Experiences of Black Persisters and Switchers in Electrical, Computer, and Mechanical Engineering Departments in the USA

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***Abstract*— In this Research Full Paper we examine the reported experiences of Black students who are majoring in or switched from electrical (EE), computer (CPE), or mechanical (ME) engineering. Prior work has shown different persistence trajectories for Black students in these majors relative to White students, as well as differences between Black men and Black women. We surveyed 79 students at four institutions in the USA, three Predominantly White Institutions and 1 Historically Black University. In all, 33 students who had ever majored in ME, 27 in CPE, and 19 in EE completed a pre-interview survey that asked about aspects of the learning environment, faculty and peer relationships, and perception of belonging. Fifty-six students persisted in these majors while 23 switched to other majors. Compared to switchers, persisters are more likely to feel that the quality of instruction is higher, feel more encouraged by professors and peers to continue, and feel a greater sense of belonging in their departments. ME students are much more likely to experience group learning in their classes than either EE or CPE students and their ME peers are more likely to encourage them to persist. The difference in persistence between EE and CPE may be explained in part by the attraction of the computer science major as an alternative option for computer engineering majors; half of our CPE switchers switched to computer science. However, teaching quality may be an additional factor as CPE students perceived teaching quality to be lower than EE students did. Future research will explore these findings in the context of our in-depth interviews with these students.**

Keywords—Black Students, Persistence, Classroom Experiences, Faculty-Student Interaction, MIDFIELD

I. INTRODUCTION

The United States Census Bureau defines Black or African-American as "A person having an origin in any of the Black racial groups of Africa" [1]. In the USA in 2017, students who self-identify as Black in university records comprised approximately 28,000 (4.5%) of the 622,500 undergraduate engineering students [2], compared with approximately 13% of the overall undergraduate population of 16.8 million [3], and earned only 4.1% of engineering bachelor's degrees [2]. While this represents an uptick from 2016, the proportion of engineering degree attainment for Black students is still below the 5.4% earned in 2002 [4], although the number of degrees awarded overall has doubled over that time [5, p. 128]. Thus, while Black students are earning more engineering degrees overall, they nevertheless continue to be underrepresented in undergraduate programs. Perhaps more worrisome, the six-year graduation rate of Black students in engineering was nearly 20 percentage points less than all engineering students in 2015 and lower than any other racial or ethnic group considered [6].

This low representation of Black students in engineering has led to nationwide efforts to broaden participation through various initiatives funded by the US National Science Foundation (NSF) (e.g., the Broadening Participation in Engineering Program [7]) and to research their impact. In 2016, 22% of bachelor's degrees conferred to Black students were in Mechanical Engineering (ME), 20% in Electrical Engineering (EE) and 8% in Computer Engineering (CPE) [8]. Our larger work is a mixed methods study [9], [10] situated in this context that builds on prior work in these disciplines [11], [12], [13]. As part of our larger study, we interviewed Black students who persisted in or have switched from ME, EE, or CPE or who have double majored in both EE and CPE (ECE) (collectively "study majors") at four sites. All four study institutions were in the top 15 of engineering bachelor's degrees awarded to Black students in 2017 [14].

Prior to being interviewed, students were asked to respond to a survey about their experiences in the study majors. This survey was adapted from the Student Experience of the Major (SEM) survey developed by the National Center for Women and Information Technology (NCWIT) for use with undergraduate students in computing majors and extended for use in engineering departments [15]. Responses to the survey questions helped the interviewers tailor many of their interview questions to the reported student experiences. In the present study, we explore the following questions:

1. Are there differences in the reported experiences of Black students by whether they remained in the study major or switched to another major?
2. Are there differences in the reported experiences of Black students by study major?

This project is supported by the USA National Science Foundation through Grant No. 1734347.

In this paper, we will report on issues of teaching and learning, faculty and student interaction, and commitment to the major by persistence and study major as reflected in the survey responses. We briefly highlight the persistence literature and prior work related to the trajectories of Black students in these majors and in engineering generally, discuss our methods in more depth, and present key findings and conclusions. Future research will integrate the survey results with the student interview data to provide a more in-depth understanding of Black student experiences in engineering.

