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DO I STAY OR DO I GO? EXAMINING ATTRACTION, SELECTION, AND ATTRITION OF BLACK MEN IN COMPUTER ENGINEERING AT PREDOMINANTLY WHITE INSTITUTIONS

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Black men are underrepresented in engineering in general and computer engineering (CPE) in particular. Using two unique datasets, (1) the Multiple Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) and (2) 10 interviews with Black men who persisted in or switched away from CPE at two predominantly White institutions, we contextualize the outcomes of Black men in CPE at predominantly White institutions and highlight these students' narratives about their educational experiences. We use Schneider's attraction, selection, and attrition framework to better understand how institutions shape the educational experiences of Black men in CPE. Our quantitative results show that Black men switch majors away from CPE at similar rates to men of other ethnicities, but they have a slightly lower rate of persistence through eight semesters. Black men who leave CPE do so earlier than they leave other majors. In our qualitative interviews, we find that early, hands-on experiences in CPE during the first year served to select students into it. Persisters better understood what the CPE major entailed than switchers when selecting the major. Attrition was associated with poor experiences in foundational courses, lack of caring faculty, and students' reconsideration of their reasons for choosing the CPE major initially. Our findings have implications for electrical and computer engineering faculty and advisors regarding how they teach and interact with their students, particularly those who are historically minoritized. Should the departments make the changes we suggest, the students would be the ultimate beneficiary of an improved environment for learning.

KEY WORDS: *attraction-selection-attrition framework, GPA, persistence, hands-on experiences, inclusive teaching, sense of belonging, undergraduate, active learning*

1. BACKGROUND

> *I feel like everyone has their own agenda. Professors are focused on research and money, class is secondary. Students with an exceptional level of struggles are certainly secondary amongst that….ECE is a very cold fire-and-brimstone type of environment. Everything is either you know it or you don't. We're a top-ranked school for a reason. You sink or swim. That cutthroat mentality. There's very little gray area. I find myself usually having to really go out of my way to prove to professors [that] I'm trying hard. Because any level of slack and they're thinking why should I care about him? I always felt like I had to do a lot to get the professor's attention.* Jaden

> *Whenever [the professor] would talk about certain practical applications [of circuit analysis], it just felt kind of dry to me...I can see the value in it, it just doesn't really resonate in a strong way... And made me kind of question whether or not I should really do electrical engineering or computer engineering. I was talking to [the professor] during advising because I had all these questions [because] I don't know if computer engineering and all that, if that's the right thing for me. Do I really just want to do programming, or do I want to do this other stuff, like learn about FPGAs and Kirchhoff's law and stuff?* James

Jaden persisted in computer engineering and James switched to computer science. Jaden's quotation represents the struggles faced by Black men at one top-ranked predominantly White institution (PWI). As a student who was committed to attaining a computer engineering degree, Jaden found ways to navigate an unwelcoming environment and overcome personal struggles to be successful. James' story illustrates the difficulty that many students face when deciding between a computer engineering and a computer science major. For some students, computer engineering offers both a hardware and software perspective that they feel strikes a perfect balance, but for others, a preference for software or hardware emerges that influences them to choose one or the other. While the decision to stay in computer engineering or switch to another major is multifaceted and personal, the environment in the department impacts students' decisions, experiences, and outcomes. The advantage of a caring professor who provides both a sounding board and sound advice cannot be underestimated as they guide students like James in their major selection decisions. In this paper we examine the personal and institutional factors that contribute to the attraction, selection, and attrition of Black men in computer engineering through quantitative data analysis and stories from two persisters and two switchers.

2. INTRODUCTION

Black men are generally underrepresented in engineering education, comprising 5.2% of undergraduate engineering enrollment and 4.3% of engineering bachelor's degrees in

2019 (American Society for Engineering Education, 2020). Low initial enrollment has been attributed to poor academic preparation (Atwaters et al., 2015) and can be traced as far back as middle school, where Black students are not enrolling in Algebra 1 and are therefore not on track to complete Calculus 1 in high school (Cottle, 2022). Several researchers (Hatfield et al., 2022; Riegle-Crumb et al., 2019) have pointed to the environment in STEM fields as reasons for underrepresented students generally and Black students in particular not persisting to degree attainment. Riegel-Crumb and colleagues (2019) have shown that in spite of Black students initially choosing STEM majors at the same rate as White students, only 34% of Black students persist to a STEM degree compared with 58% of White students. Black students have higher rates of switching out of STEM and are twice as likely to leave school as White students. These patterns are not found to the same degree in other fields. They suggest that factors such as stereotype threat, microaggressions, and lack of support and inclusion from teachers and peers leads Black students to switch majors or leave school. Hatfield and colleagues (2022) posit that the environment in introductory STEM courses at large, predominantly White research institutions systematically disadvantages minority men and leads to a lower graduation rate in STEM among Black men than men of any other ethnicity.

Research does not always capture the nuances of Black men's underrepresentation in engineering education. Too often, studies of undergraduate engineering students suffer from "systematic majority measurement bias" (Ohland et al., 2011, p. 244), where the average performance of a group [e.g., computer engineering (CPE) students] represents the average performance of the majority of students in that major (i.e., White men). Therefore it is important to disaggregate performance data by race and gender to identify patterns that may have implications for practice and ultimately realize greater equity in the engineering disciplines. Lord and colleagues (2011, 2015) answered this call for more careful analysis by disaggregating the outcomes of students by race and ethnicity specifically in electrical engineering (EE) and CPE. They found that Black men were attracted to CPE at higher rates than men of other ethnicities but that they were twice as likely to leave school entirely than to graduate with a CPE degree within six years. They recommended qualitative research to expand understanding of the reasons for these disparities in outcomes.

Our mixed-method study responds to this call through our use of both qualitative and quantitative data to explain this strong attraction of Black men to CPE and their subsequent attrition relative to men of other race/ethnicities in terms of graduation outcomes. We draw upon two unique datasets – the Multiple Institution Database For Investigating Engineering Longitudinal Development (MIDFIELD) for quantitative research and in-depth interviews with 10 Black men who majored in CPE at two predominantly White MIDFIELD partner institutions who persisted in or switched away from CPE for qualitative research. MIDFIELD contains 1,688,916 student records, including those of 615 first-time-in-college Black men whose first degree-granting major was CPE at 14 PWIs over a 30-year period. MIDFIELD allows us to establish a broader context for our in-depth analysis of the interviews which elucidate Black men's reasons for choosing CPE and subsequently persisting in it or switching to other majors. We explore the qual-

ity of peer interaction, faculty interaction, and classroom experiences that led to their decisions. At the institutions in this study, the CPE and EE majors are part of electrical and computer engineering (ECE) departments and the two majors have many courses in common, particularly introductory ones. Although our investigation is specific to students choosing a CPE major within the larger ECE department, many of our findings are applicable to the department as a whole.

We use Schneider's attraction-selection-attrition (ASA) framework (Schneider, 1987; Schneider et al., 2000) as our analytical approach for highlighting the role of organizations (i.e., departments and universities) in influencing students' decisions about college major as extended by Chatman et al. (2008). Although initial attraction to the CPE major is based on many personal factors and decision points, we frame our findings around selection and attrition using the ECE department as the lens. That is, we consider factors under the control of the department (e.g., teaching, advising, curriculum) that contribute to students' selection by, persistence in, and attrition from CPE. We also consider the factors that influence switchers' selection into other majors in order to inform ECE decision makers of the range of reasons that impact students' decision to switch and their ultimate destination within the university. In the context of the ASA framework, we investigate the following research question: What does the CPE major do to attract and retain Black men or cause them to leave?

Our study provides information to the engineering education community in general and to ECE departments in particular about the attraction, selection, and attrition of Black men into and out of the CPE major. Our findings have implications for ECE faculty and advisors regarding how they teach and interact with their students, particularly those who are historically minoritized. Should the departments make the changes we suggest, the students would be the ultimate beneficiary of an improved environment for learning.

3. THEORETICAL FRAMEWORK

First theorized in industrial and organizational psychology, the ASA framework (Schneider, 1987; Schneider et al., 2000) posits why individuals choose to remain in or leave an organization. According to this theory, organizations choose members who tend to share characteristics with people who are already there. Individuals choose to remain in an organization that shares their values, personality, and beliefs. When there is a mismatch, people leave. Consequently, organizations become more homogenous in terms of various characteristics and traits over time. In the context of our research, selection and attrition processes lead to a restricted range of students that remain in the CPE major.

According to Chatman et al.'s (2008) discussion of ASA, person-situation interactions are central to realizing a sense of "fit" with an organization, over and above feelings of congruence. Thus, interactional elements are essential for understanding selection and attrition. For example, individuals who are similar to existing organizational members in terms of demographic characteristics (e.g., race and gender) may in turn be socialized more intensively into the organization. Individuals who share demographic

characteristics interact and form networks with one another and transmit organizational culture to one another; individuals who are dissimilar may not readily form such networks and not fit into the organizational culture and eventually leave as a result.

According to ASA, the unit of analysis shifts from the individual to the organization when trying to explain why individuals select, persist, or leave organizations. Drawing from Schneider (1987), Schneider et al., (2000) and Chatman et al. (2008), we utilize the ASA framework to better understand the question of "fit" within a major and the factors that lead students to persist in or switch out of CPE. In the context of higher education, universities exert a powerful influence over student decision making through programs, policies, and practices. Thus, faculty and staff across the university play an integral, and ideally integrated, role in supporting students, as "together, all the individuals involved in the educational process have the capacity to change the very nature of the learning environments to more effectively promote student success and retention" (Rozhenkova et al., 2022, p. 2). Furthermore, Godfrey and Parker (2010) have documented evidence of a distinct engineering culture, and even "cultures within cultures" (Godfrey, 2007), referring to cultural differences in subdisciplines where "departments are like different tribes" within engineering (Godfrey and Parker, 2010, p. 6).

The ASA framework has been used in research on Black students in higher education, including research on graduate students in nursing education (Avery-Desmarais et al., 2021) and on engineering undergraduate students, including by Kellam et al. (2009), who focused on women in engineering, and more recently, by Martin (2021), who investigated students' initial major selection and the time to the selection of their ultimate graduation major. He concluded that students who enroll in their graduation major later, presumably after switching from another major, may be seeking a more welcoming culture in the destination major.

