demographics. Male students of color are shown to be the group most negatively impacted by certain effects.

This work seeks to counter the common anecdotal fallacy that academic preparedness is the primary driver between disparities in success as it is observed that gaps widen and narrow with time through the academic levels. Additionally, these data show a counter-story to the common model minority fallacy when Asian students are hypothesized to be plagued by systemic issues less than other students of color and improperly aggregated with White students.

2 Methodology

2.1 Data Collection

This work focuses on academic records of engineering students enrolled at a predominantly White, mid-sized, private, Jesuit institution in the Midwest, herein described as the university of interest. The university has four engineering departments: biomedical engineering; civil, construction, and environmental engineering; electrical and computer engineering; and mechanical engineering. The university annually enrolls approximately 11,000 students with approximately 1,200 undergraduate engineering students.

The data includes ten years of academic records from Fall 2011 – Spring 2021. The data includes the undergraduate grades of engineering students in their engineering, math, and science courses. Additional course details include the course listing, the credit hours, the course level, and the academic term in which the course was taken. Student demographic data includes race, sex, academic level, high school GPA, ACT scores, SAT scores, first-generation status, and cumulative college GPA. It should be noted that these demographics are reported from the institution, therefore the groupings are predetermined. The use of sex, as opposed to gender, as the category name is chosen due to the binary nature the data collected by the institution of interest. Further studies looking at gender beyond the binary are required. The makeup of students in the dataset is presented in Table 1.

Table 1: Percentages of total population (N=4386) represented in each sex and race intersection. Populations with less than 15 individuals are listed as n<15 and not included in select data analysis to avoid reidentification.

Race	Sex	n	Percent
Asian	Female	108	2.5%
Asian	Male	216	4.9%
Black	Female	33	0.8%
Black	Male	85	1.9%
American Indian	Female	n<15	0%
American Indian	Male	24	0.5%
Latinx	Female	140	3.2%
Latinx	Male	357	8.1%
Pacific Islander	Female	n < 15	0%
Pacific Islander	Male	n < 15	0%
Refused	Female	27	0.6%
Refused	Male	61	1.4%
White	Female	747	17.0%
White	Male	2524	57.5%

Data is cleaned to remove non-undergraduate students, zero-credit courses, and pass-fail courses. Data from students whose race or sex changed through the dataset and students with missing racial identity are omitted from race/sex specific analysis to avoid misrepresenting a student's identity. Further research is required for multi-racial students and LGBTQ+ students. Demographic groups that have a population of fifteen or fewer are omitted from the analysis to avoid reidentification. Students from demographic groups of fewer than 15 and those with altered race and sex are included in the population level statistics.

2.2 Data Analysis

The primary metric used in this analysis is term GPA which is calculated by $T = \frac{\sum_{i=1}^{k}(g_i c_i)}{\sum_{i=1}^{k} c_i}$,

where T is the term GPA; k is the number of engineering, math, and science courses for the student per term; g_i is the grade earned on a 4.0 numerical scale in the i^{th} course; and c_i is the number of credits in the i^{th} course. The conversion between letter grades and GPA points are in Table 2.

Table 2: The numeric conversion between letter grades and GPA points on a 4.0 GPA scale.

Letter Grade	GPA Points
A	4.0
A-	3.67
AB	3.5
B+	3.33
B	3.0
B-	2.67
BC	2.5
C+	2.33
C	2.0
C-	1.67
CD	1.5
D+	1.33
D	1.0
F	0.0

The effects of demographic factors on term GPA are analyzed using an ANOVA test in which the null hypothesis is $H_0: \mu_j = \mu_k$ and the alternative hypothesis is $H_1: \mu_j \neq \mu_k$ where μ_j and μ_k are the mean term GPA for the j^{th} and k^{th} group, respectively . The term GPA is used rather than course grades to limit the impact of the skewed nature of individual grades on the analysis. It should be noted that the term GPA was still skewed left due to the bounds of possible grades (A-F), however, the size of the dataset addresses the non-normality.

3 Results

3.1 Significance Testing

The ANOVA test shows that race, sex, and the intersection thereof are significant factors in the term GPA for engineering courses at a 95% confidence level. The mean term GPA for engineering courses on a 4.0 scale is presented for each race and sex intersection in Figure 1. The red line indicates the population mean, the center dot is the group mean, and the bars represent the 95% confidence interval for the mean. Populations with less than 15 individuals are not represented in Figure 1.

