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GPA Patterns of Black Mechanical Engineering Students (Work in Progress)

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Abstract

In recent years, research has associated grade point average (GPA) with a variety of student outcomes during their undergraduate careers. The studies link higher GPAs to students being more likely to graduate in their major, while lower GPAs have been linked to students switching majors or leaving the institution. Further research, which focuses on how Black female and male students remain successful in different engineering degrees, is necessary to identify the underlying elements contributing to their entrance into and exit from engineering disciplines.

This quantitative examination of trends among the GPAs of Black women and men is part of a larger NSF-funded mixed-methods study that includes in-depth student interviews of Black students who persisted in and switched from ME. In this quantitative paper, we examine the GPA patterns of Black students in Mechanical Engineering (ME). Students who have ever enrolled in ME have four potential, mutually exclusive, outcomes: 1) they can persist for 12 semesters without graduating; 2) they can graduate in ME within 12 semesters; 3) they can switch to another major; or 4) they can leave school. In this research, we identify the most common GPA patterns associated with graduated ME students.

We hypothesize a relationship between distinct GPA patterns and whether a student persists in ME, graduates in ME, switches away from ME, or leaves the institution altogether. This quantitative investigation uses the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) to collect the cumulative GPA of ME students at each term. We use a functional cluster analysis approach to group similar patterns. First, a function is fit to each student record. Then a cluster analysis is conducted on the function parameters to identify natural groupings in the data. Once students are grouped according to their GPA profile, we examine the other characteristics and outcomes of the group.

We present a visual quantitative analysis of the patterns in the GPAs of Black women and men who enroll in ME. Clustering analysis suggests that first-time-in-college (FTIC) Black female students in ME who graduated have a higher proportion of students in the higher GPA clusters than the proportion of FTIC Black male students who graduated in ME. A higher proportion of the male student population is clustered in the lower GPA cluster groups as compared to women in the lower GPA cluster groups. A higher proportion of students who graduated are in the higher GPA clusters than the proportion of graduated students in the lower GPA clusters.

Introduction

A college student's GPA is a powerful predictor of student outcomes and impacts opportunities in a student's academic career. Programs that could benefit students may have a GPA cutoff,

which excludes students from resources [1]. For example, a lower GPA can prevent students from qualifying for internships, obtaining scholarships, and joining specific majors. Excluding students based on GPA prevents students from using resources and programs that would enhance a résumé and improve their job search after graduation. GPA can also be used to identify students who may leave the institution or eventually switch majors[1], [2],[3]. Studies have shown that students who ultimately graduate have different GPAs than students that leave the institution [2]. Therefore, it is important to better understand the relationship between students' GPAs and their potential academic outcomes. Information about this relationship can give educators and academic advisors, who may be concerned about changes in a student's GPA, the opportunity to intervene earlier in a student's academic career. This window of opportunity for intervening is crucial, especially if the student is considering switching majors or leaving the institution altogether.

GPA trends are associated with engineering students in particular. Al Yagoub et al. [4] found that for the students who graduated in engineering, their graduation GPAs were similar regardless of whether they stayed in their first major or changed to another major within engineering. They found that student GPA tends to drop towards a 3.0 as the mean group average of their research data [4]. There also seems to be an association between the high-failure rate courses and students leaving the institution. When students begin to struggle in these courses, they begin to question their place in engineering [5]. Studies have indicated that academic load and GPA are dependable predictors of students leaving the institution. It is, therefore, reasonable to expect that we may be able to predict alternative student outcomes from sources such as first semester GPA and its trajectory. A broad range of literature addresses the experiences of engineering students; part of this research investigates students' academic success in their major. However, there is a gap in the literature regarding Black engineering students' academic achievement, specifically.

Therefore, we address the following research questions in this work in progress:

1. What distinct GPA profiles represent Black men and Black women in ME?
2. What is the relationship between GPA profile and student outcomes for Black men and Black women in ME?