For research on engineering education, the ASA framework draws attention to the importance of considering the broader institutional ecosystem that contributes to student success or attrition. This approach emphasizes departmental practices, policies, and patterns that lead students to remain in or switch out of the major. Such factors include whether students perceive the department to be a safe haven, the presence of social agents (e.g., teachers, advisors, etc.) who encourage students, and engineering cultures, which vary by engineering major (Lord et al., 2018; 2019). Engineering majors each support different values, practices, and beliefs about the ways of thinking, doing, and being an engineering student in a particular major (Godfrey and Parker, 2010). In our investigation we highlight various dimensions of CPE culture and practices that promote selection into or attrition from CPE.

Considering this body of research on the ASA framework, for our investigation of the experiences of Black men in CPE, we operationalize attraction, selection, and attrition as follows:

- Attraction – Something that the students know or believe about themselves and the department that causes them to choose CPE or other majors.
- Selection – Actions and activities undertaken by the ECE department that invite students to choose CPE (e.g., introductory courses, department culture).

- Attrition – Actions and activities undertaken in the context of teaching, learning, peer relationships, and advising within CPE that cause students to choose to leave in favor of a different major.

Our operationalization of attraction is congruent with Martin's (2021), but we diverge on the operationalizations of selection and attrition. Whereas Martin considers selection to be positive action on the part of the student to declare the major, we consider what the department itself does to select students into the major. Similarly, regarding attrition, Martin considers performance domains (i.e., grades) as well as academic and social integration into the major. We also consider those factors but in the context of the department's environment and culture. We believe these definitions are more consistent with Schneider's (1987) framework, particularly as interpreted by Chatman et al. (2008) regarding the interactive effect of the people and the place, and as specified by Godfrey and Parker's (2010) discussion of engineering cultures.

4. LITERATURE REVIEW

Much research focuses on the student characteristics that contribute to poor performance, and for many, ultimately leaving the major or school altogether. However, it is essential to also consider the institutional context and characteristics that contribute to student attrition (Emekalam, 2019). That is, in line with the ASA framework, the institution shapes student experiences. Below we briefly review the literature on Black men attending PWIs and research on some of the key factors that influence retention and attrition in engineering education.

4.1 Black Men Attending Predominantly White Institutions

The vast majority of African American men who graduate from college do so from a PWI (Atwaters et al., 2015), so it is important to understand what factors contribute to students being successful at these institutions. Black undergraduate students, particularly men, at PWIs face a number of stressors that have been shown to impede their academic performance and general well-being, including stereotype threat (Fries-Britt and Turner, 2002; McGee and Martin, 2011; Moore et al., 2003); invisibility and loneliness (Fries-Britt and Turner, 2002; Harper, 2013); hypervisibility (Harper, 2013); perceived pressure to represent their race (Fries-Britt and Turner, 2002; Harper, 2012); and other challenges to belonging that contribute to low rates of persistence and graduation.

Harper (2010, 2012) proposed an anti-deficit framework which, rather than asking why Black men are not successful, asks positively framed questions such as: "Which instructional practices best engage Black male collegians? How do Black men craft productive responses to stereotypes encountered in classrooms?" (Harper, 2012, p. 5). In his interviews with high-achieving Black men, he found that influential K-12 teachers, adequate funding for college that reduces the need to work and take out loans, summer

bridge programs with upper-level Black mentors, and being engaged on campus with peers and faculty contributed to Black men's persistence.

Other scholars have positively framed Black men's responses to the negative environments that they face at PWIs. Moore et al. (2003) coined the term "prove-them-wrong syndrome" to address how Black male persisters in engineering respond to negative experiences by becoming even more committed "when they perceived that their intellectual capability was doubted or slighted" (Moore et al., 2003, p. 70). McGee and Martin (2011) suggested that beyond proving-them-wrong, successful Black students created an identity where they are able to manage stereotypes so that they did not exact as big an emotional toll, allowing the students to thrive, rather than simply survive.

4.2 Importance of Sense of Belonging

McIntyre et al. (2018) suggested that multiple factors impact a student's sense of belonging in a particular major. These factors include the culture, social support, lack of diversity in instructors, and being stereotyped while pursuing undergraduate or graduate degrees at PWIs. While trying to adapt to or integrate into a dominant culture, Black male students believed that to be an engineer one must "look like an engineer, talk like an engineer, and act like an engineer" (McIntyre et al., 2018, p. 4). When faced with such choices, Black male students must change or take on that cultural identity to fit into the major or switch their major entirely.

The lack of same-race peers often leads to a profound sense of loneliness and isolation for students who are "the only ones" in their classes. Fries-Britt and Turner (2002) suggested that Black students' energy "is diverted away from their studies by their role as the 'token' representative," because campus activities are generally geared toward White students (Fries-Britt and Turner, 2002, p. 319). Students in Strayhorn and colleagues' (2013) study similarly felt invisible in class, often ignored by professors when they attempted to contribute. Harper noted that Black students often face the paradox of being both "invisible and hypervisible" (Harper, 2013, p. 193), invisible as the only ones in their classes, yet hypervisible because their absence from class may be noticed immediately and interpreted by others as lack of engagement.

4.3 Importance of Relationships with Professors and Advisors

In a landmark study of students' experience in college, Astin (1993) identified the quality of relationships with professors as the most important factor in student persistence. The factors contributing to these relationships were the frequency of talking with professors outside of class, working with professors on research or assisting with teaching, and visiting professors' homes. These activities correlated with student GPA and degree attainment but also with self-reported intellectual growth, personal growth, and satisfaction with the quality of teaching.

Students' perceptions of having caring professors have been found to influence their decisions to persist in a major field or to switch (Rainey et al., 2019). Their sense of be-

ing cared for is reinforced by all of the professorial actions listed in the preceding paragraph, and also by an approach focused on dignity and respect for all students—what Theobald and colleagues call the "head and heart" approach to teaching (Theobald et al., 2020, p. 6479). It is also essential to infuse advising with an ethic of care, providing students with both practical advice (e.g., what courses to take) and emotional support that empower students to succeed (Rozhenkova et al., 2022). Teachers and advisors who exhibit such relational characteristics contribute positively to Black male success in college (Museus and Ravello, 2010).

Academic advising can be as essential for success in college as relationships with professors (Mu and Fosnacht, 2019; Zegarra, 2019) and can play a critical role in supporting Black students who may experience marginalization in PWIs (Lee, 2018). Many universities focus on providing intensive advising during the first year of college, acknowledging that the first year is an important time to develop a foundation for subsequent success (Hoffman, 2020). The first year is an especially important time as students decide whether to remain in their major based on performance during their first year (Chen, 2013; Hunter, 2019; Seymour and Hewitt, 1997). Research shows that poor advising influences students to switch out of their current majors into another major that they perceive offers more supportive advising (Rozhenkova et al., 2022).

4.4 Importance of Teaching Environment and Practices

An important aspect of students' attitudes regarding their education is their perception of the quality of the teaching they experience. While poor teaching affects all students, studies have indicated that the effect is stronger on students from groups that are underrepresented in their field (Leonard et al., 2013). Historically minoritized students frequently describe professors as poor teachers and note that they are hesitant to ask the professors for help in office hours, a pattern that is reduced when instructors use teaching strategies that involve active student engagement (Shehab et al., 2007). A meta-analysis of numerous studies has shown that integrating active learning into course delivery significantly narrows the achievement gaps in examination scores and failure rates between nonminoritized and minoritized groups in STEM courses (Theobald et al., 2020).

Culturally responsive pedagogy (CRP) is a comprehensive approach that has been shown to increase the performance outcomes and graduation rates of African American students (Howard and Terry, 2011). The approach is student-centered and takes into account and embraces students' cultural backgrounds and lived experiences (Samuels, 2018). Lane and colleagues (2019) described CRP as asset-based where "the strengths of the students are identified, nurtured, and utilized to promote student achievement through cultural awareness" (p. 3). They stressed that to be most effective, CRP must include three elements: institutional (policies and practices), personal (educators reflecting and progressing so they are able to develop cultural responsiveness as they work with students), and instructional (use of effective student-centered strategies).

Samuels (2018) described a program to train teachers and mentors in culturally responsive pedagogy. After exploring their own cultural experiences and uncovering

biases and perceptions, the trainees identified a number of strategies they could use to operationalize the approach, including giving all students chances to talk about diversity and their own real-world experiences, encouraging participation to assure multiple perspectives are heard and discussed as students are learning, maintaining high expectations, using active engagement strategies, and developing positive relationships that help to foster a respectful environment.

5. METHODOLOGY

Considering prior work using MIDFIELD by Lord et al. (2011, 2015), our study employs a transformative mixed-methods framework, suitable for the study of marginalized populations (Creswell, 2014). Our embedded mixed-methods design includes qualitative data collection through in-person interviews which sought to explain the outcomes found by Lord et al. (2011, 2015) for Black men in CPE. Analysis of the qualitative data led to further questions which could be answered quantitatively with MIDFIELD to better contextualize the qualitative findings and more deeply probe our analysis of Black men's performance and outcomes in CPE (Fig. 1).

5.1 Quantitative Methods

5.1.1 Data Source

MIDFIELD contains 1,688,916 longitudinal student records including those of 615 Black males whose first degree-granting major was CPE at 14 PWIs over a 30-year period. We use the term "males" rather than "men" because only binary indicators of sex are recorded in the institutional data. With our mixed-method approach, themes uncovered in the interviews were explored visually through MIDFIELD to illustrate the outcomes, enrollment counts, GPAs, and pathways of Black males in CPE. The analysis is descriptive in nature and intended to help contextualize the qualitative interview data.

