BLACK STUDENTS' SUCCESS IN AN ENGINEERING PROGRAM: AN EXAMINATION OF THE ROLE OF BARRIERS, KNOWLEDGE, AND ACTIONS

By

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ABSTRACT

This study sought to understand how Black students progress in an undergraduate engineering program. Researchers explored how undergraduate engineering majors navigated barriers using heuristic knowledge and action to be successful in engineering. The research questions were: 1) What barriers do Black engineering students experience? 2) What heuristic knowledge do Black engineering students need to overcome barriers? 3) What specific actions do Black engineering students take to overcome barriers? The sample of 16 Black undergraduate current (n = 11) and former (n = 5) engineering students attending a private, Midwestern university in Fall 2020 consisted of a representative group of sophomores (n = 6), juniors (n = 7), and seniors (n = 3). An explanatory sequential mixed methods approach used a survey and interviews to examine the barriers experienced, heuristic knowledge needed, and actions students took to overcome barriers while in engineering. Descriptive statistics and interview theme analysis were used to compare the experiences of current and former engineering students. Results indicated a variation in student experiences and description of racial discrimination with former engineering students experiencing less racial discrimination. Black students need mental health resources, but former engineering students expressed the need to know about and took action to find mental health resources more often than continuing engineering students. Continuing engineering students built friendships/relationships with engineering students that did not look like them more often than former engineering students. Black students' distinct lived experiences are invaluable to their success in engineering. This study supports defining Black student success as the ability to navigate unique barriers, identify heuristic knowledge needed to address these barriers, and take action to manage these barriers to move forward on their path in engineering.

Keywords: Black students, engineering, success, anti-deficit, expertise model

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CHAPTER 1: INTRODUCTION

This study explores how Black undergraduate engineering majors navigate barriers using heuristic knowledge and action to be successful in engineering. Based on projections, racial and ethnic minorities will account for 56% of the U.S. population by 2060, yet in 2016 underrepresented minorities (URMs) comprised approximately 22% of those who earned bachelor's in science and engineering degrees, and in particular, approximately 14% of those earning engineering degrees (National Science Foundation [NSF], 2019). Increasing the number of URMs earning engineering degrees and entering the U.S. workforce would significantly contribute to diversifying STEM fields currently unable to meet societal demands for growth in science and technology, despite widespread targeted URM initiatives (Burrell et al., 2015; May & Chubin, 2003). National efforts have focused on increasing the participation of minoritized ethnic groups in engineering (May & Chubin, 2003). Despite these efforts, ethnic minority students are consistently underrepresented in the population of first-time, first-year students enrolling in engineering programs and have lower completion rates (NSF, 2019). Therefore, the aim of this study is to understand how Black students progress in an undergraduate engineering program.

Research has found ethnic minorities have been and continue to be underrepresented in STEM fields (NSF, 2019) and that unique factors impact URMs' decisions to remain in the STEM pipeline (Fries-Britt et al., 2010; Kuh et al., 2006; Seymour and Hewitt, 1997; Strayhorn et al., 2013). An examination of national samples highlights disparities in achievement between White and Black students, as well as between Black students and other ethnic groups, as early as kindergarten; these disparities continue to widen through 12th grade (Coleman et al., 1966; Massey & Denton, 1998; NEAP, 2015). Researchers have also found that race/ethnicity, as well

as gender and undergraduate classification (i.e., first year or senior), may influence variations in GPA among URMs and non-URMs (Borrego et al., 2005; Sheppard et al., 2010). In addition, SAT math scores (Borrego et al., 2005; Min et al., 2011) and campus climates at predominantly white institutions (PWIs) are also factors contributing to why URMs leave engineering (Strayhorn et al., 2013).

Previous findings have highlighted early departure trends related to ethnic minorities' persistence, retention, and graduation rates when pursuing engineering; others examined initiatives focused on addressing barriers that URMs experience in engineering. Research related to URM departure from engineering suggests that Black, Hispanic, and Native American students have a higher likelihood of leaving engineering before their third semester (Marra et al., 2012; Min et al., 2011), have a greater tendency to leave engineering compared to Asian and other (including international) students (Min et al., 2011), and have lower six-year graduation rates (Ohland et al., 2011) than non-minorities. To address URM achievement concerns, persistence, and retention trends in engineering, high schools, colleges, and universities have developed initiatives such as bridge programs, minority scholarship programs, and minority engineering programs which attempt to address various barriers URMs experience on their path to earning engineering degrees including: transitioning to the academic rigor of college learning environments (Ashley et al., 2017; Strayhorn, 2011; Tomasko et al., 2016), low-income backgrounds (Diemer & Li, 2012; Roderick et al., 2011), and lack of supportive academic communities (Landis, 1988).