Literature Review

A. *Race*

Black engineering students face challenges during college, such as negative interactions, isolation, and race discrimination. However, Black students have also found success and determination at these same institutions through family and same-race peer support, self-efficacy, personal responsibility, and more [6] [7]. Studies suggest that Black students switch majors for a multitude of motives. Academic challenges factor into this decision; however it is only one of several aspects a student considers when choosing to leave their major [8]. Studies have also suggested that Black engineering students may be at a higher risk of dropping out of

their major than students of other races [2]. However, Black students have continued to persist owing to their belief in their abilities, a strong sense of community within STEM, and strong relationships with individual faculty members that develop mentor-mentee relationships [7].

B. *Gender*

Women have different experiences than men in engineering, and therefore an effort has been made to study gender specifically within engineering [9]. Women and men tend to leave their institutions at different rates and their academic success is part of their decision process when experiencing changes in their GPA whether to switch majors or leave the institution altogether [10]. Despite outperforming men with higher GPAs, women in STEM majors hold their own academic performance in low regard [11]. One study found that women also outperform men academically in many engineering disciplines and tend to base their judgement of their academic abilities on whether they are capable of earning an "A" or "B" in a course, however men do not seem to hold this belief [12]. Men will continue to persist despite earning lower grades while women who leave engineering have higher grades than the men who persist [12]. However, research has shown that while all women have different experiences in STEM than men, they also have difference experiences from each other, one of which is due to race [13]. Therefore, it is important to examine the academic outcomes and GPAs of all minority women. Researchers should take care to treat each underrepresented group as unique, as opposed to putting them together, to ensure each distinct story and outcome are brought to light to bring about change.

Methods

The student sample for the initial study comes from MIDFIELD, a database that consists of 19 institutions and, as of January 31, 2022, 1,688,916 undergraduate student records, including 1,660 Black students who ever majored in ME [14]. For this study, we use the cumulative GPAs of Black ME students from each of their Spring and Fall semesters as well as demographic information such as gender and race. MIDFIELD allows for longitudinal examination of GPA trends in the data that will allow for further examination of students' academic career outcomes.

The criteria for students to be included in the study are:

- First-time-in-college students (FTIC). This excludes students that transferred to the institution.
- All students who had their first degree-granting-major as ME. This excludes students that switched into ME after beginning in a different major.
- Black ME students. This excludes students of other races.

We chose to include FTIC students as MIDFIELD includes more data for these students and these students more closely follow the 4-year curriculum plan for engineering students. We also only included students whose first degree-granting-major was ME.

Students were then categorized according to the four potential outcomes. These outcomes are known and mutually exclusive and have been determined through using data from MIDFIELD

and the defined criteria: 1) Students that persist for 12 semesters without graduating (Persisters); 2) Students that graduate in ME within 12 semesters (Graduates); 3) Students that switch to another major (Switchers); or 4) Students that leave the institution (Leavers).

Cluster Analysis

A cluster analysis groups objects together through a process of discovering natural groupings within the give set of data [15]. In this study, students were clustered based on their first-term GPA and the slope of the regression line of their cumulative GPA over several semesters. We used the k-means algorithm, which works to minimize within-group variability and maximize between-group variability, in order to determine the clusters [16]. The algorithm begins by creating a predetermined divided space and randomly assigning each of the data points to a different space. Once the data points have been assigned to different groups, the centroid of each group is calculated. Each data point is then reassigned to a group based on the data points' smallest distance to the centroid. Then the process is repeated until none of the data points switch groups after the centroid is recalculated and the data points are assigned. The algorithm is generally run multiple times to ensure that each of the data points have a strong group assignment [16]. The statistical software R [17] was used to create the clusters.

We used each student's first-term GPA along with the slope of their overall GPA pattern as clustering variables. We chose to repeat the algorithm twenty times to ensure robustness of the solution. We attempted a solution for 2, 3, 4, and 5 clusters. Based on the first-term GPA values and the slopes of the GPA regression lines, we chose the four-cluster solution because the data seemed to naturally cluster into 4 groups.