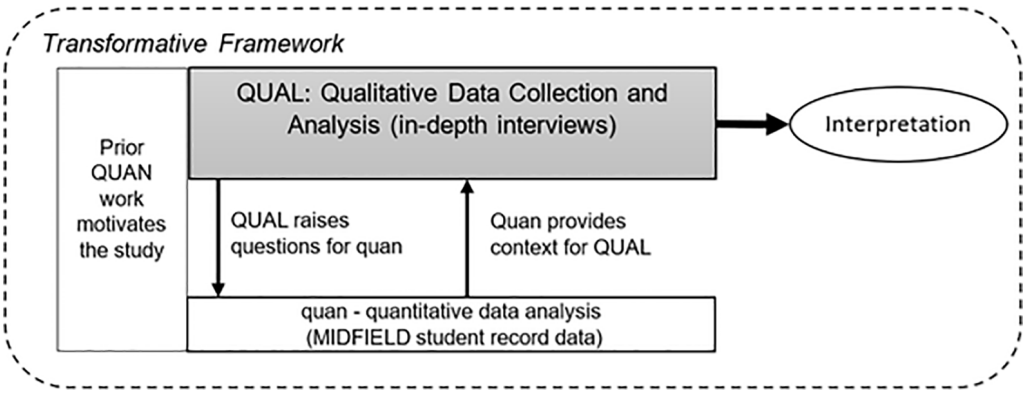

FIG. 1: Methodological framework (adapted from Creswell, 2014)

5.1.2 Data Analysis

Quantitative data was processed in the R environment (RStudio Team, 2020) using the package *midfieldr* (Layton et al., 2021) and plotted with *ggplot2* (Wickham, 2016). Records of degree-seeking undergraduate males who ever had any engineering major at PWIs that offered CPE with four years of data available in MIDFIELD were selected for analysis; this included 237,712 students of all races. Major and cumulative GPA for each of the first eight fall or spring semesters for each student were extracted and used for all analyses. This is slightly different from most MIDFIELD studies (e.g., Lord et al., 2011, 2015, 2017) but was chosen to be most consistent with the timeline of the students interviewed (who were designated as switcher or persister by their status at the time of the interview). Using these eight semesters of data, we examined four metrics, described below.

5.1.2.1 Outcomes by Race

Outcomes of persist, switch, or leave were evaluated in the eighth semester for those first-time-in-college (not transfer) students whose first degree-granting major (i.e., not including first-year or pre-engineering) was CPE. This includes students who directly matriculated into CPE, as well as those who completed a first-year or pre-engineering program and selected CPE at their first opportunity. The outcome of students who had graduated in CPE or were still enrolled in the eighth term was labeled "persist"; the outcome of students who changed majors from CPE at any point in the first eight semesters was labeled "switch"; and the outcome of students who left the institution and did not return by the eighth semester was labeled "leave." We could not interview the students who left but have included them in the quantitative analysis of outcomes.

5.1.2.2 Enrollment Counts by Semester and Major

Our analysis of enrollment by semester represents the balance of attraction, selection, and attrition of Black males in CPE and five other majors. The counts of Black males in each major include any student in the major in their given semester, regardless of whether it was their first major.

5.1.2.3 Cumulative GPAs by Semester and Race

Similar to enrollment counts, the average cumulative GPA by race includes all students enrolled in CPE in the given semester.

5.1.2.4 Pathways of Black Males who Switched from CPE

For those with outcomes of "switch," we also examined the first major students switched to after CPE. We report computer science (CS) and electrical engineering (EE) specifi-

cally. Other majors were grouped by two-digit Classification of Instructional Programs (National Center for Education Statistics, 2010), loosely based on the National Science Foundation classifications (National Science Foundation, 2018).

5.2 Qualitative Methods

Our qualitative study draws on 10 interviews with junior and senior Black men who had ever declared a CPE major at two predominantly White Research 1 institutions in MIDFIELD. Students were recruited through email by a local campus administrator. Students who volunteered for the interview were asked to provide sociodemographic information (e.g., age, parents' education) and to fill out a modified version of the NCWIT Student Experience in the Major (SEM) survey (Barker et al., 2014) prior to the interview. This survey included several items pertinent to our current investigation of CPE students, including questions about classroom practices, faculty interactions, peer interactions, sense of belonging, racism, and sexism. More details about the SEM survey and its use in this study can be found in Brawner et al. (2020). Survey results helped us to personalize the semistructured interview protocol for each interviewee, which covered many of the same topics. The protocol also included a card-sort activity wherein students identified and prioritized their reasons for choosing the CPE major (Brent et al., 2021). Interviews were held on campus during the spring and fall of 2019 and lasted from 60 to 120 minutes. Students were paid $50 for their participation.

5.2.1 Protection of Vulnerable Populations

The Clemson University Institutional Research Board approved the study, and this approval was accepted by the participants' institutions. By decoupling the recruitment email, sent by a university administrator, and the volunteer survey, filled out by willing participants, we ensured that university personnel did not know the identities of those participating in the study and that the research team did not know the members of the target population. Participants were assigned a code which was used to identify them and to connect all of their artifacts. We use pseudonyms for the study participants and obscure potentially identifying details in the findings and discussion.

5.2.2 Data Analysis, Credibility, and Validity

We used the "sort and sift: think and shift" model proposed by Maietta (2006). We read the transcripts and pre-coded them (Saldaña, 2016) by highlighting interesting passages. This "diving in" (Maietta, 2006) allowed us to become familiar with the context of each interview. After all of the transcripts had been read and quotations selected, the first author began initial structural coding of high-level concepts from the interview protocol (Saldaña, 2016), followed by successive cycles of refining the codes.

Walther et al. (2013) proposed a model for assessing the reliability and validity of interpretive research in engineering education research. This model includes

theoretical validation, procedural validation, communicative validation, pragmatic validation, and process reliability in both collecting and interpreting the data (Walther et al., 2013, pp. 640–641). We addressed process reliability by inviting all Black engineering students who had ever majored in one of the three disciplines of our overarching study (mechanical, electrical, and computer engineering) to volunteer to participate. All switchers who volunteered were interviewed, as well as representative persisters.

For the overall study, study participants fairly reflect the population of Black students in the three majors (Brawner et al., 2020). The findings are consistent with the ASA framework suggesting an analytical validity. Procedurally and communicatively, the use of the card-sort activity allowed the participants to construct both the data and its interpretation as it related to initial selection of the CPE major. The semistructured interview protocol allowed the interviewers to further explore major selection decisions, experiences in the major, and reasons for switching. Topic memos allowed the research team to highlight emerging themes and discuss them in regular meetings. Pragmatically, our findings are consistent with other literature about Black men at PWIs and Black students in engineering. Our overall process ensured reliability by: 1) having our external advisory board review our protocols and suggest revisions that would make the protocol more accurate and relevant to the population of Black men in engineering, and 2) validating the accuracy of the transcripts by listening to the recordings and making corrections.

5.3 Study Participants

We interviewed five CPE persisters and five CPE switchers at our study PWIs who were third- through fifth-year students and ranged in age from 20 to 23. The switchers had changed to computer science, computer science and math, business, and textile engineering. One of the switchers was not enrolled during the semester of the interviews and was undecided about his next major. Because most of the switchers changed their major so early in their academic careers, they refer to "ECE classes" rather than "CPE classes," since introductory courses in the curriculum are required for both electrical and computer engineers, with the curricula diverging after these students had made the switch.

5.4 Positionality

Our core research team consists of four White women with extensive experience conducting research about students who are minoritized in engineering. The first author is a White female research and evaluation consultant with research interests that include minoritized populations in higher education STEM disciplines. She did the primary qualitative data analysis, including developing the codebook, network analysis, and research memos. The second author is a White female research, evaluation, and faculty development consultant with research interests in effective teaching practices

and students who are minoritized in higher education STEM disciplines. She contributed to the data analysis and conclusions particularly related to effective pedagogical practices and their impact on the students in this study. The third author is a biracial (Black+White) graduate student in engineering and science education with research interests in using asset-based theories to analyze the experiences and outcomes of minoritized students in engineering. She conducted the quantitative analysis of the MIDFIELD data. The fourth author is a White female associate professor dually appointed in mechanical engineering and engineering and science education and serves as the advisor for the third author. Her research interests include adaptive decision making and quantitative research using MIDFIELD. She contributed to the quantitative data analysis. The fifth author is a White female professor of sociology whose research interests include minoritized students in STEM, professional identity of social scientists, and food and nutrition security. She contributed to the literature review, qualitative data analysis, and manuscript development, and is the faculty mentor from the sixth author. The sixth author is a Black, first-generation undergraduate sociology major whose lived experience most closely represents our study population. He contributed to the literature review.

The primary researchers have decades of experience studying minoritized students in engineering through both qualitative and quantitative research studies but recognize that our Whiteness, age, and socioeconomic status inherently distance us from the lived experiences of the students whom we interviewed. We sought to mitigate this by using activities, such as a card sort and identity circle, during the interviews that invited the participants to construct their own narratives (Brent et al., 2021; Mobley et al., 2019).

During the study we engaged an external advisory board which consisted of two Black women, one an associate dean for diversity and inclusion in her College of Engineering and the other an associate professor of computer science, and a Black man who is an associate professor of engineering fundamentals. They reviewed our interview protocols and annual reports and provided guidance on our process and insight into our findings. We have included a diverse pool of students on the research team, including the third and sixth authors. We have intentionally chosen to focus on the CPE major and the students' experience in it, turning a critical lens on the department, its people, and their impact on Black men's persistence and attrition.

Acknowledging Harper's (2010) achievement framework, rather than employing a deficit narrative of Black students' achievement, we focus on those attributes and behaviors that make them successful in their chosen majors.

6. FINDINGS

6.1 Quantitative Analysis: Black Males in CPE at PWIs

In this section we quantitatively illustrate the outcomes, enrollment counts, GPAs, and pathways of Black males compared to men of other races in CPE and of Black males in

CPE relative to other majors to establish context of the qualitative research and highlight the distinct outcomes that compel us to study this very specific group.

6.1.1 CPE has Higher Attrition of Black Males Compared to Males of Other Races

Black males persist through eight semesters at slightly lower rates than other race/ethnicity males and switch majors at slightly higher rates. They also leave the institution without a degree at a higher rate than most other race/ethnicities (Table 1).