II. Literature Review

A. Literature on Factors Related to Persistence

In groundbreaking work about why undergraduate students leave the sciences [16], Seymour and Hewitt identify 23 reasons that students leave Science, Math, and Engineering (SME) majors. This work was recently revisited in [17], which includes Technology as part of the now-expanded definition of STEM majors. In reviewing the findings from both studies [18], Hunter states that all of the reasons for leaving STEM majors found in the first study appear in the second, but that the relative ranking of the reasons and the intensity of importance of some items changed over time. The reasons were broadly organized by Hunter as: issues of poor teaching, poor curricular design, and the negative climate of STEM; career-related issues; pull factors; issues arising outside of college; attitudinal factors; and financial issues [18, p. 92]. The top five reasons switchers cite for leaving are pull factors (discovery of an aptitude for a non-STEM subject), attitudinal (discouraged, loss of interest) and career-related (rejection of STEM careers, shift to more appealing career). However the next two factors in rank order, "competitive, unsupportive STEM culture that makes it hard to belong" and "poor quality of STEM teaching" are actually cited as general concerns at higher rates, by 81% and 96% respectively of switchers, even when they ranked lower as reasons to switch (52% and 48% respectively) [18, pp. 90-91]. Poor teaching quality was also the number one concern of persisters (72%). For students in the recent study, poor teaching included six dimensions: disorganized teaching, delivering course material at inappropriate level, unapproachable demeanor, inadequacies in presentation, disengaged teaching, and indications that teaching is under-valued [19, p. 157]. Poor teaching quality was mentioned by the highest number of students in both studies (83% in 1997 and 78% in 2019). The competitive and unsupportive culture increased in ranking from 12th (mentioned by 20%) in 1997 to 6th in 2019 (mentioned by 53%) [18, pp. 90-91].

Among students of color (i.e., all non-White ethnicities), poor teaching quality was mentioned by 96% of switchers and 92% of persisters and a competitive and unsupportive culture was mentioned by 88% of switchers and 60% of persisters. A much higher percentage of switchers of color (62%) cited the competitive and unsupportive environment as a reason for leaving than did White switchers (49%). By contrast, only 35% of switchers of color cited poor teaching as a reason for switching compared with 53% of White switchers [18, pp. 105-106].

Research has shown that students' classroom experiences impact their retention and persistence. A review of the research on strategies for improving classroom climate [20] cites numerous studies finding that positive faculty-student interactions can help students develop an engineering identity and leads to greater persistence. In addition, research indicates that pedagogies of engagement (i.e., cooperative, problem-based, project-based, case-based, and service learning) result in greater social integration and academic learning. Perceptions of belongingness in the classroom are especially important for retention. A small study of eight first-year engineering persisters and switchers found that persisters engaged in more social connections, like engineering clubs, than switchers. Persisters also had a better connection with their peers, faculty, and engineering generally than did switchers [21]. Another study [22] identified four factors as particularly important for racial minority students—instructional styles that promoted activity and engagement, positive interpersonal relationships with faculty, feelings of connectedness in the classroom, and positive interaction with peers. Litzler and Young found that students of all races who were committed to completing an engineering degree had, among other things, higher levels of student interaction and experiences with high quality teaching by faculty [23, p. 337].

Classroom experiences are also an essential component of student perceptions of campus climates [24]. Research indicates that classroom environments have a significant impact on students' self-assessments, learning behaviors, and academic performance [25]. For example, Huang's [26] study of students at Predominantly White Institutions (PWIs) and Historically Black Colleges and Universities (HBCUs) showed that culturally responsive teaching practices can promote students' academic self-efficacy and sense of belonging. Trauth and colleagues' qualitative study on Black engineering students attending a PWI revealed that the students reported they had positive classroom experiences when instructors used interactive methods for presenting classroom material [27].

The authors of a recent study [28] collected data on exam scores and failure rates in courses that were taught by instructors using traditional lecturing and active learning techniques. They defined active learning as "any approach that engages students in the learning process through in-class activities, with an emphasis on higher-order thinking and group work" [28, p. 6480]. The authors analyzed the effect of the change on underrepresented minority and low-income students and found that active learning reduced the achievement gap in exam scores and passing rates. Ballen and colleagues [29] found that not only did active learning reduce the achievement gap, but also led to a greater sense of social belonging for underrepresented minority students. Ro and colleagues' [30] study of engineering students at a nationally representative sample of institutions revealed that students in classrooms where instructors more often used group learning self-rated higher on design and contextual competence. Black students especially benefited from being in classes that involved group learning; they reported having better design skills. Cessna and colleagues [31] developed a narrative framework based on current research on underrepresented minority (URM, defined as students who identify as neither White nor Asian studying STEM in the USA) student success and found that student identity and self-efficacy with science in particular can be

encouraged or discouraged by the way faculty set up their classes and the type of relationships they cultivate with all students. When students feel a part of the community of learners in science, they are more likely to persist in the field.