The cluster groups were labeled with their respective average GPA (B+, B-, C, D) as well as whether the average slope of the GPA regression line in the cluster was increasing or decreasing. We then found the proportion of students in each grade cluster, the proportion of women and men in each grade cluster, and the proportion of each outcome by gender in each cluster.

Limitations

Our study has several limitations. We chose to only look at the Spring and Fall semesters of each student as many students do not have summer GPAs. Another potential restriction of the study is that academic forgiveness policies of various institutions were not considered. These policies could possibly partially explain higher slopes of individual students' GPAs from semester to semester. If the student was able to "forgive" their grade, the grade itself is often removed from the cumulative GPA calculation. The process of forgiving a grade is not tracked in MIDFIELD other than the forgiveness' effect on cumulative and term GPA. We also chose to exclude 28 outliers whose first-term GPA was 0.00. After an examination was completed of the 0.00 GPAs, there were a variety of reasons that a student could have this GPA. Some students withdrew from the semester entirely which MIDFIELD assigned as a 0.00 GPA, while some students failed the semester entirely, and some students had grades but the GPA still read as 0.00 in MIDFIELD.

This could possibly be from a late grade entry where the system had already calculated the GPA before the grade was entered. Therefore, we decide to exclude this group of students from the study. The graduate group never had a major other than ME. Persisters were only considered if they continued to persist in ME without graduating with a degree for 12 semesters. We did not continue to track the majors or outcomes of Switchers after they left ME. Finally, once Leavers left the institution, nothing is known about their educational trajectory after their departure.

Results and Discussion

This study sample included 1,632 Black Mechanical Engineering students of which 364 were female and 1,268 were male. The four groups that the k-means cluster analysis established is based on a student's first-term GPA and the slope of the linear regression line of their GPA over 12 Fall and Spring Semesters (Table 1).

Table 1. Cluster Group Assignments

Cluster Grade Association	First GPA	Slope Trend	Slope
B+	3.61	Decreasing	-0.100
B-	2.88	Decreasing	-0.084
C	2.24	Decreasing	-0.035
D	1.29	Increasing	+0.037

The first row after the headings row in Table 1 shows the first cluster of students, which is defined by a first semester average GPA of a "B+" and a decreasing slope of -0.100. This indicates that for every Spring or Fall semester a student is at the institution, the cumulative GPA decreased an average of 0.1 points each semester. The second cluster has a first semester average of a "B-" and a decreasing slope of -0.084 per semester. This indicates for every Spring or Fall semester that the student remains at the institution the average GPA decrease for this cluster assignment is -0.084 GPA points per semester. The third cluster has a student GPA average of a "C" and a decreasing slope of -0.035 per semester enrolled. Finally, the fourth cluster has a student GPA average of a "D" and the only increasing slope of 0.037 per semester.

