Board 104: Academic Pathways of Black Men and Women in Electrical and Mechanical Engineering

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Academic Pathways of Black Men and Women in Electrical and Mechanical Engineering

Abstract
We present a visual, quantitative analysis of the academic pathways of Black men and women who enroll in Electrical Engineering (EE) or Mechanical Engineering (ME) at any point during their undergraduate experience (N=4816). Our research provides evidence that more Black students choose EE than ME, in contrast to national data for all races that show that more students major in ME than EE. While more Black students initially enroll in EE overall, ME attracts a larger proportion of its Black students from other majors and retains a larger fraction. Black women are particularly persistent in ME (58%). Most Black students who leave EE or ME leave the institution without a degree. Seventy-eight percent of Black men and 65% of Black women who leave ME leave the institution without a degree. Of those leaving EE, 74% of Black men and 64% of Black women leave the institution without a degree. This examination of quantitative differences between disciplines lays a foundation for qualitative study through in-depth student interviews of Black students in these majors.

Introduction
The phenomena of low enrollment and persistence of Black students in engineering disciplines are affected by an interwoven tangle of individual, institutional, and disciplinary climate factors. Our multi-pronged study seeks to untangle these influences by combining large-scale quantitative analysis and in-depth student interviews with key informant interviews and profiles of relevant school policies and programs. Black students experience diverse pathways into, through, and out of engineering that vary according to discipline. For this project, we have selected one discipline in which Black students enroll at an above-average rate, Electrical Engineering (EE), and one discipline in which Black students persist at an above-average rate, Mechanical Engineering (ME). Computer Engineering (CpE) and EE are often within the same department, so qualitative interviews include CpE students, however, CpE is not addressed in this paper because it was not offered at all the study institutions during the period of available data. We have selected four schools with a large number of Black students in the study disciplines. In this paper, we present one aspect of the quantitative analysis: examining the academic trajectories of Black men and women who enroll in one of these disciplines at any point during their undergraduate experience. Visualizing these pathways can help lay the groundwork for conducting and interpreting student interviews as well as identifying barriers that may disproportionately affect Black men or women.

Background
The need to diversify engineering
In recent decades, the emphasis on increasing the number of engineering graduates has been coupled with greater concern about the lack of diversity in engineering fields. Research has identified the benefits of identity diversity (e.g., race, ethnicity, gender, socioeconomic status, etc.) in engineering education, including more innovative groups [1], greater engagement in active thinking processes, growth in intellectual engagement and motivation, and an increase in academic skills [2, 3]. A variety of educational policies and programs have been initiated to
boost participation and increase graduation rates of under-represented minorities (URMs) in engineering education.

However, despite numerous calls to diversify engineering [4], [5] and the initiation of these policies and programs, there is still a lack of diversity in the proportion of engineering bachelor’s degrees awarded to people of color that is then reflected in the profession [6]. The representation of minorities among engineering graduates is not keeping pace with the changing demographic landscape of the general population or undergraduate population of the 21st century. The majority of undergraduate engineering degrees in the U.S. are awarded to students who identify as White. In 2015, White students received 65% of the engineering Bachelor’s degrees, Asian students over 13%, and Hispanic students nearly 11%. However, Black students received only 4% of all engineering degrees [7], an increase from 2014 and reversing a nine-year decline from 5.3% in 2005 to 3.5% in 2014 [8]. Our research quantifies the pathways of Black engineering students through the EE and ME disciplines as a precursor to our related qualitative research which seeks to explain these patterns.

**Differences across engineering majors**

While there are commonalities across many engineering fields, Lattuca and colleagues’ [9] research demonstrated substantial differences across engineering majors in teaching approaches and students’ experiences. Recent investigations explore the idea of the culture of engineering education and the need to understand this culture before we can effect systemic change [10], [11]. For example, Godfrey [12] showed that different engineering disciplines exhibited different cultures, or “cultures within cultures,” affecting the participation of women.

Our mixed-methods project explores the different disciplinary cultures of EE and ME as these fields provide a sharply contrasting picture of engineering matriculation, persistence, and attrition for Black students. EE is one of the largest and oldest engineering disciplines, dating back to the 1880s [13]. EE attracts an above-average percentage of Black males and females compared to other engineering disciplines [14]. ME dates back to the 19th century and is currently the largest engineering discipline [15], awarding 23.8% of engineering degrees in the U.S. and Canada in 2015 [7]. ME attracts a smaller percentage of Black engineering students but is better at retaining them (especially females) to graduation [16].