Together, these studies show that Black students are more likely to persist to graduation in majors where there are positive faculty-student relationships, pedagogical styles that encourage collaboration among students and active learning in classrooms, and positive interactions with peers. The present study investigates the experiences of Black students in these areas in the study majors.

B. Black Students in the Study Majors

The Multiple Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) has enabled researchers to study discipline-specific academic pathways longitudinally while disaggregating by race and gender. Researchers have used MIDFIELD to extensively study the outcomes of students in CPE, EE, and ME and our overarching study is situated in this literature [11], [12], [13], [32], [33]. With respect to initial choice of major, these studies revealed that Black engineering students select EE and CPE at higher rates than their peers. Black men (30%) and Black women (21%) choose EE at far higher rates than men (17%) and women (12%) of all races together. In CPE, 12% of Black men that start in engineering start in CPE, compared to 9.5% of all men; and 12% of Black women that start in engineering start in CPE, compared to 4.4% of all women. The rates of choosing ME are similar to other races (19% of Black men and 10% of Black women). 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.

ME is relatively effective at retaining Black students. The graduation rate of Black students who start in ME are higher than the average graduation rate of Black students in seven of the largest engineering majors (including ME). While EE and CPE attract a larger percentage of Black engineering students than of other races, they do not have better outcomes, and the outcomes in CPE are particularly poor. Looking at starting major for first-time-in-college (FTIC) students, all race-gender groups have higher six-year-graduation rates in EE than CPE, especially Black women (36% vs. 14%) and Black men (32% vs. 17%), despite similar curricula. Forty-six percent of Black women and 42% of Black men who ever enrolled (i.e., starters, transfers, and switchers) in EE persisted to graduation from the time they declared the major compared with 22% and 28% respectively for Black women and men in CPE. Most Black students, 74% of Black men and 64% of Black women, who leave EE leave the institution without a degree. Compared to other engineering disciplines, CPE graduation rates are low for women of all races/ethnicities and for Black men. The most likely 6-year destination for Black men starting in EE (48%) and CPE (55%) is to fail to graduate in six years. Similarly, when Black students leave ME, they typically leave the institution rather than switching majors: 78% percent of Black men and 65% of Black women who leave ME leave the institution without a degree [33]. The present study responds in part to calls for qualitative research to help explain the different persistence patterns for Black students in EE and CPE [11], and ME [13].

III. METHODS

This section describes our interview recruitment process, pre-interview survey, and interviewee demographics.

A. Recruitment Process and Sample Selection

At each of the four study institutions, our institutional contact emailed all enrolled current and former EE, CPE, and ME majors with a link to a qualification survey. This survey asked for student demographic, contact, and scheduling information. For the purposes of selection, no distinction was made between CPE and EE students; however we attempted to represent each major proportionally to the population. It was difficult to recruit switchers because, as demonstrated in the literature review above [11], [13], [33], many Black engineering students leave school rather than switching majors and remaining at the institution. Every switcher who volunteered to be interviewed was selected, regardless of major and they are thus overrepresented in our sample relative to the population. A few switchers were interviewed by videoconference when they were unavailable during the in-person interview visits. We attempted to interview sufficient numbers of women, transfer students, and older students to draw conclusions; therefore, volunteers in those demographics were more likely to be selected for an interview. We did not interview first-year students as we wanted all of our interviewees to have experience in the study majors beyond foundational math and science courses.

B. The SEM Survey

Once students were selected to be interviewed, they were asked to complete a pre-interview survey based on the NCWIT Student Experience of the Major (SEM) survey [15]. The full SEM survey includes questions in nine domains known to influence students' decisions to persist in a STEM major, including: Classroom Climate, Student Faculty Interaction, Collaborative Learning, Racism and Sexism, and Commitment to the Major. More details about the SEM, including the rationale for the creation of each domain can be found in [34]. The full survey contains 70 questions, from which we selected 19 key questions in six of the domains that we considered likely to best inform our interview protocol. The present study reports on 12 of these questions that we have grouped into three categories: Teaching and Learning, Faculty and Peer Interaction, and Commitment to the Major. All questions used a 4-point Likert-type scale that was appropriate to the question (e.g., Never-Often; Strongly Disagree-Strongly Agree; or Poor-Excellent) and are shown below:

Teaching and Learning

- *Rate the overall quality of instruction in your classes.*
- *How often have your [study major] professors used group learning activities in class?*
- *I feel comfortable asking questions during my classes.*