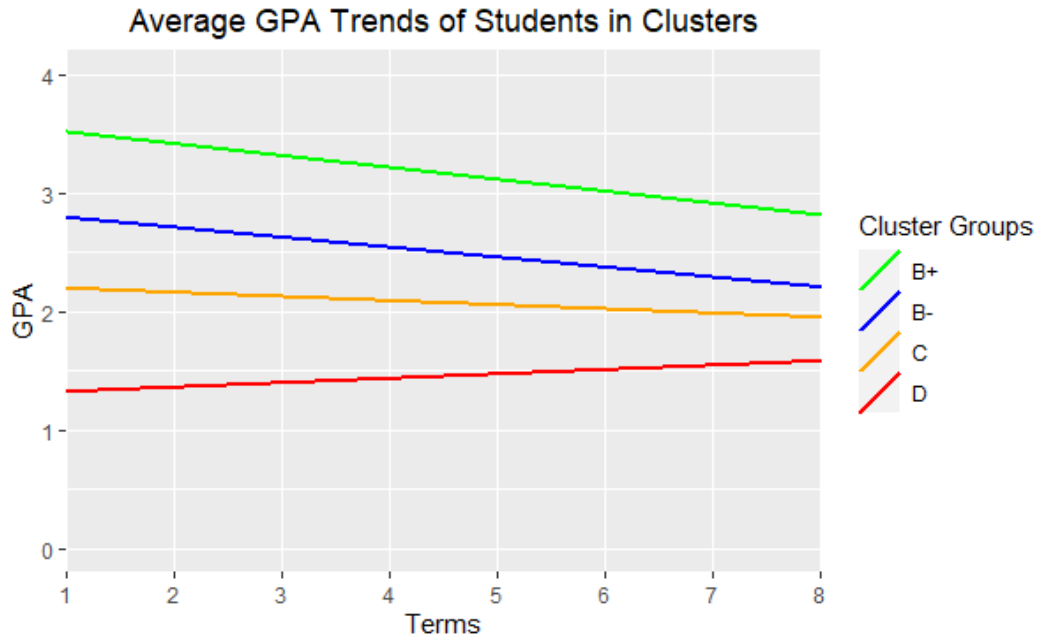

Figure 1. A graph of the average GPA trends for the students in each of the designated clusters.

Figure 1 above depicts the overall trends of the cluster groups, also described in Table 1. The y-axis is the GPA of the students and the x-axis is the term of the GPA. The "B+" and "B-" groups have similar GPA trends indicated by the green and blue lines. While the cluster groups have a different intercept at the first-term on the x-axis, the B+ and B- lines appear to be nearly parallel. This indicates that while the first-term GPA of students in the top two clusters are different, they have a similar decreasing GPA pattern as their semesters enrolled increase at the institution. This decrease in GPA could potentially stem from an increase in coursework difficulty in the later semesters [5]. While the students start at different GPAs, their GPA decreases at the same rate. The "C" cluster, indicated by the orange line, has a slope that is decreasing at a slower rate than the "B-" and "B+" clusters. This indicates that in this category, while the students' average first-term GPA is a "C," their GPA remains more stable than the "B+" and "B-" cluster which is indicated by a slope that is closer to zero. Finally, the "D" cluster is shown by the red line in figure 1. While the GPA starts at a D average, it is the only cluster whose GPA increases. This could indicate that the student changes their academic performance to stay enrolled at the institution as many institutions required a 2.0 GPA in order to remain enrolled in good standing. Students with lower GPAs are often put on probation or suspended and required to increase their GPA in order to remain enrolled.

Table 2. Cluster Assignments by Gender

Cluster	Women (column %)		Men (column %)		Total % of Students in each Grade Cluster	Total # of Students
	N	%	N	%		
B+	118	32.4%	298	23.5%	25.5%	416
B-	140	38.5%	437	34.5%	35.4%	578
C	72	19.8%	364	28.7%	26.7%	436
D	34	9.3%	169	13.3%	12.4%	202
Total	364		1268		100%	1632

Table 2 shows the entire group of Black engineering students in ME and their proportion according to gender in each of the clusters. The results of this analysis indicate that while women constitute a smaller percent of the total number of students within ME (22.3% of female students vs. 77.7% of male students), a higher percentage of the women are in the "B+" and "B-" clusters. This does not mean there are more women in the top two clusters than men; however, it does indicate that the proportion of women is higher in the first two clusters than the proportion of men in the same category. The analysis also shows that the proportion of men is higher in the second two clusters, "C" and "D", while there is a smaller proportion of women in these same two clusters. These results could support the findings found in [12], that found women use a higher standard to judge their academic abilities than the men did.

