

## Student Demographics and Outcomes in Mechanical and Aerospace Engineering Including Migration between the Disciplines

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# **Student Demographics and Outcomes in Mechanical and Aerospace Engineering Including Migration between the Disciplines**

## **Abstract**

There is a large amount of overlap in Mechanical (ME) and Aerospace Engineering (AsE) curricula, and yet the student populations look quite different in terms of race and gender representation. This study includes institutional data from 6 institutions, all of which offered ME and AsE over the period 1987-2010. This large sample (over 20,000 first-time-in-college engineering students) allows us to adopt an intersectional framework to study race and gender together. In this paper, we examine the demographics of students in ME and AsE and their six-year graduation rates. Then we consider the exchange of students between these two similar disciplines and how that affects the graduation rate of each.

Overall, ME does not recruit many women, but it retains many to graduation. AsE, however, has recruitment and retention patterns that highlight the intersectionality of race and gender. For example, being a Hispanic female in AsE is more complex than just the superposition of being a Hispanic student in AsE and being a female in AsE. Within each racial/ethnic group, men who start in engineering choose AsE and ME at higher rates than women who start in engineering. In Aero, the gender gaps are small to moderate among White, Hispanic, and Asian students, with a larger gap between Black men and women choosing AsE (9% vs. 4%). Mechanical Engineering on the other hand, has large gender gaps within all racial/ethnic groups with more men than women choosing ME

Many students switch from AsE to ME and vice versa. By studying the differences between AsE and ME and the exchange between them, both disciplines can learn from each other about how to improve their recruiting and retention of underrepresented groups.

## **Introduction**

Studying the demographics and outcomes of Mechanical Engineering (ME) and Aerospace Engineering (AsE) students provides valuable insight to the professions. Despite numerous calls to diversify the engineering profession<sup>1,2</sup>, ME and AsE lack diversity even compared to other engineering disciplines<sup>3</sup>. This is of particular concern because ME is one of the oldest and largest engineering disciplines<sup>4,5</sup>. At many institutions, the ME and AsE degree programs are managed by the same administrative unit. Although the curricula in ME and AsE are quite similar, how do demographics and student outcomes differ? Research on Electrical Engineering (EE) and Computer Engineering (CpE), which also have similar curricula, also showed substantial differences in student populations and outcomes<sup>6</sup>.

For all engineering disciplines combined, many studies have shown no gender gap in engineering persistence<sup>7-13</sup>. In a large multi-institution study, comparable rates of persistence or graduation were found for women and men of all races and ethnicities when the data were aggregated by discipline<sup>14,15</sup>. One of the few studies that disaggregated by gender and major found that women were more likely to persist in ME than men. AsE was not offered at the institution<sup>16</sup>. A more

recent study found that women and men had comparable six-year graduation rates in ME and AsE<sup>17</sup>. Both were single-institution studies in the U.S.

Previous work focused on ME showed that men consistently outnumber women but the rates of matriculation and six-year graduation vary by race and gender. Retention is higher in ME than in the aggregate of all engineering majors for Asian, White, and Black students, but not for Hispanic students. Black males have particular challenges in ME while Asian females are most likely to graduate. Nearly half of all ME graduates started somewhere other than ME<sup>18</sup>, mostly in other engineering majors. This work extends that prior work by considering both ME and AsE including the migration of students between the disciplines. Like the previous work, this work adopts a critical race theory framework<sup>19</sup> and considers the intersection of race and gender<sup>20</sup> rather than aggregating all women or all minorities.

## Methods

### *Data Source*

Data for this study are from the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD)<sup>21</sup>, comprised of whole population data from 11 public institutions. Over the period 1987-2010, 137,649 are first-time-in-college (FTIC) students matriculating in engineering.

### *Population*

Only the six institutions offering both ME and AsE are included in this study. Thus the study population includes 20,533 FTIC students who self-identified as Asian, Black, Hispanic or White, declared ME or AsE as a major, and have sufficient data to calculate six-year graduation rates during the period from 1987-2010. Because neither of the Historically Black Colleges and Universities (HBCU) in MIDFIELD offers a degree in Aerospace Engineering, Black students are less well represented in this population than in the entire MIDFIELD population. International students are not included in this study.