The first critique of past research focuses on the use of deficit approaches in engineering research to examine the achievement of Black students. Engineering research maintains the deficit narrative when guided by theoretical frameworks, research questions, and research

methodologies that consistently highlight racial/ethnic minorities' academic weaknesses and/or deficits in academic performance. The erroneous confirmation of achievement deficits for racial/ethnic minorities as a result of deficit-focused engineering research, either intentionally or unintentionally, supports the continued and problematic use of deficit frameworks, research questions, and research methodologies in engineering. To address this issue, this study used Harper's Anti-Deficit Achievement Framework [ADAF] (2010) to guide the theoretical framework, research questions, and research methodologies toward an asset-based examination of Black students in engineering. This framework attempts to elicit insights at three "pipeline points" (p. 72): pre-college socialization and readiness, college achievement, and post-college persistence in STEM. This study focuses specifically on college achievement.

This study utilizes Padilla's (1991, 1994) Expertise Model of Successful College Students, an anti-deficit framework, to conceptualize successful pathways of Black students in engineering. Modeling successful pathways provides a counter narrative of Black student achievement. Centering Black students as experts in creating their own success in engineering intentionally shifts the widespread deficit narrative often created by researchers to a strength-based narrative told by students. The study built on this work by capturing and validating Black students' successful paths through engineering but limited its scope to examining heuristic (informal) knowledge.

The second critique of past research focuses on the use of research methods in engineering that lead to the invisibility of Black students. Aggregating URMs (typically Black, Hispanic, and Native American students) into a single group can lead researchers to miss important variations within and between racial/ethnic groups (Ohland et al., 2011). In addition, it is common practice for schools to report mean scores as performance indicators - for example,

GPA, retention rates, and graduation rates - for engineering students where the performance of all students is aggregated into one mean score. This is also an example of how commonly used methods of analyzing engineering students' performance obscure or hide the performance of Black students. Therefore, Black undergraduate engineering students were the sole focus of this study. By focusing on Black students, their performance was illuminated through the study's methods. Analyzing Black engineering students as a distinct group allowed important and often invisible similarities and differences between Black students to emerge.

The third critique of past research focuses on the harmful inaccuracies and limitations of only using graduation rates and GPA as the basis for defining Black student success. Institutions and researchers often use academic assessments, such as GPA and graduation rates, as indicators of student success or to compare the academic success of majority and URM students. Research suggests URMs' paths to graduation present unique barriers not experienced by majority students (Fries-Britt et al., 2010; Kuh et al., 2006; Seymour and Hewitt, 1997; Strayhorn et al., 2013). Therefore, if the path to graduating or to earning a certain GPA is more challenging for URM students than majority students, then we must consider what that success indicates about these students which may be different. More specifically, the personal qualities (e.g., persistence) required to achieve success in engineering may be different for URM and majority students. These qualities - not graduating or earning a particular GPA - may be most important to the future success of URM students. Acknowledging URM success may be different from majority student success. Specifically examining Black student success independent of majority and other URM students can help us understand how Black engineering students successfully navigate their path to graduation.

The use of deficit approaches in engineering is addressed using the Anti-Deficit Achievement Framework (Harper, 2010) which guides researchers to use a strength-based line of inquiry to understand Black students' college achievements. Padilla's (1991, 1994) Expertise Model of Successful College Students provides researchers a way to conceptualize how Black students use heuristic knowledge and take action to resolve barriers faced in college to successfully graduate. To address the use of research methods in engineering that lead to the invisibility of Black students, only Black engineering students will be included in the target population. Focusing on Black students highlights them as an important, distinct group in engineering. The methods used sought to understand variations and/or relationships that may exist between Black engineering students. The limitations and consequences of using GPA and graduation rates alone to define Black student success is addressed by examining the unique aspects of Black students' experiences in engineering. An examination of these unique experiences - the barriers Black students face, the heuristic knowledge they gain, and specific actions they take - illustrate aspects of Black engineering student success not highlighted in GPA and graduation rates.