Table 3. Cluster Group Assignments of Students who Graduated in ME

Cluster	Women (column %)		Men (column %)		% of Total Graduated Students	Graduated Students
	N	%	N	%		
B+	73	48.03%	173	37.45%	40.07%	246
B-	60	39.47%	164	35.50%	36.48%	224
C	16	10.53%	106	22.94%	19.87%	122
D	3	1.97%	19	4.11%	3.58%	22
Total	152		462		100%	614

Table 3 depicts specifically the groups of Black engineering students who graduated in ME and their cluster assignments with regard to gender. The results of this are intuitive. The highest percentage of students that graduated within ME, belonged to the cluster with the highest first semester GPA (B+). Some of the students' GPA followed the trend which could be explained by their course workload and difficulty increasing causing their GPA to decrease. After the "B+" cluster, the "B-" cluster is the next highest graduated cluster. The second cluster holds 36.48% of the total number of students that graduated within ME. The third cluster has a "C" label as the students' average first-term GPA, and the third most graduates. The final cluster has a "D" label as the students' average first-term GPA and has the least amount of graduates. This result is intuitive as many institutions have an indicator and probation policies that go into effect when a student's GPA is below a 2.0 and the student would need to make significant changes to increase their GPA. When the graduates are disaggregated by gender, the women have the highest percent

of graduates in the highest cluster. The men also have the highest percent of graduates in the bottom two clusters. Future research could future investigate this trend.

Conclusion

This work-in-progress paper reports on the preliminary results of Black women and Black men engineering student GPA trends in ME at 19 institutions. The clusters indicate that while students have different averages at the "B+" and "B-" clusters, their GPA rate of change is the same over the semesters. This demonstrates that students' GPAs tend to decrease at the same rate over the terms, despite having different GPA starting points. There is a higher proportion of the women ME students in the top two grade clusters ("B+" and "B-") than there is of the men ME students in the same clusters. Accordingly, the proportion of the men in the bottom two clusters ("C" and "D") is greater than the proportion of the women in the bottom two clusters. Finally, the analysis of students who have graduated with an ME degree is intuitive as the most students are in the highest grade cluster; then the proportion of the graduates in each cluster decreases, moving from the highest GPA cluster to the lowest GPA cluster. When the graduate group is divided by gender, the women have the highest proportion in the top cluster.

In future iterations of this analysis, we will continue to explore the GPA patterns and trends of engineering students of different races, including Asian, Native American, and Hispanic. Once the criteria for choosing students for the study are successfully established, in future research, we will be able to expand the group of students to include more majors. We hope to be able to expand our query to include additional engineering disciplines as we continue to seek further insight into possible trends that would allow instructors and administrators to intervene earlier when students begin to experience academic challenges and before they leave the institution or the major.

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References

[1] K. D. Kendricks, A. A. Arment, K. V. Nedunuri, and C. A. Lowell, "Aligning Best Practices in Student Success and Career Preparedness: An Exploratory Study to Establish Pathways to STEM Careers for Undergraduate Minority Students," *J. Res. Tech. Careers*, vol. 3, no. 1, p. 27, Jan. 2019, doi: 10.9741/2578-2118.1034.

[2] D. Dorris, J. Swann, and J. Ivy, "A Data-driven Approach for Understanding and Predicting Engineering Student Dropout," in *2021 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual Conference, Jul. 2021, p. 36575. doi: 10.18260/1-2--36575.