Faculty and Peer Interactions

- *Whenever I have a question about my homework I ask the professor teaching the class.*
- *Whenever I have a question about my homework I ask other students in the same class.*
- *How many of your [study major] courses discourage or forbid you from working with other students on assignments?*
- *My [study major] professors encourage me to continue in the major.*
- *I feel comfortable talking to my [study major] professors one-on-one.*
- *Other students in my [study major] classes have encouraged me to continue in my major.*

Belonging and Commitment to the Major

- *I feel like I belong in my [major] department.*
- *How likely are you to complete your [study] major? (not asked of switchers)*
- *Since entering my [study] major, I have seriously thought about changing to a different major (yes or no; not asked of switchers).*

The qualification survey data was combined with the SEM survey data from all institutions. Students who completed one or both surveys but were ultimately not interviewed were discarded from further analysis. One person switched from EE without having taken any EE classes and thus did not respond to the relevant portions of the SEM survey; otherwise, complete information is available from all interviewees. The recruitment and interview protocols were reviewed by the appropriate Institutional Review Board and determined to be exempt from further review.

C. Population and Participants

Each school was asked to provide data about its engineering student population with respect to race, gender, study major, and persistence. Unfortunately, schools did not provide their data in a common format and complete information was not available for each school. Using the data they provided, plus publicly available information on school websites regarding gender breakdown, we assume that 21% of the population of the three majors across the four institutions together is female and 79% is male. However, we cannot allocate these students to a particular major with similar confidence. Study major was unknown for 16 switchers from two institutions. Eight of these were identified as "ECE" switchers; five were assigned as EE and 3 were assigned as CPE based on a conversation with the institution's engineering assessment director who indicated that 2/3 of black students with an ECE double major choose EE as the first major and 1/3 choose CPE as the first major. The other 8 students were assigned to the three majors in proportion to the known switchers (3 CPE, 2 EE, 3 ME). The eligible population included 932 persisters and 124 switchers (with 4 students potentially double counted) as shown in Table 1. Nearly half had ever declared a mechanical engineering major ("ever ME"). A significantly higher percentage of students switched from CPE to another major (21%) than from EE (10%, z_{CPE-EE} =3.89, p<.001)) or ME (9%, z_{CPE-ME}=4.93, p<.001). Table I shows the population data by major and switching status.

TABLE I POPULATION DATA FOR STUDY INSTITUTIONS

	CPE	EE	ME	Total
Persist (current majors)	187	276	469	932
Switch (former majors)	51	29	44	124
Total	238	305	513	1056
Switchers as a % of ever majors	21%	10%	9%	12%
Ever major as % of population	23%	29%	49%	100%

We interviewed 23 switchers (19% of the population) and 56 persisters (6% of the population) across the four study institutions. Nearly three-fourths (17/23) of the switchers indicated that they had taken three or more classes in the study major, giving them sufficient experience to report on issues of climate. Four participants indicated that they were double majoring in Electrical and Computer Engineering (ECE). They were assigned to either EE or CPE for further analysis based on the text of their interviews that indicated which major they considered to be their primary major. Three were assigned to EE and one was assigned to CPE. As noted above, one EE switcher changed majors prior to taking any EE courses and thus is not included in the analyses. The study major and persistence status of our interviewees is shown in Table II.

TABLE II. INTERVIEW PARTICIPANTS

	CPE		EE		ME		Total	
	Female	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*
Persist	8	9	6	8	10	15	24	32
Switch	0	10	2	3	2	6	4	19
Total	8	19	8	11	12	21	28	51

D. Limitations

Data were explored, but not reported, by study institution to ensure that conclusions about study majors were sustained across institutions. Findings where one institution appears to skew the results are not reported here. Likewise, because there were only 4 switchers with data from EE, we rarely make comparisons to the other majors that had more switchers (ME – 8; CPE – 10) or to EE persisters (N=14), although they are shown in figures for completeness. We did not use the SEM scales as defined by NCWIT [15] for analysis as our goal was to use the questions to guide and personalize our interview protocol. The survey was administered only to those students who volunteered and were scheduled to be interviewed. Our sample unintentionally overrepresents CPE students and intentionally overrepresents women and switchers. Thus, we do not claim that these survey results are representative of the population of Black EE, CPE, and ME students. However, we believe that the results provide valuable insight into the relative experiences of Black persisters and switchers in these majors.