### *Metrics*

To facilitate the comparison of the pathways of ME and AsE students at schools with first year engineering (FYE) programs and schools where students matriculate directly to specific engineering majors, the Semester 1 ME and AsE enrollments at FYE schools are imputed. This imputed Semester 1 enrollment, Semester 1\*, is calculated by allocating the total FYE matriculated population to specific majors at semester 1 in the same proportion as students chose each major after FYE. This assumes that the retention through the transition from FYE programs is the same for all engineering majors. For example, if 100 students matriculate to FYE programs, and 75 students declare a specific engineering major immediately after leaving FYE, then there is 75% retention. If 15 students declared ME after FYE, then 20 ME students would be imputed at Semester 1\* ( $15 / 75\% = 20$ ). The retention rates used in imputing Semester 1\* enrollment are computed for each race-gender combination. For the included schools, FYE-to-engineering major retention ranges from 51% for Black females to 73% for Asian males.

In this paper, a student is considered to have graduated if that student has graduated by the sixth year from matriculation, following a standard of reporting used by the Integrated Postsecondary Education Data System (IPEDS)<sup>22</sup>.

## Results and Analysis

### *Who starts in ME and AsE?*

Focusing on ME and AsE starters, Table I shows the number of engineering (ENGR) starters in this dataset and the number choosing ME and AsE disaggregated by race and gender. The average SAT Math score for students starting in each major is also included at the bottom.

TABLE I. DEMOGRAPHIC DISTRIBUTION OF STUDENTS STARTING IN AERO, ME, AND ENGR.

Race/Sex	ENGR starters	AsE starters	% AsE	ME starters	% ME
White Male	49025	5755	12	9702	20
Hispanic Male	1737	231	13	285	16
Black Male	2771	260	9	460	17
Asian Male	3845	356	9	552	14
White Female	11664	1229	11	1304	11
Hispanic Female	485	58	12	46	10
Black Female	1484	52	4	121	8
Asian Female	1031	64	6	78	8
All Male	57378	6602	12	10999	19
All Female	14664	1403	10	1549	11
All students	72042	8005	11	12548	17
<b>Average SAT Math</b>	<b>647</b>	<b>649</b>		<b>655</b>	

Both AsE and ME have average SAT math scores above that of the general engineering population (which is higher than the general college population). AsE has a two point advantage while ME has an eight point advantage. Based on this data, it would appear that these two groups of students are generally academically well-prepared.

For the race/gender groups in the top 8 rows of Table 1, the percentages of engineering starters choosing ME and AsE are shown in Figure 1. The rows indicate race, and the data markers indicate percentages by gender. For example, 12% (5755/49025) of White male engineering starters start in AsE while 9% (356/3845) of Asian male engineering starters start in AsE.

In the first panel of Figure 1, racial-ethnic groups are ordered by decreasing representation in ME. Thus, White students are in the top row because ME attracts the highest fraction of that population (20% of males and 11% of females, 18% of all white students). Asian students are in the bottom row of the ME panel because only 13% of that population chooses ME. The same pattern by race is found in among female students choosing ME. Among male students, a slightly higher fraction of Black males choose ME than the fraction of Hispanic males who choose ME.

The row order is maintained in the second panel of Figure 1 for easy comparison. The dashed vertical lines shown on the panels represent the aggregate percentage of all engineering students who choose that major: 17% for ME and 11% for AsE. Thus populations with dots to the right of these aggregate values are choosing the majors at higher rates than other engineering students. For example, White men are particularly attracted to ME, while Asian women are least likely to

select ME. Hispanic men and women and White men choose AsE more than other race-gender groups. Black women are the least likely to choose AsE. ME is preferred over AsE by all race-gender groups except Hispanic women.