Figure 1 shows that White females are performing above the population mean; Asian females, White males, and American Indian males are performing at the population mean; and Latinx females, Asian males, Latinx males, Black females, and Black males are performing below the population mean. There is a 0.7 GPA point spread between White females and Black males; this equates to the difference between a B- and a C. Figure 1 can be interpreted such that subgroups with overlapping bar regions do not have statistically significant differences in their population means.

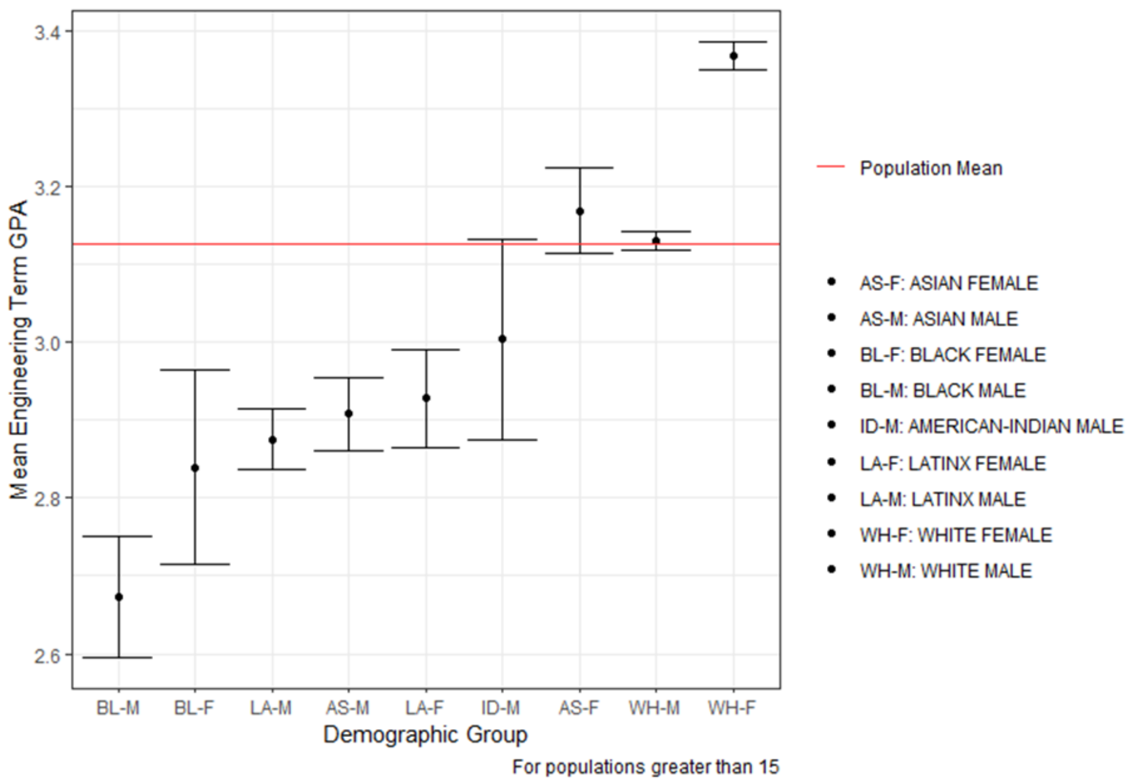

Figure 1: The mean term GPA on a 4.0 scale of undergraduate engineering courses broken down by student demographic across 10 years of academic data. The red line is the population mean, the dot is the mean value, and the bars represent the 95% confidence interval for each grouping. Populations with less than 15 students are omitted.

It was found that the course level is a significant factor on the earned grade by engineering students. As such, the performance of the groups in Figure 1 was analyzed relative to the course level. Figure 2 presents the term GPA in engineering courses as a function of course level (1000, 2000, 3000, 4000). The data is presented as a difference from the overall population mean for each course level so the relative performance of demographic groups can be observed. A positive difference is noted as performing above the mean at that course level whereas a negative difference is performing below the mean. The ribbons are the 95% confidence interval of the mean for each group at each course level. The mean term GPA on a 4.0 scale for each demographic group at each level is shown in Table 3. The table cells are shaded with darker cells indicating lower mean term GPA. In Figure 2, it can be noted that Asian females, Latinx females, and White females demonstrate a positive improvement relative to the mean from 1000 to 2000 level courses. The men of color, including Asian males, Black males, and Latinx males demonstrate a decrease in performance from the first to second year courses. This drop is most notable in Black males with a drop of nearly 0.5 GPA points relative to the mean. The authors argue that this drop seen in men of color from year 1 to year 2 contradicts the common argument that student success disparities are solely attributed to academic preparedness. If this were the case, the disparity would be noticeable in the 1000 level courses, but that does not appear to be present in the data.