IV. FINDINGS

For the purposes of this survey, we selected three particularly relevant characteristics of good practice in undergraduate education from Chickering and Gamson's [35] widely used list: 1) Encourages student-faculty contact. 2) Encourages cooperation among students. 3) Encourages active learning. As we will indicate in each section below, there is also

evidence to suggest that those three characteristics also have effects on success for URM students. In addition, we asked students to rate the overall quality of instruction, a measure that allowed students to put all the disparate pieces together to indicate how effective they thought the teaching was across all the classes taught in their study major. Each graph below displays the answers to the relevant questions by major and persistence status. Numbers within the bars represent the number of students choosing that response to inform the reader of the effect of certain small sample sizes on the percentages.

A. Learning Environment

As shown in Fig. 1, few students (6%) rated instruction as excellent and another 42% overall rated it good; more than half (52%) rated it fair or poor. A higher percentage of ever-CPE students rated instructional quality as fair/poor (67%) than any other major (ME – 54%; EE 28%). Given the similar curricula and required courses, it is interesting to note that 71% of all ever-EE majors rated the teaching quality as Excellent or Good (the highest of the three majors) compared with 33% of ever-CPE majors. Not surprisingly, perhaps, a higher percentage of persisters overall (53%) rated teaching quality as excellent/good compared to 37% of switchers. CPE is the only one of the three majors where persisters gave lower ratings to teaching quality (71% Fair/Poor) than switchers (60%). By comparison, in ME, 63% of switchers rated teaching quality as Fair/Poor compared with 50% of persisters. Among persisters, 86% of EE majors rated instructional quality as excellent or good compared with 29% of CPE majors and 50% of ME majors.

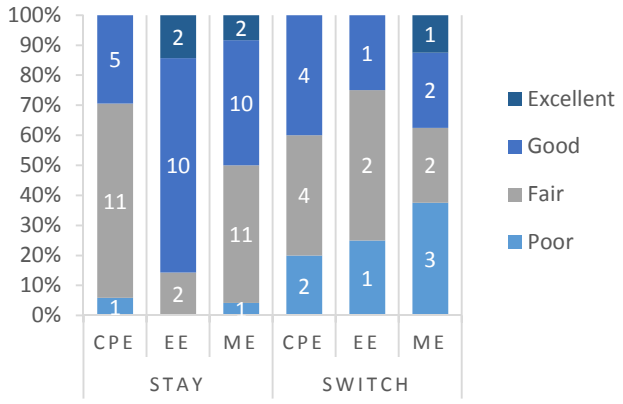

Fig. 1. Rate the overall quality of instruction in your classes

How comfortable a student is asking questions in class may be related to factors such as class size, professor encouragement, and personal factors, such as introversion. As shown in Fig. 2, we found that persisters (82% agree/strongly agree) were more comfortable asking questions in class than switchers (46%). The gap between persisters and switchers was highest in ME where 88% of persisters, but only 38% of switchers, felt comfortable asking questions compared with a much smaller gap among persisters (71%) and switchers (60%) in CPE.

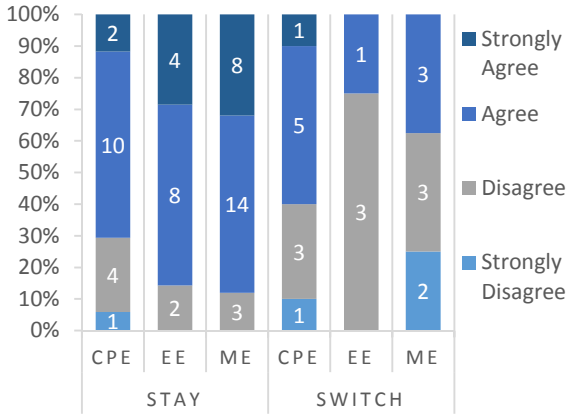

Fig. 2. I feel comfortable asking questions in class

Collaborative learning, such as in-class group exercises and study groups for homework, allow students to be more engaged with the course material and their classmates [28] and has shown particularly positive effects for Black students with respect to their engineering design skills [21]. To address this construct, we asked students about group learning in class. Here (Fig. 3), ME shows a substantial difference from both EE and CPE, likely reflecting the commonalities in ECE coursework and instructional staff. Fifty-two percent of ever-ME students said that professors "often" use group learning in class, compared with 11% of ever-CPE students and 6% of ever-EE students.