6.1.2 CPE Attrition of Black Males Happens Early

Figure 2 shows the number of students at each semester in CPE compared with EE, mechanical engineering (ME), civil engineering (CVE), chemical engineering (CHE), and industrial/systems engineering (ISE) to contextualize with prior work (Lord et al., 2017). The number of CPE students decreases immediately from the first semester and continues steadily through the eighth. This pattern is different from EE, ME, and CHE, which each lose a few students initially and then gain more students until the third semester, due to a net increase in students switching in. By the fourth semester, EE, ME, and CPE are decreasing the number of students at similar rates to each other. CVE and CHE begin with fewer students and have a much lower rate of loss over eight semesters. Unlike the other majors, ISE experiences a net gain of students until the fifth semester because it is the most popular major for engineering students to switch into (Lord et al., 2017).

6.1.3 Black Males in CPE have Lower GPAs on Average than Other Men

Figure 3 shows the average cumulative GPA for each semester of men of different races in CPE. Black males have the lowest GPA on average throughout the four-year period, and while other domestic male students have an upward trend by the fifth semester, Black male students have a slight decline in their GPA starting at the fifth semester and continuing until their eighth semester.

TABLE 1: Outcomes of males in CPE by race/ethnicity

Race/ethnicity	*n*	Persist %	Switch %	Leave %
Black	615	29	40	32
Native American	63	30	38	32
Hispanic/Latinx	415	31	40	29
Other/Unknown	268	34	28	38
White	7694	34	37	29
Asian	1127	37	35	28
International	704	40	31	29

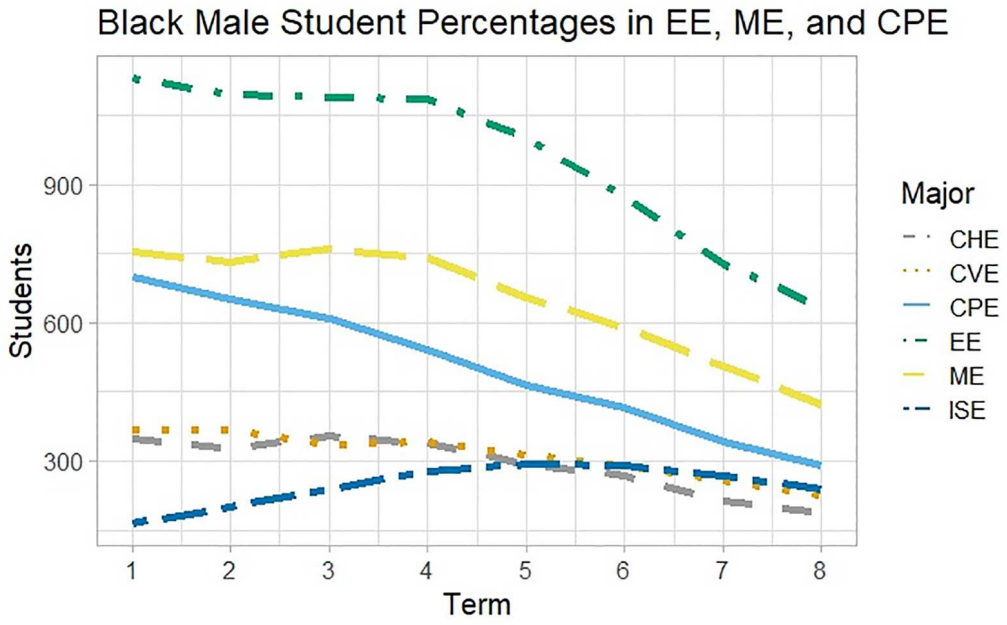

FIG. 2: Black male student count in CPE and five large engineering majors

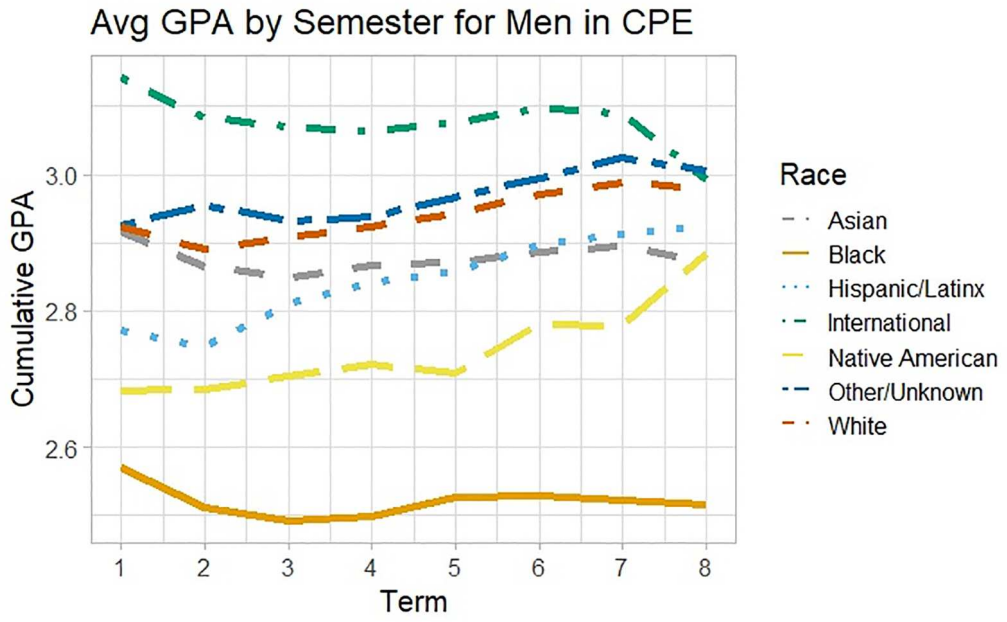

FIG. 3: Average GPA by semester for men in CPE

6.1.4 Destination Majors of Black Male Switchers from CPE

CS and EE were the most common destination majors for Black male switchers after leaving CPE (Fig. 4). "Other engineering majors" was the fourth most popular destination for Black male students who switched from CPE. This trend could indicate that students were not leaving due the workload of CPE but rather the environment or other factors that CPE perpetuated. Business was the fifth most popular destination for Black male students who switched from CPE. These results align with our qualitative findings, where two of the five switchers interviewed switched to CS from CPE, one switched to another engineering major, and one to business.

Taken together, these four metrics demonstrate that CPE is not effectively supporting and retaining Black males.

6.2 Qualitative Analysis: Findings from In-Depth Interviews

In this section we use four case summaries that illustrate the range of experiences that contributed to our 10 Black male participants either choosing to persist in CPE or switching to a different major. We identify our four students as "The Determined Persister," "The Isolated Persister," "The Happy Switcher," and "The Thoughtful Switcher." Their stories will be shared in turn below. Considering the ASA framework, we describe what attracted them to CPE, how they were selected in to CPE by the people and environment there, what factors contributed to persistence in and attrition from CPE, and where

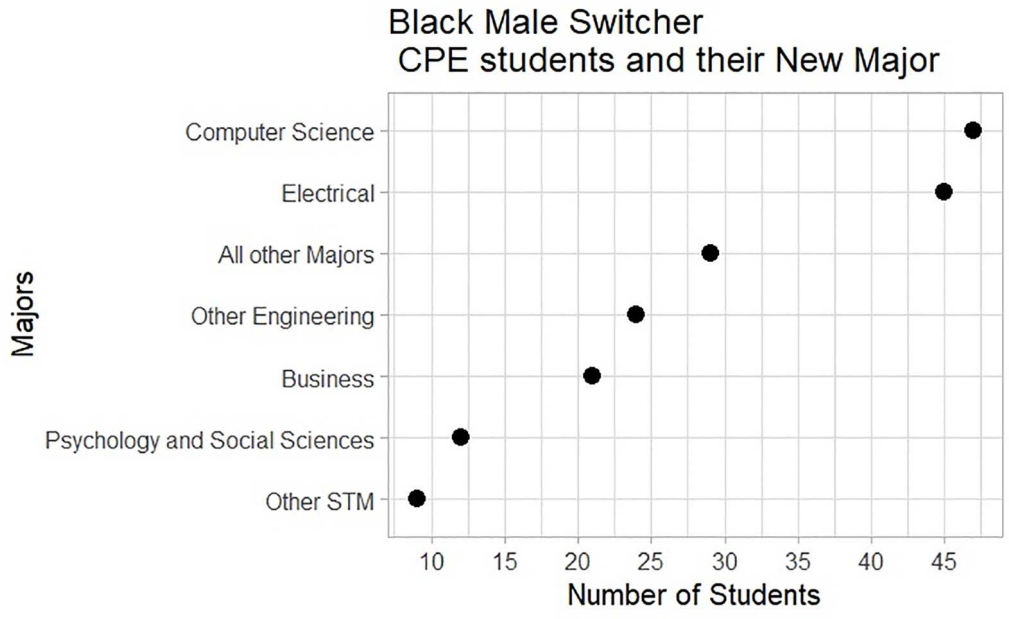

FIG. 4: Destination majors of CPE switchers ($N = 240$)

relevant, how they were selected into their new majors. Direct quotations have been modified slightly for readability and to obscure identifying details.

6.2.1 Jaden, The Determined Persister

I started off to finish the major that I had chosen.

Jaden was a fifth-year senior from a working-class immigrant family that settled in a predominantly Black suburb near his university. He attended a STEM magnet high school where the student enrollment was nearly 100% Black. For two years Jaden received a state scholarship, until his GPA fell too low to maintain it at the end of his sophomore year. He was injured at the end of his sophomore year, which made him unable to work over the summer to make up for the loss of the scholarship. He worked full time the following fall, which caused his GPA to fall "closer to a 2.0." He sought help from the academic success center on campus, which helped him with time management. They also recommended that he drop the digital systems course he was taking that semester and take it later. From there, he was able to improve his GPA by finding "jobs that worked better time-wise" and allowed him the flexibility to focus on his studies.