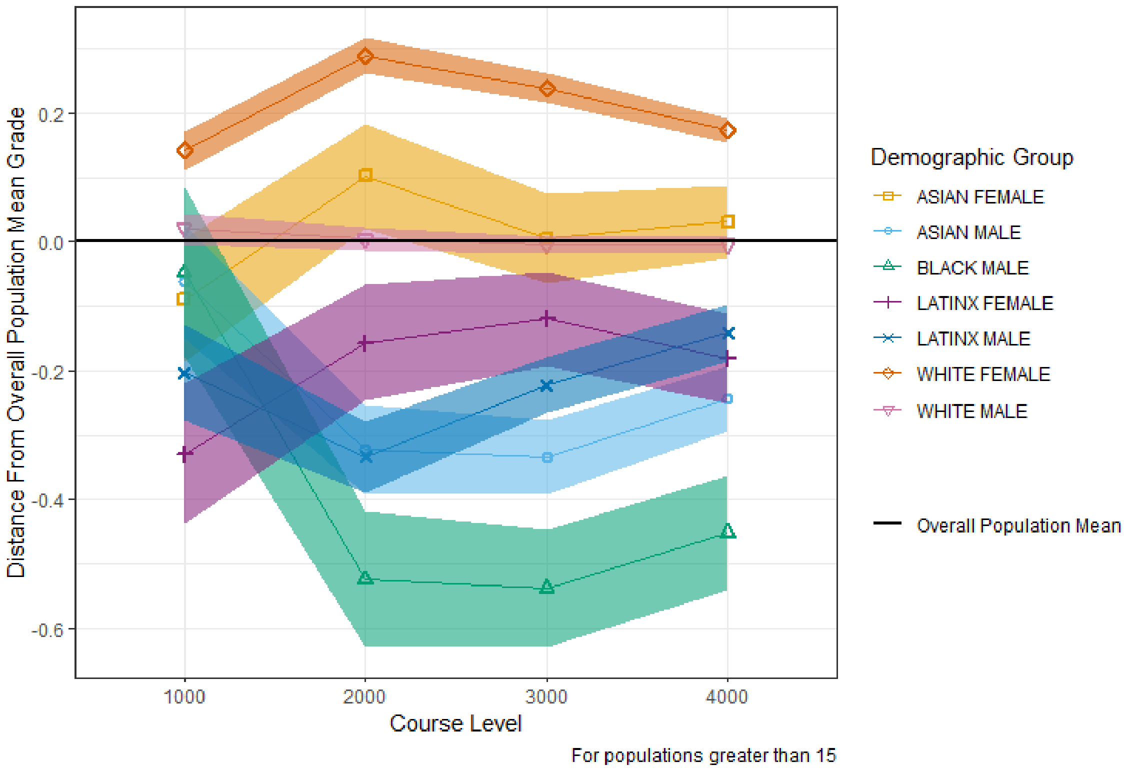

Figure 2: The mean term GPA for engineering courses plotted by course level (x-axis). The term GPA is plotted relative to the population mean at each course level to show the relative performance between demographic groupings. The ribbons indicate the 95% confidence interval of the mean for each population group at each course level. Populations with less than 15 individuals at each course level are omitted from the dataset.

Table 3: The mean term GPA for students at each course level in engineering courses on a 4.0 scale. The darker the square in the table, the farther the data is from 4.0 to show the relative nature of the values. Populations with less than 15 individuals at each course level are omitted from the dataset.

Population	1000	2000	3000	4000
ASIAN FEMALE	3.32	3.07	2.99	3.39
ASIAN MALE	3.35	2.65	2.65	3.11
BLACK MALE	3.36	2.44	2.45	2.91
LATINX FEMALE	3.08	2.81	2.87	3.18
LATINX MALE	3.20	2.63	2.76	3.22
WHITE FEMALE	3.55	3.26	3.22	3.53
WHITE MALE	3.43	2.97	2.98	3.35
OVERALL	3.41	2.97	2.99	3.36

At the university of interest, many 1000 level courses that engineering students take are outside of the engineering department, as such the analysis presented in Figure 2 is expanded to include engineering, math, and science courses taken by engineering undergraduate students in the same period. This data is presented in Figure 3. Similar conclusions to that of Figure 2 can be drawn. The greatest differences in student success are observed at the 2000 and 3000 level courses and the relative performance of males and females in specific demographic groups is consistent with females performing above their male counterparts. These combine to support the hypothesis that academic preparedness is insufficient to explain differences in student success.