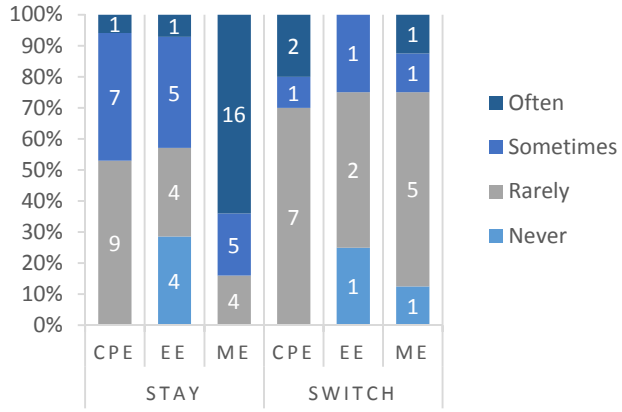

Fig. 3. How often do professors use group learning in class

Among persisters, 84% of ME students report that their professors sometimes or often use group learning compared to only 47% of CPE persisters and 43% of EE persisters. Switchers were less likely to experience group learning overall, with only 28% indicating that their professors "sometimes" or "often" use it without much variance among the three majors. The gap between ME switchers and persisters was quite large (80% vs. 26%) compared to the gap between CPE persisters and switchers (47% vs. 30%). EE appears to show a similar pattern to CPE (43% vs 25%), but should be viewed with caution due to the small number of switchers in EE (N=4).

B. *Faculty and Student Relationships*

We asked students about their interactions with their professors outside of class. Research on the SEM survey itself [34] has confirmed other studies and shown that student-faculty interaction is a significant predictor of commitment to the major, although not for minority students in their research. However, other studies (e.g., [22]) have confirmed the importance of positive faculty-student relationships for Black student persistence. In general, our survey results show positive relationships between students and faculty. Seventy-eight percent of respondents feel comfortable talking to their study major professors one-on-one, 64% feel encouraged to continue in the major and 77% sometimes or often ask the professor for help if they have questions about homework.

As in the case of aspects of classroom climate, there were differences between switchers and persisters in whether students feel comfortable talking with their professors one-on-one (Fig. 4). Eighty-eight percent of persisters agreed or strongly agreed that they felt comfortable compared with only 54% of switchers. All EE persisters and 96% of ME persisters felt comfortable talking with their professors one on one, but only 65% of CPE persisters did. Interestingly, among switchers, 80% of CPE switchers felt comfortable talking with their professors (a higher percentage than the persisters), but 75% of ME switchers did not.

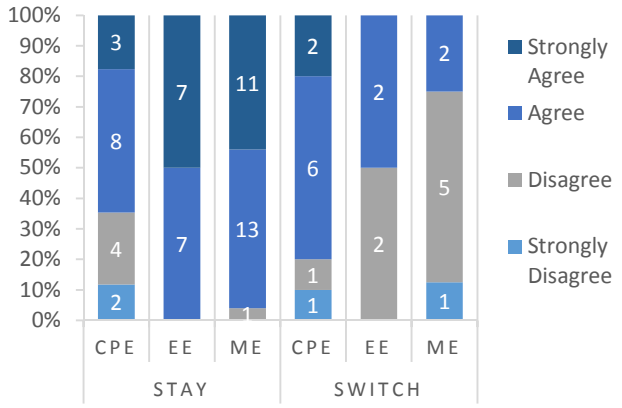

Fig. 4. I am comfortable talking to professors one on one.

With respect to seeking help on homework, students had a similar response pattern to their comfort talking with their professors. Eighty-four percent of all persisters sometimes or often asked for help compared with only 59% of switchers. CPE persisters are less likely to ask their professors for help (65%) compared with EE persisters (93%) and ME persisters (92%); CPE switchers were about as likely to seek help (70%) as persisters, but the gap between ME persisters (92%) and ME switchers (63%) was much wider.

About two-thirds of all students feel encouraged by their professors to continue in the major with 64% agreeing or strongly agreeing. EE (79%) and ME (76%) persisters are somewhat more likely to feel encouraged than CPE persisters (63%), but 70% of CPE switchers also felt encouraged by their professors to remain in the major. This contrasts with no EE switchers and only 25% of ME switchers who felt encouraged by their professors to continue in those majors (Fig. 5).