6.2.1.1 Jaden's Attraction to CPE

Beginning in middle school, Jaden taught himself web design, which led him to consider CS and CPE degrees because of the prospective salaries and job opportunities "which go hand in hand." He liked the problem-solving aspect of many video games, which made engineering generally appealing. However, he considers CPE problem solving "special" because of all the factors that need to be considered from an end-user perspective. As a first-year student, Jaden sought input from older students on the differences between CS and CPE, but he also had an interest in small electronic devices. He settled on CPE because

> *I did like the idea of being able to build actual devices as well as … the software that actually makes it do what it's actually doing. … That's why I chose computer engineering so I could be right in the middle. And I still enjoy being there and I feel it was the right choice because with electrical engineering I wouldn't have had as many opportunities with my time to learn the software side of things.*

Considering the aspects of both EE and CS that he found attractive, Jaden really couldn't "choose between learning hardware and learning software," so he chose computer engineering and believes he "found the best mix" for himself.

6.2.1.2 Selection of Jaden by CPE

Early experiences with the major gave Jaden a sense of belonging and excitement about the computer engineering major. During his first year, he enrolled in

a first-year seminar class for ECE majors that "was pretty cool because I got to be with other first year ECE students to learn why they were interested in the majors they had chosen." Part of the class involved hearing from upper class students and graduates about their class experiences, internships, and jobs, which helped him "feel more at ease" with his decision. By the end of his first year he "was pretty excited" about what he "was learning and could learn in electrical and computer engineering." As he continued in the curriculum, he experienced a collaborative environment where:

> *Everybody was very willing to help each other figure out concepts and problems and things like that. That studying together, that it's 2 a.m. and we're still working on this problem kind of vibe and culture was very common here and it helped people grow and matriculate together.*

As a Black man navigating a predominantly White campus, Jaden admitted to feeling like an outsider "to a certain degree" in his classes. Particularly when asked to form groups he expressed some discomfort and feeling of awkwardness "you feel somewhat othered in that sense." Over time, he navigated this discomfort by focusing "less on what race people are" and expecting people to "be decent human beings and get the project done." He realized that he is fortunate not to have "felt the direct indecency of people," and tried to use his "privilege as a man" to be "very persistent in getting the [group] goal accomplished."

In spite of being the only, or one of three Black students in a typical class of 40, Jaden felt comfortable asking questions to his professors during lectures, depending on the professor's teaching style. He noted that some of them "can be pretty boring," but "the information is still pretty cool or it's at least very important to getting to the cool stuff," so the nature of the material itself helped Jaden to persist. He considered the professors to be "on average good," and he thought that "what makes them good [is that] they're very competent in what they're doing and a lot of them in my experience are very excited to share what they know with students."

6.2.2 Randall, The Isolated Persister

> *I'm going to prove that I deserve to get this degree from here.*

Randall was a fifth-year senior from a middle-class family in a predominantly Black nearby suburb. Randall described his high school as 100% Black, where "only the cream of the crop" went to college and even fewer to a prestigious school like his, where he found the diversity to be a "huge culture shock." Randall was admitted conditionally to his college, with the requirement that he begin in the summer. He received a state scholarship and campus job that covered tuition and housing his first year. Unfortunately, his first-year grades dropped below the minimum to keep his scholarship, and a "rough couple of semesters" caused his grades to dip further to where he lost his campus job

and housing. He covered costs through loans and increasing work hours, which further impacted his GPA.

6.2.2.1 Randall's Attraction to CPE

Randall credited his high school math and physics teacher who caused him to "think about things more as an engineer instead of as a consumer." Randall wondered what sorts of jobs he could get with his love for math and physics and, as a tech-savvy person, believed that CPE was the obvious choice. The growth of the field and the potential salary would allow him to "do something you love and something that puts food on the table. For me, computer engineering was all of that."

Randall did his research on the CPE major relative to CS. He wanted "to know how computers actually work and that requires learning about hardware." His program of study did not include many opportunities for application development, but he believed that "once you know the nitty gritty, the hardcore details of computing, then all the higher-level stuff is much easier to pick up," which is why he did not feel like he "missed out on anything by not being a computer science major."

6.2.2.2 Selection of Randall by CPE

As a first-year student, Randall took an introduction to ECE, which included a hands-on design project to build and program Lego® robots. As a child he had enjoyed playing with Legos, and at the end of this course "in that moment, I sort of felt like everything I had done sort of just came full circle." However, as much as Randall loved math and physics and the prospect of being a computer engineer, he faced curricular challenges early on. He compared himself to his peers "who have been coding since they were born" and noted that he did not have that sort of experience and wished that there was "a class or something you could take if you don't really have any experience…an introductory course that assumes you know nothing."

As a man who grew up surrounded by Black people, Randall felt that he needed to fight to belong at a place where he does not "feel like everybody feels like I belong here. I don't feel like things were designed for me to belong here." He described several microaggressions, such as being mistaken on campus for a football player, but the most egregious example happened while working on a class project where Randall said:

> *I'm the only Black guy in the group, and there's a White guy in the group. A lot of times, every time I present like a new idea for … how to solve a problem, he calls it ghetto or [says], that's a really ghetto way of doing it…. It's just like being shut down like that, it's like, whoa I definitely feel like I have to prove myself. It's like almost I can tell he doesn't think I'm a smart person.*

Randall revealed this story after discussing "subtle racism" on campus and being asked to provide an illustration. He said that he chose to put up with this behavior rather than

calling out the other student or reporting the situation to the professor because he believed that in the workforce he will "have to learn how to work with those kinds of people." He remarked that if he had been with a group of Black people he would have felt "empowered" to retaliate, but "to look around and be the only Black person in a group, and pretty much the only Black person in the whole class, it's like I don't even feel like I have a voice."

While some fellow students overtly challenged Randall's belonging in CPE, he also noted that CPE "probably has the professors that are probably the worst at making students feel passionate about the material." Not only did Randall find most lectures to be boring, but he felt like he had "only met a couple of professors" who "genuinely care" about him. He believed that "professors are focused on research and money, class is secondary," and that students with "an exceptional level of struggles are certainly secondary amongst that." This was manifested by his perception that some professors would try to rush him out of their offices when he went to ask questions during office hours. There were exceptions, of course, like his favorite professor who encouraged students to work out problems on the board in front of the class. Randall would always "be the one to voluntarily go to the board because I'm guaranteed to learn that way." Unfortunately, with a few exceptions, Randall did not expect his professors to be motivating and described his "standards as being pretty low as far as a professor being amazing."

6.2.3 Ray, The Happy Switcher

> *That extra year I tacked on to my graduation is well worth the 30, 40, 50 years of happiness that I'll gain throughout the rest of my life.*

Ray was a fourth-year junior who switched from CPE to business during his third year. He attended a brand new predominantly Black technical high school. Ray was conditionally admitted to his university as a summer freshman, which he considered to be a great way to acclimate to campus. Ray received a prestigious foundation scholarship which paid for all of his college expenses. As a result, he worried less about how to pay for school and focused instead on what he wanted to do with his life. Ray was very close to his father, whose passing led to a difficult semester, after which he retroactively withdrew for poor grades. The withdrawal put him behind with respect to satisfactory academic progress and put his scholarship at risk, which he had successfully reinstated. The following year, Ray experienced a severe crisis that nearly caused him to fail to make satisfactory academic progress again, which would have again put his scholarship at risk. He ultimately finished the semester so he did not need to take another semester of incompletes, and his business professors waived some assignments so that he only needed to retake one course.

6.2.3.1 Ray's Attraction to CPE

Ray had always loved computers and technology, so much so that every time he was around technology he thought, "Oh my goodness, I want to do this major and that

seems like a great career." Being able to get paid to do what he loved was quite attractive to him. His father and extended family, which includes several engineers, also influenced his choice. He loved helping people, and as a teenager he assisted friends and family in troubleshooting computer and phone problems. Ray's high school classes allowed him to gain experience in manufacturing, robotics, and computer networking. Considering his interests, he decided that, "Computer engineering is right up my alley," when he was applying to college. As a college student, he took a job in the campus instructional technology office in order to continue to help people solve their technology problems.

6.2.3.2 Selection of Ray by CPE

Ray "loved the first couple of actual classes" when he began his college career. His first engineering class was a hands-on digital design class that reminded him of his manufacturing and engineering classes in high school. He also took a special topics course which he described as "basically senior design for sophomores," which included a lot of hands-on activities. These two "saviour classes…almost kept me doing computer engineering." He described those two classes as "what I came here for" and the teachers as being very encouraging, particularly when compared to the other classes and teachers he encountered later.

6.2.3.3 Ray's Attrition from CPE

While Ray had extremely positive early experiences in the ECE department, he struggled in the prerequisite calculus and physics classes. He passed Calculus 1 on the third attempt and never passed physics; he found himself "just kinda' drowning. It was just the vicious cycle and I kept on going 'cause I was like 'I can't be that guy who switches from computer engineering to business.' What will my family think?" His enjoyment of the hands-on classes made him continue and take digital systems, "a known weed-out class." However, he hated going to this class. In spite of the professor being "nice as all get out," the class was not what he "thought computer engineering was." After the second attempt, he decided that the class "did what it was supposed to do. It weeded me out."

In addition to facing academic difficulty, Ray found the "dog-eat-dog world" of ECE to be so competitive that people were not willing to help each other, which contributed to his feeling of not belonging there. He never made friends in CPE. He described how with the ECE upperclassmen "you'll just see this light bulb kind just die inside of them," and he did not want that for himself.

Ray's decision to switch majors was also impacted by his father's death. His father had been particularly supportive of his decision to major in CPE. Although the choice of CPE "felt right at the time," Ray had a chance to reflect on what he really wanted to do in life and decided that even though he loved computers and his job at the instructional technology office, he no longer wanted to pursue computer engineering as a career.

6.2.3.4 Selection of Ray by Business

Ray's interest in business came during his summer freshman experience when he took microeconomics. He then took macroeconomics as a free elective while still a CPE major. He said, "Those classes were fun, I loved going to them. They weren't easy, but they were definitely something that I was motivated to put the time into." He got A's in both of them and decided, "If this is how business is, I love that." Compared to the highly competitive environment in CPE, he described business as much more collegial and collaborative. "It's a positive-sum game instead of a zero-sum game. If I win, you can win as well. You don't have to get put down in the dirt for me to get risen." Similarly, he believed that business professors "really care" and "have a passion for teaching" compared with ECE professors who do "the side gig of teaching because they have to." He found that the way business classes were taught, which encouraged active and open discussion, was far more appealing than CPE lectures, where "It's a lot more talking at you." He also found it more comfortable as a Black man in business where "there are other Black people in my class and I've never felt like 'Oh, we have to answer for everyone,'" which he found "refreshing."