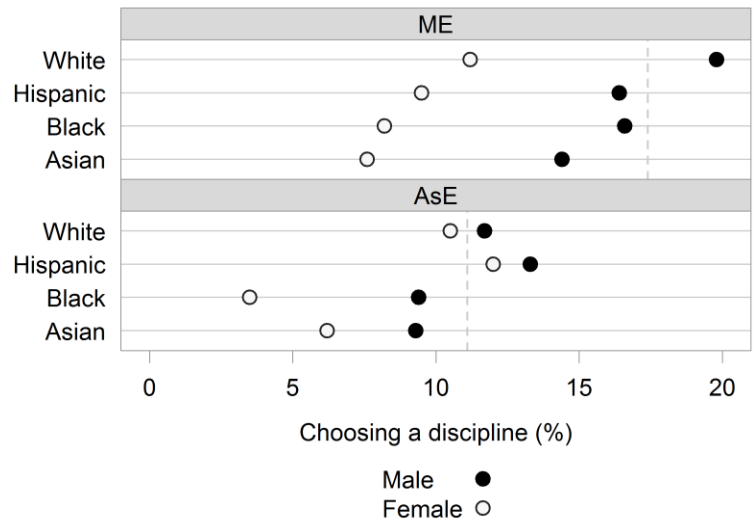


Figure 1. Engineering starters choosing ME and AsE.

**Among ME students, the male-female gap is substantial and consistent across racial/ethnic groups;** 7-9% more men of each race group choose ME than women. The largest male-female gap in choosing AsE is 5% between Black men and women.

**In AsE, race differences overshadow gender differences, particularly among females.** While Hispanic women choose AsE at an above average rate of 12%, only 4% of Black women in engineering choose AsE.

*Who graduates in ME and AsE?*

Figure 2 shows the six-year graduation rates of ME and AsE starters in their respective disciplines. Closed circles indicate ME and open circles indicate AsE.

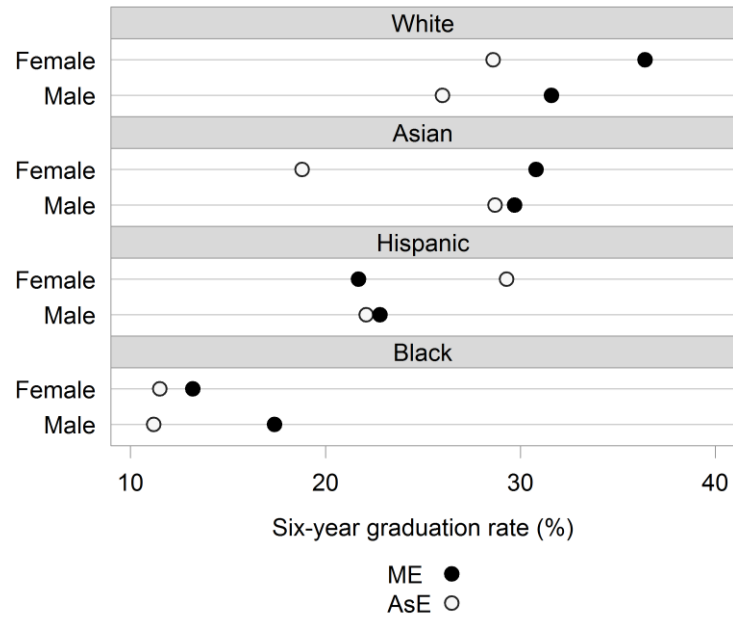


Figure 2. ME and AsE starters graduating in six years in ME and AsE, respectively.

As shown in Figure 2, White females have the highest six-year graduation rate in ME (36%). Hispanic females have the highest rate in AsE (29%) with Asian males and White females not far behind. Based on all MIDFIELD institutions, the percentage of a race-gender group starting and graduating within six years in the same discipline aggregated across a family of disciplines (Bio, Chemical, Civil, Computer, Electrical, Industrial, and Mechanical Engineering) range from a high of 41% of Asian males to a low of 30% for Black males. **In AsE the six-year graduation rate for Black males is an alarming 11%.** Black females, who choose AsE at the lowest rate, also graduate at a low rate of 12%. They do only slightly better in ME at 13%. Asian women, who have the second highest aggregate rate of graduation in their first major (41%) have a graduation rate of less than 19% in AsE.