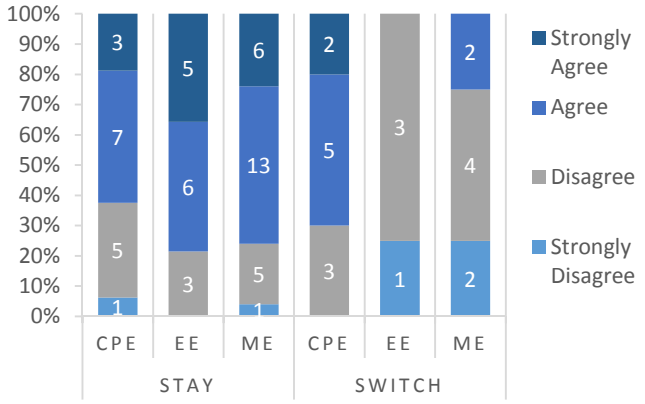

Fig. 5. My professors encourage me to continue in the major

We asked students about interaction with peers on homework and whether they were discouraged from working with others on their homework, which would tend to suppress this peer interaction. When students have trouble on homework, nearly three-fourths of the ever-majors "often" asked other students in the same class, with little difference among the three majors (EE – 70%, ME – 78%, CPE – 70%). Persisters (75%) were somewhat more likely to ask their peers for help than switchers (64%). When students work together on homework, it is possible that this collaboration may be perceived as cheating. We asked students if they were discouraged or forbidden from working with others on assignments. Only 18% of students indicated that they were discouraged in all or most of their classes and 39% indicated that they were not discouraged in any of their classes. Switchers (38%) were more likely to report that they were discouraged from collaborating than were persisters (11%).

We also asked students whether other students encouraged them to continue in their major (Fig. 6). Nearly three-quarters of respondents sometimes or often felt encouraged by their peers to continue in the major. The pattern was similar to other responses by major where 85% of ever-ME majors and 83% of ever-EE majors felt encouraged by other students compared with only 52% of ever-CPE majors. More than twice as high a percentage of persisters (86%) as switchers (41%) felt encouraged by their peers. Among persisters, 100% of EE students and 89% of ME students were encouraged by their peers compared to 71% of CPE persisters. In ME, 75% of switchers also felt encouraged to persist by their peers in addition to the 89% of persisters. By contrast, 80% of CPE switchers (and 75% of EE switchers) rarely felt encouraged by their peers to persist.

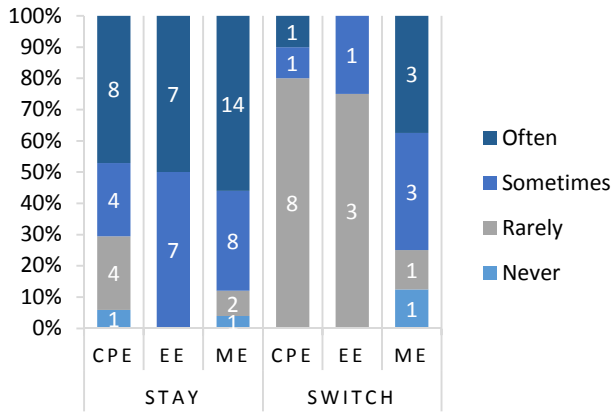

Fig. 6. Other students encourage me to continue in the major.

C. *Belonging and Commitment to the Major*

Both persisters and switchers were asked about their sense of belonging in the study major. We asked switchers this question to help inform whether the lack of a sense of belonging contributed to their decision to switch. Not surprisingly, nearly three fourths of switchers disagreed or strongly disagreed that they felt like they belonged in the study major. Conversely, 84% of persisters agreed or strongly agreed that they do. As on many of our other questions, CPE persisters were less inclined to agree that they felt like they belonged (71%) compared with EE persisters (86%) and ME persisters (92%). Two other questions addressed commitment to the major for persisters. Nearly all (86-88%) persisters indicated that they were very likely to graduate in their major with no differences by discipline. However, CPE persisters were far more likely to have considered changing majors (75% answered "yes") compared with EE (21%) or ME (28%) persisters.

V. Discussion

The purpose of this paper is to explore the differences in reported learning and relationship experiences of Black students who have persisted in or switched from CPE, EE, and ME. Prior research suggests that elements of the learning environment as well as relationships with faculty and students may be part of the explanation. Our findings indicate that, indeed, there appear to be substantial differences in the experiences of persisters and switchers. The data is observational, that is, we do not know if the experiences necessarily led to the decision to persist or switch, however, theory and intuition tell us that people who have qualitatively worse experiences in a major are more likely to explore other majors than those whose experiences are good.

Our interview protocol included asking each student about his or her responses to the SEM survey questions in order to allow us to probe into these areas in greater depth. For instance, in one interview of an EE persister, the interviewer pointed out that the student had rated the quality of instruction as "good" and asked for elaboration. The student replied that "[professors] make themselves available to us all the time." A fuller analysis of our in-depth interviews with the students will allow us to learn more about the qualitatively different experiences of persisters and switchers and the impact of those differences on their decisions to persist or switch.