6.2.4 James, The Thoughtful Switcher

> *I felt like I made a mature decision to follow the thing that is interesting to me and not just giving into pressure from people to do what they expect me to do.*

James was a junior who switched from CPE to CS before his sophomore year and added a double major in math before his junior year. James was valedictorian of his high school class, which, though predominantly White, had a substantial population of Hispanic and Black students. He was one of few Black students in his advanced placement (AP) classes, though. Both of his parents served in the military, which afforded him a scholarship that he could use at the college of his choice. He accepted admission to a prestigious private school, yet he continued to agonize over his decision to attend due to the loans he would need to take to finance the balance of his education. As he reflected, he realized that the decision to attend that university with the added financial burden would not serve him well because he is a "very debt averse person." That summer, he explained his thinking to his current university and had his admission reinstated.

6.2.4.1 James' Attraction to CPE

James cited problem solving and possibility for invention as the top two reasons for choosing a CPE major. As a child, he was inspired by the animated *Dexter's Laboratory*, and *Jimmy Neutron*, where the protagonists were boy geniuses who "were not only ideating but also creating, going from idea to implementation…on a very quick timescale." In high school he participated in Science Olympiad on an electric car team, which allowed him to work with low-level electronics and program Arduinos® by reusing and

changing existing code. This experience influenced his selection of CPE because "The only thing I had any exposure to at that point [that] would've been relevant to choosing engineering was really just electronics-related stuff. So I was thinking electrical or computer engineering has to be the thing I should do."

6.2.4.2 Selection of James by CPE

James entered university as an undecided engineering student. Because of his AP credits, he was able to take the first introduction to ECE, which is typically a second-semester course, during his first semester. At the end of the semester, he declared the CPE major. The next semester he took the next ECE course, which emphasized C programming and fundamental data structures. He was "fascinated by the theory of it" and how to program efficiently.

6.2.4.3 James' Attrition from CPE

During his second semester, James also took Introduction to Circuits. He enjoyed solving circuit problems but found the practical applications "dry." Because the subject matter no longer resonated with him, he began to question whether he should continue in the major and whether it was right for him. He was doing well and was advised by friends to stick with it, yet he asked himself: "Is this serving me? Is this getting me where I want to go?" He struggled to answer these questions because he "didn't have a very informed perspective of what the curriculum was offering [or] enough knowledge conceptually of either area to really know which one I had more affinity for." James reached out to his computer systems professor who advised him to look at the curricula for both CS and CPE side by side and think about the classes he "would regret not being able to take." He found it easier to make decisions when viewed "from a regret minimization perspective" and ultimately decided that CS was what he wanted to do.

6.2.4.4 Selection of James by Computer Science and Math

That summer, James took Introduction to Java online, which "felt very natural. It felt like there was an alignment between my interest and also maybe somewhat of my aptitude…which is a really good feeling." He changed his major to CS after taking that class.

A high school experience with an exceptionally talented math student made James believe that he should not major in math. James' introspection through his first two years of college made him realize that he does not "have to be a great mathematician to be a worthy human being." Near the end of his sophomore year, he approached a math advisor and found that due to the overlap of courses in the math and CS curricula, he would not need extra time to graduate with a double major. He loved the math department because it is small and "the faculty really seem to care." As a student, he was initially "very uncertain" of his ability to do the work, but as he progressed, he felt like his "world is

expanding." He also found that his improved mathematical reasoning skills "translate to programming really well."

James' felt "pretty on top of my stuff when it comes to conceptual stuff," so his sense of belonging was related to his ability to do the technical aspects of the work rather than the people in the majors. "A proof is a proof…it doesn't matter if you're Black or White." He did not feel like he belonged in CPE because it "is not the subject that I'm really most interested in" but had little to do with the people there.

7. DISCUSSION AND IMPLICATIONS

In this study we have examined the factors that motivated Black male students to major in computer engineering (attraction), those that led to their being admitted to the department or not (selection), and those that influenced their decision to persist in CPE or to switch to another department (attrition). In particular, we sought to better understand the overrepresentation of Black men who initially choose to major in CPE and their subsequent underrepresentation in terms of graduation outcomes as noted by Lord et al. (2011, 2015). In this section we return to our original research question, "What does the CPE major do to attract and retain Black men or cause them to leave?" to summarize our findings.

As we have operationalized attraction to CPE, for Black male students their choice of the major was related to precollege factors including a STEM-focused high school curriculum, the influence of a high school teacher, competency in math and science, extracurricular experiences such as Science Olympiad, and family expectations. The same factors have been found in other studies of choice of major (Harper, 2012; Thiry and Weston, 2019). The students' initial decision is therefore based on factors essentially out of the control of the departments that offer the computer engineering major.

7.1 Sense of Belonging

Our interviewees were all Black male students at a PWI, and most of them reported a sense of being isolated. Randall, the isolated persister, felt overwhelmed by his almost entirely White classmates, who had much more experience than he had with computers and programming, disparaged his intelligence, subjected him to microaggressions, and one of them labeled things he said as "ghetto." He said, "I don't feel like things were designed for me to belong here," echoing Fries-Britt and Turner (2002). He contemplated switching to computer science but decided that CPE came closer to matching his interests and stayed in it. Jaden liked his peers, found them helpful, and stayed in the major. On the other hand, Ray found his peers in business friendly and helpful but not those in engineering, and he chose to leave CPE.

Both of our study campuses offer formal support programs for Black students, especially in the first year, but none of the 10 male CPE majors we interviewed took part in them. They knew about them and sometimes suggested that they wished they had been a part of them or that they knew other people who had taken advantage of them. Some

even took advantage of them vicariously due to beginning in the summer when those programs were offered, forming friendships with participants.

Students reported low levels of institutional support once they were no longer in the general education and first-year engineering classes. This finding has several implications for ECE departments. First, departments should look critically at what is available to all students but specifically Black males to help support them academically in the gateway courses that students perceive as difficult.

Peer mentoring programs have been shown to positively affect student engineering identity and retention (Huizing, 2012; Zhu et al., 2020), but most take place only in the first year and are not specific to departments. Adding such programs at the department level could go a long way toward improving students' academic performance and satisfaction in their departments by reducing isolation and building community as well as coaching academic performance.

Professors and advisors should conference with their students at regular intervals, attempt to become aware of and discourage racial disparagement and microaggressions, make sure they are neither ignoring Black students nor singling them out excessively in class. If a course has students with strong backgrounds in the course subject and other students with little or no experience (for example, a first-year or second-year course in computer science or computer engineering), the institution should consider Randall's suggestion and create an introductory course or series of seminars that level the playing field for novice students, as has been recommended by Achenbach et al. (2018) for women and other underrepresented students in CS. Jaden participated in a first-year seminar program that he credits with influencing his decision to persist in CPE, even though he reported feeling like an outsider in his classes.

7.2 Students' Understanding of the Field They are Preparing to Enter

A factor that set the persisters apart from the switchers in our study was that, at the time of choosing a major, the persisters generally had a much better understanding of what computer engineering entails. Switchers, on the other hand, liked computers and technology, which made computer engineering seem like a logical choice to them, but they did not fully understand what computer engineering involves, which is common for switchers from engineering disciplines (Thiry and Weston, 2019).

Colleges of engineering with first-year courses that give students information about all of the engineering disciplines and hands-on experiences with several disciplines may help to alleviate this problem since students have an opportunity to explore disciplines before committing to a specific major. All four students had inviting hands-on experiences in their first year, but the content and difficulty of the first foundational course caused three of them to struggle and the fourth to reconsider his major. Programs should consider what makes first-year courses successful in getting students excited about the major and consider including such elements in the foundational courses. Programs should also make a point of including information about computer science when it is not housed with engineering. In the absence of first-year courses, advisors should talk with

incoming students about their expectations for the major and why they chose it so that they can give guidance to students who may have misconceptions about the discipline.

7.3 Relationships with Professors

All of the students interviewed, including the four described in this paper, talked either positively or negatively about their relationship with their course instructors. Randall reported meeting only a couple of professors who seemed to care about their students, experiencing professors who tried to rush him out of their offices during office hours, and none who talked with him outside class or engaged him in research. Ray sensed that his ECE professors saw teaching as a "side gig" to their research while business professors had a passion for teaching, and he ended up switching to business.

To convey a sense of caring, a key for professors would be talking to students outside of class, and more importantly, listening to them, as the circuits professor did for James. Engaging them in hands-on course-related activities in class rather than lecturing nonstop has also been found to convey a sense of caring. Rainey et al. (2019) concluded that active learning environments better communicated teacher caring to students and enhanced students' desire to continue in the discipline. They found this effect to be higher for underrepresented minorities than students in the majority.

7.4 Quality of Teaching

In a sequel to the landmark study, *Talking about Leaving* (Seymour and Hewitt, 1997), Hunter (2019) found that both persisters (72%) and switchers (96%) described poor teaching and other problems with instructor pedagogy (p. 93). In our study, students reported that the teaching in their CPE classrooms was primarily lecture-based, and many faculty did not seem to care about them or their learning. This finding echoes Rainey and colleague's research (2019) that reported on the same complaints from students in STEM classes.

An open secret in STEM curricula is that certain courses are designed and taught in such a way to cause students to face significant challenges and many people to switch majors because of the experience (Weston et al., 2019). Courses such as the required calculus sequence for engineers, introductory engineering courses, and introductory computer science courses fall into this category. Weston et al. (2019) identify seven characteristics of weed-out courses: 1) assessments misaligned with content and understanding; 2) heavy volume and pace; 3) level too high/abstract for an intro class; 4) rote learning/lectures; 5) teacher indifference; 6) poor explanations of content; and 7) competitive class culture (p. 201). Randall and Ray, in particular, mentioned all seven of these factors in the context of the initial required foundational course in ECE. They took these courses after becoming excited about the major in early courses that included significant hands-on opportunities and extensive interactions with the professors and other students. While the major was inviting early on, it soon made the students less excited. Randall specifically mentioned his perception that the required foundation class

was taught as though he was expected to already know the material. Ray found the class environment too competitive and overwhelmingly difficult. Jaden withdrew from the class and retook it at a time where he would be able to focus on the content more easily, highlighting the importance of effective advising in helping to retain students in the major. Weston et al. (2019) consider the difficulties that students experience in the courses to be instructor created rather than simply due to conceptual difficulty per sé.