**Most race-gender groups have higher graduation rates in ME than in AsE.** Hispanic females are the only exception. In addition to the higher rate of choosing AsE shown in Figure 1, Hispanic females have much higher graduation rates in AsE than ME. They also have higher graduation rates than their male peers in either major. **In AsE, women of each race except Asian have equal or higher graduation rates than their male peers.**

*Who graduates in ME or AsE? (Exchange between ME and AsE)*

In addition to having overlapping curricula, at two of the six schools represented here, ME and AsE are even managed by the same administrative unit, so some exchange of students might be expected between the degree programs as students fine-tune their career goals. Figure 4 illustrates the six-year graduation rates for each race-gender group when we include graduation in either major (MAE). From left to right, the windows show graduation rate in the discipline (without exchange), the change in graduation rate due to the exchange (MAE  $\Delta$ ), and the resulting MAE combined graduation rate. The panels indicate major *and* gender, the rows race, and the data markers graduation rate. Here the usual data markers are replaced by letters indicating race. For example, 31% of Asian females who start in ME graduate in ME (left

window). Another 15% graduate in AsE (center window) for a MAE graduation rate of 46% (right window).

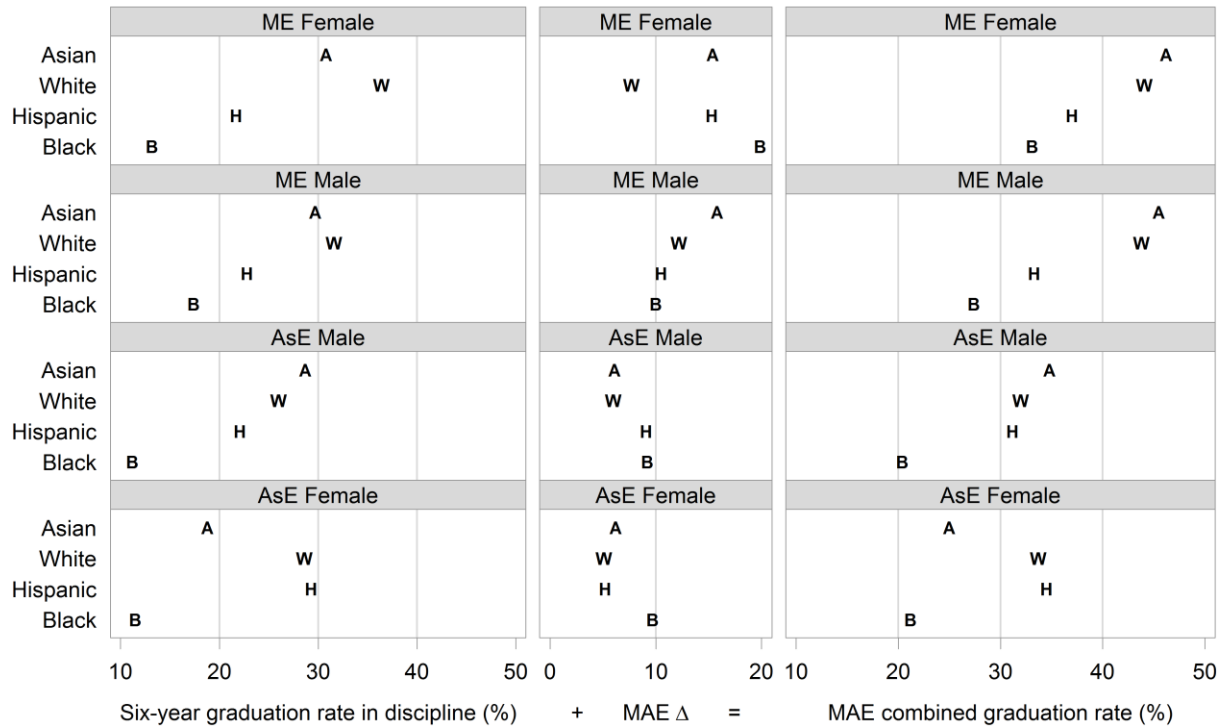


Figure 3. Six-year graduation rate of starters accounting for ME-AsE exchange.