[3] R. Wang, "The Impact of Grades on College Major Choice, Dropout, and Labor Outcomes," Ph.D. dissertation, Econ Dept., University of North Carolina - Chapel Hill, Chapel Hill, NC, 2020.
[4] H. Al Yagoub, H. Ebrahiminejad, and M. Ohland, "Work in Progress - The GPA Trajectories of Engineering Students," in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida, Jun. 2019, p. 33570. doi: 10.18260/1-2--33570.
[5] J. P. Salazar-Fernandez, M. Sepúlveda, and J. Munoz-Gama, "Describing Educational Trajectories of Engineering Students in Individual High-Failure Rate Courses that Lead to Late Dropout," p. 10.
[6] B. Berhane, S. Secules, and F. Onuma, "Learning while Black: Identity Formation and Experience for Five Black Men who Transferred into Engineering Undergraduate Programs," *J. Women Minor. Sci. Eng.*, vol. 26, no. 2, pp. 93–124, 2020, doi: 10.1615/JWomenMinorScienEng.2020024994.
[7] O. Qaqish, C. S. Grant, and T. Bowles, "Success Factors that Shape Black Male Transfer and Academic Experiences in Engineering," *Community Coll. J. Res. Pract.*, vol. 44, no. 10–12, pp. 885–898, Dec. 2020, doi: 10.1080/10668926.2020.1771628.
[8] R. Brent, C. Mobley, C. E. Brawner, and M. K. Orr, "'I feel like I've found where I belong.' Interviews with Black engineering students who change majors," in *2019 IEEE Frontiers in Education Conference (FIE)*, Covington, KY, USA, Oct. 2019, pp. 1–5. doi: 10.1109/FIE43999.2019.9028429.
[9] M. S. Ross, B. M. Capobianco, and A. Godwin, "Repositioning race, gender, and role identity formation for black women in engineering," *J. Women Minor. Sci. Eng.*, vol. 23, no. 1, pp. 37–52, 2017, doi: 10.1615/JWomenMinorScienEng.2017016424.
[10] C. Astorne-Figari and J. D. Speer, "Drop out, switch majors, or persist? The contrasting gender gaps," *Econ. Lett.*, vol. 164, pp. 82–85, Mar. 2018, doi: 10.1016/j.econlet.2018.01.010.
[11] A. Espinoza and D. G. Cole, "When Gender is Considered: Racial Ethnic Minority Students in STEM Majors," *J. Women Minor. Sci. Eng.*, vol. 15, no. 3, pp. 263–277, 2009, doi: 10.1615/JWomenMinorScienEng.v15.i3.50.
[12] M. K. Orr, I. Ngambeki, R. A. Long, and M. W. Ohland, "Performance trajectory of students in the engineering disciplines," in *2011 Frontiers in Education Conference (FIE)*, Rapid City, SD, USA, Oct. 2011, pp. S3H-1-S3H-4. doi: 10.1109/FIE.2011.6143005.
[13] E. D. Tate and M. C. Linn, "How Does Identity Shape the Experiences of Women of Color Engineering Students?," *J. Sci. Educ. Technol.*, vol. 14, no. 5–6, pp. 483–493, Dec. 2005, doi: 10.1007/s10956-005-0223-1.
[14] S. M. Lord, M. K. Orr, M. W. Ohland, R. A. Long, and R. A. Layton, "Is MIDFIELD for me? Exploring the Multiple Institution Database for Investigating Engineering Longitudinal Development," in *2021 IEEE Frontiers in Education Conference (FIE)*, Lincoln, NE, USA, Oct. 2021, pp. 1–4. doi: 10.1109/FIE49875.2021.9637270.
[15] M. Orr, L. Benson, M. Ohland, and S. Biggers, "Student Study Habits And Their Effectiveness In An Integrated Statics And Dynamics Class," in *2008 Annual Conference & Exposition Proceedings*, Pittsburgh, Pennsylvania, Jun. 2008, p. 13.1111.1-13.1111.11. doi: 10.18260/1-2--3838.
[16] K. Ehlert, C. Faber, M. Kennedy, and L. Benson, "Utilizing Cluster Analysis of Close-Ended Survey Responses to Select Participants for Qualitative Data Collection," in *2017*

ASEE Annual Conference & Exposition Proceedings, Columbus, Ohio, Jun. 2017, p. 29099. doi: 10.18260/1-2--29099.
[17] R Core Team, *R: A language and environment for statistical computing*. Vienna, Austria, 2021. [Online]. Available: https://www.R-project.org/.