Departments seeking to improve outcomes for Black men should attend to instructors' pedagogical choices, particularly in the gateway courses where students are more likely to encounter challenges. Theobald and colleagues (2020) provide guidance in their meta-analysis of active learning studies. Active learning is an evidence-based teaching approach that engages students in content-related tasks individually or in small groups during class (Felder and Brent, 2016; Hernández-de-Menéndez et al., 2019). In their meta-analysis, Theobald et al. found that "on average, active learning reduced achievement gaps in examination scores by 33% and narrowed gaps in passing rates by 45%" (Theobald et al., 2020, p. 6476). The highest levels of improvement were achieved by using active learning with deliberate practice (challenging tasks, emphasis on deficit skills or knowledge, immediate feedback, and repetition) and inclusive teaching practices (treating students with dignity and respect, showing genuine interest in the students, and communicating confidence in their ability to meet high standards).

Tanner (2013) offers 21 specific strategies that can be helpful in developing equitable classrooms. While she does not label these strategies as culturally responsive pedagogy, they are, in fact, congruent with descriptions by Howard and Terry (2011) and Samuels (2018), noted previously. Tanner describes the strategies specifically for biology instruction, but they apply equally well to all STEM classrooms. The strategies fall into five categories:

- Giving students opportunities to think and talk about course content (e.g., wait time after asking questions, think-pair-share, reflective writing);
- Encouraging, demanding, and actively managing the participation of *all* students (e.g., random calling using popsicle stick or index cards, whip around, calling on random student to report out on group work);
- Building an inclusive and fair classroom environment for *all* students (e.g., learning and using student names, integrating culturally diverse examples, using active learning strategies);
- Monitoring behavior to cultivate divergent thinking (e.g., asking open-ended questions, establish classroom community norms);
- Teaching *all* of the students (e.g., make connections with all students with the goal of establishing good relationships, collect assessment evidence).

While active environments and inclusive teaching can lead to higher performance and satisfaction, care should be taken when assigning group work outside of class. Black students and other students who are in a minority in their discipline can face isolation and microaggressions in group interactions. It is essential to follow best practices for teamwork such as assigning instructor-formed groups, making sure students from

minority populations are not outnumbered in groups, and providing team training and coaching to students so they are aware of expectations about group communication and roles (Felder and Brent, 2016, Chapter 11).

8. LIMITATIONS

Our quantitative analysis (Table 1) shows that nearly a third of Black men who declare a CPE major leave their institution by the eighth semester. Unfortunately, this population, about whom little is known as it relates to CPE, was unavailable to us to be interviewed and is a limitation to our conclusions regarding the factors that cause attrition from CPE. While certainly some faced academic challenges, which may be similar to those described above and addressed similarly, others may have left for financial, physical or mental health, or other reasons.

As a qualitative study, these results are not necessarily generalizable to the whole population of Black men who ever majored in CPE at predominantly White research 1 institutions; however, they fairly represent the range of experiences that we found among our 10 participants. While we believe that many of the experiences of Black men as they relate to curriculum, classroom practices, professor relationships, and instructional quality may be similar for some men of other ethnicities or women, they were not the focus of this study.

9. FURTHER RESEARCH

It is out of scope for this paper to discuss the impact of how these students paid for their educations, but our findings align in some ways with Harper's (2012) findings that academically successful Black men do not worry about finding full-time work or using loans. The loss of their state scholarships put Jaden and Randall in substantial academic peril, peril that would cause many students to leave school entirely, although they persevered. Ray had similar financial and academic challenges, but his scholarship was more forgiving as it related to GPA. In light of the recent public discourse around student loan forgiveness, further research should examine how financial aid policies impact persistence, particularly for Black men in engineering.

Several of the 10 students were U.S.-born of immigrant parents, including Jaden and Ray. The impact of family expectations on these students' decisions was substantial and intertwined with their immigrant culture. It is an exploration worthy of further research.

10. CONCLUSION

Our mixed-methods study of Black men in CPE attending PWIs has highlighted the factors that contribute to both success and attrition of students in the major. The ASA framework has helped us clarify the role of institutional policies and practices in shaping student decisions regarding whether to remain in CPE. The quantitative results indicate that CPE experiences the highest attrition of Black males, compared to males of other

races, and that this attrition happens early in these students' academic careers. Additionally, the qualitative data revealed that our interviewees experienced a sense of isolation in their major, with several also experiencing poor teaching and receiving poor advising from faculty. More intentional advising, accurate information about the content of the CPE major, and more inclusive teaching practices would help to improve the experiences of Black male CPE students attending PWIs.

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REFERENCES

Achenbach, G., Barker, L. J., & Thompson, L. (2018). A systemic approach to recruiting and retaining women in undergraduate computing. CoNECD - The Collaborative Network for Engineering and Computing. Crystal City, VA. Retrieved from https://peer.asee.org/29502.

American Society for Engineering Education. (2020). Engineering and Engineering Technology by the numbers. American Society for Engineering Education. Retrieved from https://ira.asee.org/wp-content/uploads/2019/07/2018-Engineering-by-Numbers-Engineering-Statistics-UPDATED-15-July-2019.pdf.

Astin, A. W. (1993). *What matters in college? Four critical years revisited*. San Francisco, CA: Jossey-Bass.

Atwaters, S. Y., Leonard, J. D., & Pearson, Jr., W. (2015). Beyond the Black-White minority experience: Undergraduate engineering trends among African Americans. In J. B. Slaughter, Y. Tao, & W. Pearson, Jr. (Eds.), *Changing the face of engineering: The African American experience* (pp. 149–188). Johns Hopkins University Press.

Avery-Desmarais, S. L., Revell, S. M., & McCurry, M. K. (2021). A theoretical framework to promote minority PhD and DNP student success in nursing education. *Journal of Professional Nursing*, 37(6), 1149–1153. DOI: 10.1016/j.profnurs.2021.10.002

Barker, L., Hovey, C. L., & Thompson, L. D. (2014). Results of a large-scale, multi-institutional study of undergraduate retention in computing. *Proceedings of the IEEE/ASEE Frontiers in Education Annual Conference*. Madrid, Spain. DOI: 10.1109/FIE.2014.7044267

Brawner, C. E., Orr, M. K., Brent, R., & Mobley, C. (2020). Experiences of Black persisters and switchers in electrical, computer, and mechanical engineering departments in the USA. *Proceedings of the IEEE/ASEE Frontiers in Education Conference*, (pp. 1–9). Uppsala, Sweden. DOI: 10.1109/FIE44824.2020.9273823

Brent, R., Orr, M., Brawner, C. E., & Mobley, C. (2021). Who tells your story? A card-sort activity for eliciting authentic narratives. *International Journal of Qualitative Methods*, 20, 1–11. DOI: 10.1177/16094169211053104

Chatman, J. A., Wong, E. M., & Joyce, C. (2008). When do people make the place? Considering the interactionist foundations of the attraction-selection-attrition model. In D. B. Smith (Ed.), *The people make the place: Dynamic linkages between individuals and organizations* (pp. 63–86). Lawrence Erlbaum Associates.

Chen, X. (2013). STEM attrition: College students' paths into and out of STEM fields (NCES 2014-001). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Retrieved from https://nces.ed.gov/pubs2014/2014001rev.pdf.

Cottle, P. (2022). The pipeline to math-intensive STEM careers for Florida's Black students is a rough ride. Bridge to Tomorrow: Retrieved from https://bridgetotomorrow.wordpress.com/2022/11/19/the-pipeline-to-math-intensive-stem-careers-for-floridas-black-students-is-a-rough-ride/.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage Publishing.

Emekalam, A. (2019). Reducing attrition from STEM disciplines: Understanding the student athlete's perspective. *Peer Review*, 21(1-2), 34–38.

Felder, R. M., & Brent, R. (2016). *Teaching and learning STEM: A practical guide*. San Francisco, CA: Jossey-Bass.

Fries-Britt, S., & Turner, B. (2002). Uneven stories: Successful Black collegians at a Black and a White campus. *The Review of Higher Education*, 25(3), 315–330. DOI: 10.1353/rhe.2002.0012

Godfrey, E. (2007). Cultures within cultures: Welcoming or unwelcoming for women? *Proceedings of the 2007 ASEE Annual Conference*. Honolulu, HI. DOI: 10.1002/j.2168-9830-2010.tb01038.x

Godfrey, E., & Parker, L. (2010). Mapping the cultural landscape in engineering education. *Journal of Engineering Education*, 99(1), 5–22.

Harper, S. (2010). An anti-deficit achievement framework for research on students of color in STEM. *New Directions for Institutional Research*, 148, 63–74. DOI: 10.1002/ir.362

Harper, S. R. (2012). Black male student success in higher education: A report from the National Black Male College Achievement Study. University of Pennsylvania, Center for the Study of Race and Equity in Education.

Harper, S. R. (2013). Am I my brother's teacher? Black undergraduates, racial socialization, and peer pedagogies in predominantly White postsecondary contexts. *Review of Research in Education*, 37, 183–211. DOI: 10.3102/0091732X12471300

Hatfield, N., Brown, N., & Topaz, C. M. (2022). Do introductory courses disproportionately drive minoritized students out of STEM pathways? *PNAS Nexus*, 1, 1–10. DOI: 10.1093/pnasnexus/pgac167

Hernández-de-Menéndez, M., Vallejo Guevara, A., Tudón Martínez, J. C., Hernández Alcántara, D., & Moralez-Menendez, R. (2019). Active learning in engineering education. A review of fundamentals, best practices and experiences. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 13, 909–922. DOI: 10.1007/s12008-019-00557-8

Hoffman, D. F. (2020). Institutional and major persistence among first-generation engineering students in a first-year program: A grounded theory study (Publication No. 27834965) [Doctoral dissertation, Kansas State University]. ProQuest Dissertations and Theses Global.