Accounting for exchange between ME and AsE, the MAE graduation rates of students starting in AsE are greatly improved, particularly for Black men and Black women, but are still well below the aggregate graduation rate of these groups. Black women who start in ME (at institutions that offer AsE) are actually more likely to graduate in AsE than in ME.

## Discussion

With all races aggregated, our findings may be compared with another single-institution study in the U.S. by Stine<sup>17</sup>. She also found that fewer students chose AsE at matriculation, that AsE has a lower graduation rate than ME, and that more men than women choose ME but graduation rates are comparable between sexes. At matriculation, Stine found that 13% of female engineering starters chose AsE compared to 12% of male engineering starters. Her results showed larger gender difference for ME where 12% of female engineering starters chose ME compared to 26% of male engineering starters. Our dataset had fewer women than men choosing AsE (10% vs 12%) and a greater difference between women and men in ME (11% vs 19%) although our percentages are smaller than Stine's in all cases. This could be because of a limited number of choices at the institution. In Stine's work, all races were aggregated. Our work shows that there is variation by race which suggests interesting stories and areas for future research.

Overall, ME does not recruit many women, but it retains many to graduation. AsE, however, has recruitment and retention issues that seem more intersectional in nature. Several interesting questions emerge from this quantitative analysis. Qualitative research would be needed to explore the answers.

-What about AsE is so desirable to and supportive of Hispanic females but not so for Black and Asian females?

-Why do Asian women do so poorly in AsE relative to other majors? Asian women are the most successful group in ME and Chemical Engineering (ChE)<sup>23</sup> and the most successful women in EE and CpE<sup>6</sup>. This suggests a cultural issue unique to AsE.

-Why are Black students, particularly women, so likely to switch between AsE and ME? Is this rooted in disciplinary culture, curriculum, or employment prospects?

The causes of the high rate of loss of underrepresented minorities from AsE and ME must be investigated. The identification of disproportionate exchange of Black women between ME and AsE raises new questions. If high school students are equally informed (or uninformed) about the nature of ME and AsE, the percentage of ME students who ultimately realize AsE is a better fit should be similar to the percentage of AsE students who ultimately realize ME is a better fit. Rather, these findings indicate that a much higher fraction of Black female ME students switch to AsE than vice versa. Is there some reason why high school students would be better informed regarding AsE? Is this disparity in student switching behaviors due to the fact that ME is a broader discipline? Is there any sense in which the messages that these students receive prior to entering college are misleading? These questions and more remain to be answered.

## Conclusions

The findings presented here indicate a need to broaden the diversity of students who choose mechanical and aerospace engineering, as well as improving the retention of certain groups. ME retention rates overall are generally good relative to other engineering majors, but there is still room for improvement, particularly with respect to Hispanic students. AsE has challenges in recruitment and retention overall with low graduation rates compared to other engineering disciplines. While recruiting happens through a variety of channels, retention is the responsibility of ME and AsE educators and administrators. Faculty members must do their best to create an environment of inclusion for *all* students. Since AsE is a smaller major to begin with, underrepresented students may feel particularly isolated. Educators can reach out to student groups that may already exist on their campus such as National Society of Black Engineers (NSBE), Society of Hispanic Professional Engineers (SHPE), American Indian Science and Engineering Society (AISES), or Society of Women Engineers (SWE) to talk directly with these students about their experiences or seek training and resources from the National Action Council for Minorities in Engineering (NACME), National Association of Multicultural Engineering Program Advocates (NAMEPA), and Women in Engineering Proactive Network (WEPAN).

This research gives a data-driven quantitative picture of undergraduate students in ME and AsE and can be used to better target recruitment and retention efforts. More research is needed including qualitative research to investigate why students have the outcomes described here.



Organizations with an interest in ME and AsE should find ways to support research into these qualitative questions—by encouraging researchers to study these issues, by encouraging ME and AsE programs to assist in providing data to those studies, and even to identify sources of financial support to make sure those questions are addressed. As ME and AsE leaders and educators better understand who their students are, hopefully they will work to enhance diversity and thereby strengthen the fields.

## Acknowledgement

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