**Methods**

This study utilizes the Multiple-Institution Database For Investigating Engineering Longitudinal Development (MIDFIELD) to uncover the academic trajectories of Black men and women in Electrical and Mechanical Engineering. MIDFIELD includes student-unit academic data for four of the top 15 schools in the U.S. in number of Black engineering graduates [7], which allows us to take an intersectional approach, recognizing that Black men may have very different experiences than Black women in these predominantly White and male-dominated fields. For this paper, we focus on the four schools where interviews are also being conducted as part of the qualitative phase of this study. These institutions allowed students to indicate a specific engineering discipline as their first major during the period studied (1987-2004).

Sankey flow diagrams are used to visualize how students move into, out of, and through these engineering disciplines. These diagrams depict movement through a system, with the widths of
the arrows representing the number of students following a particular path. We examine the majors that Black students enter after leaving EE and ME, and the majors that they come from when they migrate into EE and ME. We define “ever EE” and “ever ME,” and as students who ever declared electrical or mechanical engineering, respectively. Conforming to IPEDS (Integrated Postsecondary Education Data System) standards, we use the 6-year point to investigate outcomes and only include students for whom six calendar years of data after matriculation are available. Including all the data for each student would bias the results in favor of earlier cohorts who have had more time to return and using a longer window would eliminate the more recent cohorts from the study. There are several groups of students for whom the 6-year point is not an accurate representation of their final educational outcome: those who are continuing at year 6, but eventually drop out (we know of 58 in engineering and 24 in other majors), and those who have stopped out in year 6 but later returned (we know of 145 who returned to engineering and 66 who returned to other majors).

**Sample**

We investigate the 4816 Black students at the study institutions who ever majored in ME or EE as shown in Table 2. The first two columns sum to more than the total column because 106 students appear in both the Ever ME and Ever EE columns. This means that they declared each major at a different point in their academic trajectory.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Ever ME</th>
<th>Ever EE</th>
<th>Total</th>
<th>Ever EE/ Ever ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>481</td>
<td>908</td>
<td>1363</td>
<td>1.9</td>
</tr>
<tr>
<td>Men</td>
<td>1351</td>
<td>2182</td>
<td>3453</td>
<td>1.6</td>
</tr>
<tr>
<td>Total</td>
<td>1832</td>
<td>3090</td>
<td>4816</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**Results**

Nationally, across all races, less than half as many students graduate in EE as in ME [17]. However, among Black students in our study, the relationship is reversed, with 1.7 times as many Black students choosing EE than choosing ME (Table 2).

**Electrical Engineering**

The pathways of Black students who ever enrolled in electrical engineering are shown in Figure 1. On the left is the starting major, grouped into EE, other engineering disciplines (Other-ENG), and non-engineering disciplines (Non-ENG). The darker bands represent men and the lighter bands represent women. The width of each band represents the number of students on that path. Year 6 destinations are depicted on the right and include students who either graduated in or were continuing in EE, another engineering discipline, or a non-engineering discipline six years after matriculation or for whom the sixth-year destination is “Left Inst.” The Left Inst. category indicates that the student left the institution without a degree. They may have transferred, dropped out, or stopped out. Counts are summarized in Table 3.
Figure 1. Black students ever enrolled in Electrical Engineering

Table 2. Black men and women ever enrolled in EE by Starting Major and Year 6 Destination

<table>
<thead>
<tr>
<th>Year 6 Destination</th>
<th>Starting Major</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EE</td>
<td>Other-ENG</td>
<td>Non-ENG</td>
</tr>
<tr>
<td>EE</td>
<td>692</td>
<td>119</td>
<td>101</td>
</tr>
<tr>
<td>Other-ENG</td>
<td>109</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Non-ENG</td>
<td>169</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Left Inst.</td>
<td>791</td>
<td>65</td>
<td>82</td>
</tr>
<tr>
<td>Grand Total</td>
<td>1761</td>
<td>214</td>
<td>207</td>
</tr>
</tbody>
</table>

*ranges are reported to protect student anonymity
As shown by the large EE box on the left side of Figure 1, most Black students who ever enroll in EE choose it as their first major, but a significant portion start in other engineering majors (10%) or even non-engineering majors (9%) and many of them graduate in EE. The thickness of the light green bands shows that almost 30% of Black students starting in EE are women, well above the national average of 13.7% for all races in electrical engineering [17]. Overall, the Year 6 Destination EE box is slightly taller than the Left Inst. box, meaning that more Black students will persist in EE than leave the institution without a degree. From Table 3, we see this pattern is driven by the women. At six years, more Black women who ever majored in EE persisted in EE than left the institution. Conversely, more Black men left the institution than persisted in EE, at six years. Black women who left EE were more likely to switch majors and persist than Black men. Nearly three-fourths of Black men who leave EE leave the institution without a degree compared to 64% of Black women. Nearly 46% of Black women and 42% of Black men persisted in EE.