Howard, T., & Terry, C. L. (2011). Culturally responsive pedagogy for African American students: Promising programs and practices for enhanced academic performance. *Teaching Education*, 22(4), 345–362. DOI: 10.1080/10476210.2011.608424

Huizing, R. L. (2012). Mentoring together: A literature review of group mentoring. *Mentoring & Tutoring: Partnership in Learning*, 20, 27. DOI: 55.10.1080/13611267.2012.645599

Hunter, A.-B. (2019). Why undergraduates leave STEM majors: Changes over the last two decades. In E. Seymour, & A.-B. Hunter (Eds.), *Talking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education* (pp. 87–114). Springer. DOI: 10.1007/978-3-030-25304-2

Kellam, N., Babcock, A., & Gattie, D. (2009). The engineering learning environment and its role in the attraction and retention of women in engineering programs. *ASEE Southeast Section Conference*. Marietta, GA. Retrieved from https://sites.asee.org/se/wp-content/uploads/sites/56/2021/05/2009ASEESE126.pdf.

Lane, T. B., Gaines, J. E., Willis, S., Ahmad, S., Morgan, K. L., & Vomvoridi-Ivanovich, E. (2019). Culturally responsive pedagogy in an engineering summer intervention program (Research). *Proceedings of the American Society for Engineering Education Annual Conference*. Tampa, FL. DOI: 10.18260/1-2--32573

Layton, R., Long, R., & Ohland, M. (2021). *midfieldr: Tools for studying MIDFIELD student unit record data in R. R package version 1*. Retrieved from https://github.com/MIDFIELDR/midfield.

Lee, J. A. (2018). Affirmation, support, and advocacy: Critical race theory and academic advising. *NACADA Journal*, 38(1), 77–87. DOI: 10.12930/NACADA-17-028

Leonard, J., Atwaters, S., Leggon, C., Pearson, J. W., & Gaines, M. (2013). Blacks, historical disadvantage, and engineering education: Lessons learned from the United States of America. *South African Society for Engineering Education Biennial Meeting Conference Proceedings*. Cape Town, South Africa.

Lord, S. M., Layton, R. A., & Ohland, M. W. (2011). Trajectories of electrical and computer engineering students by race and gender. *IEEE Transactions on Education*, 54(4), 610–618.

Lord, S. M., Layton, R. A., & Ohland, M. W. (2015). Multi-institution study of student demographics and outcomes in electrical and computer engineering in the U.S.A. *IEEE Transactions on Education*, 58(3), 141–150. DOI: 10.1109/TE.2014.2344622

Lord, S. M., Ohland, M. W., & Layton, R. A. (2017). Comparing student outcomes for women and men in electrical engineering to civil, chemical, industrial and mechanical engineering in the USA. *2017 27th EAEEIE Annual Conference*. DOI: 10.1109/EAEEIE.2017.8768663

Lord, S. M., Ohland, M. W., Layton, R. A., & Camacho, M. M. (2018). "Not all those who wander are lost." Examining outcomes for migrating engineering students using ecosystem metrics. *Proceedings, IEEE Frontiers in Education Conference* (pp. 1–5). DOI: 10.1109/FIE.2018.8658685

Lord, S. M., Ohland, M. W., Layton, R. A., & Camacho, M. M. (2019). Beyond pipeline and pathways: Ecosystem metrics. *Journal of Engineering Education*, 108(1), 32–56. DOI: 10.1002/jee.20250

Maietta, R. C. (2006). State of the art: Integrating software with qualitative analysis. In L. Curry, R. Shield, & T. Wetle (Eds.), *Improving aging and public health research: Qualitative and mixed methods* (pp. 117–139). American Public Health Association and the Gerontological Society of America.

Martin, B. A. (2021). An investigation of engineering majors: Graduates' enrollment timelines and first-year students' perceptions and exploration (Publication No. 28769538) [Doctoral dissertation, Clemson University]. ProQuest Dissertations Publishing.

McGee, E., & Martin, D. B. (2011). "You would not believe what I have to go through to prove my intellectual value!" Stereotype management among academically successful Black mathematics and engineering students. *American Educational Research Journal*, 48(6), 1347–1389. DOI: 10.3102-0002831211423972

McIntyre, B. B., Verdin, D., Baker, R. A., Godwin, A., & Milton, T. (2018). Uncovering latent diversity: Steps towards understanding "what counts" and "who belongs" in engineering culture. *Proceedings of the 2018 ASEE Annual Conference*. Salt Lake City, UT. DOI: 10.18260/1-2--31164

Mobley, C., Brawner, C. E., Lord, S. M., Main, J. B., & Camacho, M. M. (2019). Digging deeper: Qualitative research methods for eliciting narratives and counter-narratives from student veterans. *International Journal of Qualitative Studies in Education*. DOI: 10.1080/09518398.2019.1659440

Moore, J. L., Madison-Colmore, O., & Smith, D. M. (2003). The prove-them-wrong syndrome: Voices from unheard African-American males in engineering disciplines. *The Journal of Men's Studies*, 12(1), 61–73. DOI: 10.3149/jms.1201.61

Mu, L., & Fosnacht, K. (2019). Effective advising: How academic advising influences student learning outcomes in different institutional contexts. *The Review of Higher Education*, 42(4), 1283–1307.

Museus, S. D., & Ravello, J. N. (2010). Characteristics of academic advising that contribute to racial and ethnic minority student success at predominantly White institutions. *NACADA Journal*, 30(1), 47–58. DOI: 10.12930/0271-9517-30.1.47

National Center for Education Statistics. (2010). CIP: The Classification of Instructional Programs. Retrieved from https://nces.ed.gov/ipeds/cipcode.

National Science Foundation. (2018). Science and Engineering Degrees, by Race and Ethnicity of Recipients: 2008–2018. Retrieved May 25, 2022, from Table A-1. Classification of fields of study. Retrieved from https://ncsesdata.nsf.gov/sere/2018/html/sere18-dt-taba001.html.

Ohland, M. W., Brawner, C. E., Camacho, M. M., Long, R. A., Lord, S. M., & Wasburn, M. H. (2011). Race, gender, and measures of success in engineering education. *Journal of Engineering Education*, 100(2), 225–252. DOI: 10.1002/j.2168-9830.2011.tb00012.x

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2019). A descriptive study of race and gender differences in how instructional style and perceived professor care influence decisions

to major in STEM. *International Journal of STEM Education*, 6(6). DOI: 10.1186/s40594-019-0159-2

Riegle-Crumb, C., King, B., & Irizarry, Y. (2019). Does STEM stand out? Examining racial/ethnic gaps in persistence across postsecondary fields. *Educational Researcher*, 48(3), 133–144. DOI: 10.3102/0013189X19831006

Rozhenkova, V., Sato, B. K., & Buswell, N. T. (2022). "My blood is boiling when I think about advising": The role of academic advising in STEM student retention. *Journal of College Student Retention: Research, Theory & Practice*. DOI: 10.1177/15210251221084122

RStudio Team. (2020). RStudio: Integrated development for R. Boston, MA. Retrieved from http://www.rstudio.com/.

Saldaña, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). Sage Publishing.

Samuels, A. J. (2018). Exploring culturally responsive pedagogy: Teachers' perspectives on fostering equitable and inclusive classrooms. *SRATE Journal*, 27(1), 22–30.

Schneider, B. (1987). The people make the place. *Personnel Psychology*, 40(3), 437–453. DOI: 10.1111/j.1744-6571.1987.tb.00609.x

Schneider, B., Smith, D. B., & Goldstein, H. W. (2000). *Attraction-selection-attrition: Toward a person-environment psychology of organizations.* Lawrence Erlbaum Associates Publishers.

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Shehab, R. L., Murphy, T., Davidson, J., Foor, C., Rhoads, T. R., Trytten, D., & Walden, S. (2007). Academic struggles and strategies: How minority students persist. *Proceedings of the 2007 American Society for Engineering Education Annual Conference*. Honolulu, HI.

Strayhorn, T. L., Long, L. L., Kitchen, J. A., Williams, M. S., & Stentz, M. E. (2013). Academic and social barriers to Black and Latino male collegians' success in engineering and related STEM fields. *Proceedings of the 2013 American Society for Engineering Education Annual Conference*. Atlanta, GA. DOI: 10.18260/1-2-19146

Tanner, K. D. (2013). Structure matters: Twenty-one teaching strategies to promote student engagement and cultivate classroom equity. *CBE–Life Sciences Education*, 12(3), 322–331. DOI: 10.1187/cbe.13-06-0115

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, N., Behling, S., Chambwe, N., Cintron, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, II, L., Jorde, H., Keller, M., Lacey, M. E., Littlefield, C. E., Lowe, A., & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, 117(12), 6476–6483. DOI: 10.1073/pnas.1916903117

Thiry, H., & Weston, T. J. (2019). Choosing STEM majors. In E. Seymour, & A.-B. Hunter (Eds.), *Talking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education* (pp. 115–135). Springer. DOI: 10.1007/978-3-030-25304-2

Walther, J., Sochacka, N. W., & Kellam, N. N. (2013). Quality in interpretive engineering education research: Reflections on an example study. *Journal of Engineering Education*, 102(4), 626–659. DOI: 10.1002/jee.20029

Weston, T. J., Seymour, E., Koch, A. K., & Drake, B. M. (2019). Weed-out classes and their consequences. In E. Seymour, & A.-B. Hunter (Eds.), *Talking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education* (pp. 197–243). Springer. DOI: 10.1007/978-3-030-25304-2

Wickham, H. (2016). *Ggplot2: Elegant graphics for data analysis* (2nd ed.). Springer International.

Zegarra, M. (2019). The importance of academic advising. Retrieved from https://www.fnu.edu/importance-academic-advising/.

Zhu, L., Garganus, J., Eggleton, C., Topoleski, L. D., Ma, R., & Madan, D. (2020). Identifying NSF S-STEM-sponsored program activities that have a positive impact on mechanical engineering S-STEM scholars. *Proceedings of the ASEE Annual Conference*. Virtual.