Our findings are strongest as they pertain to the first research question above related to persistence. In general, students who persist feel more encouraged to do so by their professors and other students. Students who persist in the majors also report feeling more comfortable talking to their professors one-on-one outside of class and, in EE and ME, are more likely to seek help from their professors on homework. Persisters are also more likely to seek help on homework from classmates while more switchers than persisters perceive that they are discouraged or forbidden from working with other students, which could explain the reticence to seek help. These findings are concordant with [22] and [23]. Persisters also report a better in-class environment where they are more likely to experience group learning in class and more comfortable asking questions during class. This also confirms prior research about the benefits of collaborative learning generally and for minority students in particular [30], [36]. Persisters also have more positive impressions of the quality of instruction.

Our second research question led us to explore the perceptions of learning and relationship experiences among the three majors in order to inform our overarching research questions from our larger study related to retention of Black students in ME, EE, and CPE. These findings could point to areas that departments and individual faculty could change to improve retention for their Black students. Here we explore further what elements may be in place in ME that makes it differentially better at retaining Black students than both EE and CPE as well as why EE retains Black students better in spite of being in the same ECE department with a largely common curriculum as CPE.

Based on our survey data, it appears that aspects of the learning environment, such as the ability to do homework in teams and collaborative learning in class, that have been shown to lead to positive outcomes [22], [36] are more likely to be experienced in ME classes than in ECE classes. This may help explain why Black students are retained in ME at a higher rate than the aggregate of most other engineering disciplines [13]. Because there is a relatively large gap between switchers and persisters in ME, but not in ECE as it relates to experiencing group learning, we surmise that group learning in ME may be relatively common in upper level classes, but not in the lower division classes that students take before they switch. By contrast, there is little difference in apparent exposure to group learning between ECE switchers and persisters, indicating that the level of exposure is constant across the curriculum. The use of group learning in classes does not appear to differ between EE and CPE, likely reflecting the common curriculum and instruction. However, because ME shows higher persistence than either EE or CPE [11], [12], [32], ECE departments should consider including more opportunities for group learning in their classes, particularly in the lower division when students are making decisions to switch.

While there were few differences in relationships with faculty outside of class among departments, peer relationships appear to be more supportive in ME, with both persisters and switchers feeling encouraged to continue in the major. By

contrast, in ECE, even though persisters generally felt encouraged to continue, more than three-fourths of switchers did not feel encouraged to persist. Thus, they may lack the positive peer relationships that tend to promote persistence [22], [23] that is found throughout the ME experience.

Another purpose of our research is to inform why EE and CPE have different outcomes for Black students in spite of generally being offered in a common ECE department with similar coursework and faculty [12]. Our survey data provides less insight into this question. We surmise that one explanation may be because of the realization on the part of some CPE students that computer science is a better fit for their interests. Five of the 10 CPE switchers changed to computer science and 75% of persisters had contemplated switching to another major, often computer science. However, we should not completely discount the impact of classroom environment as an explanation. In our study, ever-CPE majors were far less inclined to rate instructional quality as Excellent or Good than ever-EE majors and for those who persisted in each major, the gap was even larger.

Students appear to differentiate between their professors as instructors and their professors outside the classroom. From an instructional standpoint, only EE persisters were overwhelmingly positive about their experiences. However, most students, particularly persisters, felt comfortable talking to their professors individually. CPE switchers felt even more comfortable than persisters and felt encouraged to continue in their CPE major, perhaps indicating that they sought advice from faculty before making the decision to switch.

Relationships with faculty are an important contributor to persistence and there appear to be good faculty and positive relationships in both ME and ECE departments. However, positive faculty relationships are not sufficient for guaranteeing positive student experiences, as confirmed in the literature and in our findings reported here. Classroom environment is another important factor; in ECE overall it appears that effective teaching strategies, such as group learning, are not being incorporated as often as they are in ME. Our results also reveal that CPE and EE students experience their majors in different ways, even if the students are located in the same department, or even the same classes, which may explain why Black CPE starters are more likely to graduate in a major other than CPE [11]. We will explore these results more fully though in-depth analysis of our qualitative interviews to better understand *why* these patterns exist.

VI. Future Research

Future research will use the interview data to provide details about the impact of both teaching and learning and relationships on Black students' decisions to persist in the study majors or to switch from them. We expect that our research will inform ECE and ME departments as they consider the impact of teaching practices on the persistence of Black students in these majors. Substantial differences between switchers and persisters were observed, but there were few notable differences between majors. However, the results are in the theorized direction. In future work, we will combine these results with our interview data and with weighted statistical analysis of the survey data to provide a fuller explanation of decisions to persist or switch from our study majors.

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