**Mechanical Engineering**

The pathways of Black men and women who ever enrolled in mechanical engineering are displayed in Figure 2 and summarized quantitatively in Table 4.
Figure 2. Black students ever enrolled in Mechanical Engineering.

Table 3. Black men and women ever enrolled in ME by Starting Major and Year 6 Destination

<table>
<thead>
<tr>
<th>Year 6 Destination</th>
<th>Starting Major</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>ME</td>
<td>Other-ENG</td>
<td>Non-ENG</td>
<td>Total</td>
<td>ME</td>
<td>Other-ENG</td>
<td>Non-ENG</td>
<td>Total</td>
<td>ME</td>
<td>Other-ENG</td>
<td>Non-ENG</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>ME</td>
<td></td>
<td>414</td>
<td>125</td>
<td>74</td>
<td>613</td>
<td>185</td>
<td>64</td>
<td>28</td>
<td>277</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other-ENG</td>
<td></td>
<td>39</td>
<td>&lt; 10*</td>
<td>&lt; 10*</td>
<td>50</td>
<td>22</td>
<td>&lt; 10*</td>
<td>&lt; 10*</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ENG</td>
<td></td>
<td>90</td>
<td>10-20*</td>
<td>10-20*</td>
<td>115</td>
<td>27</td>
<td>&lt; 10*</td>
<td>&lt; 10*</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Inst.</td>
<td></td>
<td>437</td>
<td>79</td>
<td>57</td>
<td>573</td>
<td>105</td>
<td>16</td>
<td>12</td>
<td>133</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>980</td>
<td>224</td>
<td>147</td>
<td>1351</td>
<td>339</td>
<td>95</td>
<td>47</td>
<td>481</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*ranges are reported to protect student anonymity
While the largest group of Black students who ever enrolled in ME started there, many also came from other engineering (17%) and non-engineering (11%) majors. One quarter of Black students starting in ME were women. More than twice as many Black women persisted in ME as left the institution, while Black men were more evenly split between the two outcomes. Those who leave ME tend to leave the institution altogether rather than changing majors. This is especially true of Black men who leave ME, 78% of whom leave the institution without a degree, compared to 65% of Black women who leave ME. Overall, 45% of Black men and 58% of Black women who enroll in ME persist in ME.

**Limitations**

Computer engineering was introduced into the curriculum at two of the four schools in this study in the early 2000’s and therefore there were few students who had the full six years available to measure outcomes in the initial dataset. A time lag in data collection plus an additional six-year lag waiting for outcomes limits the current work in that CpE could not be included and that the results are historical representations that may not hold true for current students. The MIDFIELD dataset is currently being updated with more recent academic years for the original MIDFIELD partner schools which will allow us to add computer engineering to the analysis and contrast these academic pathways with both electrical and mechanical engineering academic pathways.

**Discussion, Conclusions, and Future work**

Confirming earlier research with a larger portion of the MIDFIELD dataset [14], [16], these results show that EE is particularly good at attracting Black students to the discipline but not particularly good at retaining them. By contrast, ME does not attract as many Black students as does EE, but retains them at a higher rate. Additionally, we see that when Black men leave Mechanical or Electrical Engineering, they are most likely to leave the institution without a degree. This raises many questions for future investigation. Using MIDFIELD, we will further explore the timing of the departures and GPA or academic status at the time of departure. Research has shown that departure decisions due to poor institutional fit often happen in the first 2-6 weeks [18]. This type of departure would call for different interventions than if departures resulted from academic trouble or poor fit with one’s major. One potential approach to improving outcomes for these students is to provide more opportunities for exploring academic majors, even after a major has been declared. Student-centric advising (rather than major- or department-centric) can help guide students to consider all of their options.

The qualitative portion of our project is designed to shed light on the reasons for some of the phenomena observed in the quantitative analysis reported here. Our interviews of key informants at our study institutions will provide deeper information about the contextual, policy, and programmatic factors that may influence student academic pathways and outcomes. Our in-depth interviews with students who remain in these majors and those who switch to other majors will help us to better understand what factors contribute to retention and attrition. Unfortunately, we do not have access to students who have left the institution altogether, so even those findings may not capture their full experience. Triangulation across multiple types and sources of data will allow us to build a robust picture of the experience of Black men and Black women in these engineering disciplines, which will in turn help inform policy and direct resources appropriately.
Acknowledgements
This material is based upon work supported by the National Science Foundation under Grant No. 1734347. 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. The authors would like to thank Cindy Waters for her contributions early in this project.

References Cited