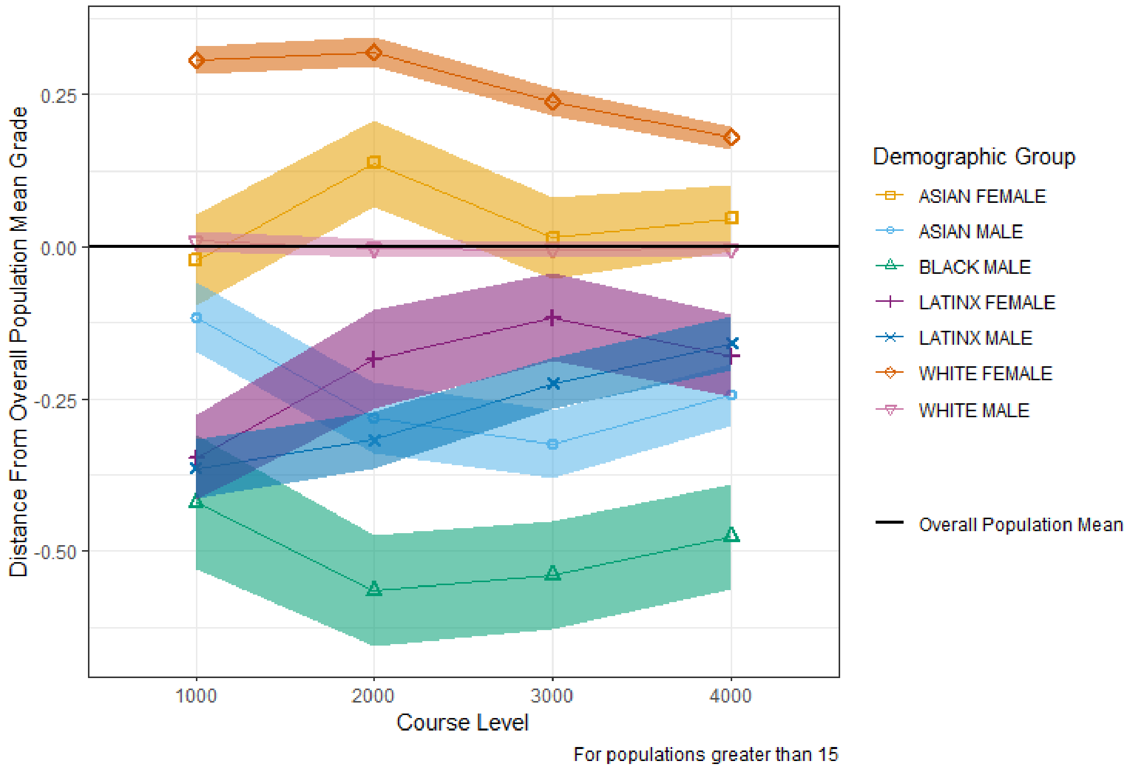

Figure 3: The mean term GPA for engineering, math, and science courses plotted by course level (x-axis). The term GPA is plotted relative to the population mean at each course level to show the relative performance between demographic groupings. The ribbons indicate the 95% confidence interval of the mean for each population group at each course level. Populations with less than 15 individuals at each course level are omitted from the dataset.

4 Discussion

As detailed in the introduction, there are well-documented disparities in higher education student success with respect to student background, race, and first-generation status. This study seeks to counter the anecdotal theory that academic preparedness is the dominant factor affecting student success in higher education by demonstrating the effects of course level on relative performance. Furthermore, this work demonstrates the need for disaggregation by race and sex in analysis of student success. Figure 1 shows a correlation between the race, sex, and average term GPA of students in their engineering course and Table 1 details the disparities in representation. The data highlights the importance of an intersectional approach to disparities in STEM fields and higher education, which is often overlooked. When discussing disparities in STEM and higher education, the issue is typically viewed as one centering gender inequality or racial inequality. When women in STEM are discussed without acknowledging race, it is implied that the experience of White women in STEM is the same as the experience of women of color in STEM. Programmatic design that is conducted based on this belief will be done without considering that there are aspects of the student experience that varies with intersectional identities. In Figure 1 and Figure 3, White women are performing above the mean, whereas Asian women are performing at the mean and Latinx women are performing below the mean. It is hypothesized that the systems that currently exist at the institution of interest are more effective at supporting White women than their Latinx female colleagues, which highlights a need for an intersectional perspective of the gender disparity in STEM. The same can be said about discussing students of color in STEM without acknowledging gender as Figure 1 and Figure 3 details the differences amongst racial groups along gender lines. Designing or evaluating programmatic interventions without the intersectional approach may fail to address the nuance of the student experience.

4.1 Course Level Influence on Student Success

The data presented in Figure 2 and Figure 3 is shown as the distance from the population mean rather than the raw performance at each course level to understand how the relative performance of the student populations is affected by course level. In these data, men of color (Asian, Black, and Latinx) all exhibit a drop in relative performance from the 1000 to 2000 level courses. As educators attempt to address the disparities in student success, understanding the drop which appears to affect male students of color more than their White and female colleagues is of importance. Of note, Asian male students are sometimes grouped with White male students when discussing student success in higher education [16], [17], however, this data demonstrates the inaccuracy in that grouping. The authors hypothesize that the model minority fallacy [16] may be contributing to a lack of targeted student support when Asian students are assumed to have comparable experiences to their White peers. This is in alignment with prior work by Trytten et al., who found that Asian American engineering students did not conform to the model minority academically and faced discrimination in engineering [19]. The data presented herein is from a single, predominantly white institution. Therefore, future work is necessary to explore this hypothesis.

The increase in the gap between students of color and their White peers from the 1000 to 2000 level courses is incompatible with the common assumption that academic preparedness is the sole reason for disparities in student success. This data suggests that there is a difference in the first- and second-year success based on race and sex, which leads the authors to hypothesize that effects local to the academic institution, in part, are a factor in the performance of these groups. It requires significantly more study to understand what aspects of the educational environment leads to this disparity; however, it is of importance to note that this student success gap does not fall solely on the shoulders of the student and their prior academic environments. Furthermore, this analysis did not include any investigation of socioeconomic status. Often, when race is discussed with academic preparedness arguments, race and socioeconomic status are conflated. The authors warn that this conflation should be avoided.

Figure 3 shows a larger gap in the 1000 level courses when science and math data are included in the analysis. This indicates that there is room for growth in the foundational science and math courses when considering the equitable success of various groups. These courses are often prerequisites for higher level engineering courses and have been shown to impact the persistence of minoritized students at a higher rate than their non-minoritized colleagues [11].

4.2 Limitations

This study presents a reflective view of ten-years of performance in engineering at a single institution. Although there are more than four thousand students represented in the dataset, it should be noted that a single institution may limit the direct transfer of conclusions to other institutions. Likewise, engineering is a unique test bed for this analysis due to the lack of representation of non-White and non-male students. This duality in minoritization can result in unique trends specific to engineering. However, the authors hypothesize that these data may be transferrable to other institutions and disciplines due to the nature of higher education and challenges in the first-to-second year transition that are documented in literature [9], [10]. Furthermore, the analysis technique and data visualization contribute to the understanding of the relative impacts of academic institutions on certain student groups.

An ANOVA is presented to confirm the effects of race and sex on term GPA. The term GPA data was skewed left due to the bounds of the grades possible (A-F). As noted in the methods, the term GPA was chosen over earned grade to reduce the effects of the skew. The dataset is sufficiently large to address normality concerns. However, the non-normality is a limitation of the ANOVA analysis.

Due to the nature of data collection at the university of interest, additional factors that may affect student experiences were not available in this analysis, including, but not limited to, LGBTQ+ and socioeconomic status. This study focuses on the intersection of race and sex, but the authors acknowledge that there are more dimensions to student identity. Future work understanding how intersectionality with other factors affect success is of significant importance.

5 Conclusion

The performance of engineering students does vary with course level, race, and sex. At the institution of interest, all engineering student groups perform lower in 2000 and 3000 level engineering courses than in 1000 level engineering courses. Performance in 1000 level courses engineering courses for all groups is higher than that of 1000 level science and math courses. However, the relative impact of these courses is greater in male students of color. Demographic factors do appear to impact the performance by course level, specifically the intersection of race and sex. Race and sex are significant factors in overall academic performance outside of the performance by course level. White females are consistently performing above the overall population mean, White males and Asian females are consistently performing near or at the population mean, and all other demographic groups are consistently performing below the population mean, with Black males, achieving the lowest performance. Although all student groups see a drop in performance from 1000 to 2000 level engineering courses, race and sex are significant factors on the degree to which performance drops. Future work to understand why these disparities in student success are present and appear to worsen over the academic career is critical to achieving equity in higher education.

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