Padilla et al. (1997) stated that to build a local model of successful minority students in college, researchers need to understand what barriers to success URMs experience, what heuristic knowledge URMs must possess, and what specific actions URMs engage in to overcome these barriers. The research questions below were adapted from Padilla (1991, 1994) to conceptualize a local model of successful Black students and better understand how Black students progress in college within engineering. Therefore, the main research questions in this study are:

RQ1. What barriers do Black engineering students experience?

RQ2. What heuristic knowledge do Black engineering students need to overcome barriers?

RQ3. What specific actions do Black engineering students take to overcome barriers?

Compared to past research, the implications of this study should be useful for several reasons. Using anti-deficit and expertise models as critical frameworks, this study centers Black students in engineering as expert contributors to their own success. Taking a more inclusive view of "successful" students to include Black students currently in or beyond their third semester in engineering allowed for more student success stories to be elicited and examined independent of White students and other URM student experiences. Focusing on Black students also revealed the success pathways for Black engineering majors and highlighted the often-invisible similarities and differences among Black students in engineering. The identification of barriers, knowledge acquired, and actions necessary to be successful in engineering provided institutional-specific information to critically evaluate initiatives intended to directly or indirectly impact academic success of Black students. Finally, the results offered Black, first year engineering majors campus-specific knowledge of other Black students to hopefully increase their persistence to graduation.

Definition of Terms

Underrepresented Minorities (URMs)

Underrepresented minorities (or URMs) are defined as students belonging to one of the following racial or ethnic minority groups: Black or African American, Hispanic or Latino, American Indian or Alaska Native. The NSF defines an underrepresented minority as a "category [that] comprises three racial or ethnic minority groups (Blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives) whose representation in S&E [Science & Engineering] education or employment is smaller than their representation in the U.S.

population" (NSF, 2019). Black students identified by the site institution and/or self-identified by participants were the focus of this study.

Black Students

Black students are defined as students identified by the site institution and/or self-identified by participants as belonging to the "Black or African American" racial or ethnic minority group.

Successful Engineering Students (or Continuing Engineering Students)

Successful students in engineering are defined as students with confirmed third (sophomore), fifth (junior), or seventh (senior) semester enrollment in a primary major in the College of Engineering at the site institution. Student success has been broadly defined to include, but is not limited to, academic/college achievement (Kuh, et al., 2006; Sparkman et al., 2012), persistence (Kuh et al., 2006; Stebelton & Soria, 2012), retention (Sparkman et al., 2012; Wade, 2019), and graduation (Stebelton & Soria, 2012; Wade, 2019) in engineering research. In this study, the definition of a successful engineering student aligned with retention literature as a measure of success based on the present enrollment in the Fall 2020 semester.

Students Who Left Engineering (or Former Engineering Students)

Students who left engineering are defined as students who were engineering majors but switched majors to be outside of the College of Engineering during or after their second semester at the site institution. In this study, the definition of a student who left engineering also aligned with retention literature as a measure of a lack of success in engineering, based on the absence of enrollment in a College of Engineering major in the Fall 2020 semester.

Barrier

A barrier was defined as an obstacle that Black engineering students experienced while enrolled at the site institution that had the potential to or did hinder their progress toward graduating with an engineering degree. Padilla (1999) described barriers as "obstacles...that must be overcome by the student in order to attain a college degree" (p. 135). The obstacles Black students, particularly males, experience - stereotype threat (Steele, 1997; Steele & Aronson, 1995), financial concerns (Myers, 2008; Robinson, 2016) navigating biases and racism (Fries-Britt, 2017; Harper, 2012), and feelings of isolation and invisibility (Myers, 2008; Strayhorn et al., 2013) are well documented in the literature.

Heuristic Knowledge

Heuristic knowledge is information Black students acquire through firsthand experience, observation, or from others, that aids their ability to overcome barriers faced in college. Padilla (1991, 1994) posited that college students develop heuristic knowledge early in their undergraduate careers to overcome barriers or obstacles. Heuristic knowledge is "experiential knowledge, that enhances [students'] ability to overcome barriers" (Myers, 2008, p. 72). Felder Thompson (2005) stated, "heuristic knowledge is information acquired informally oftentimes by personal observation or experience (trial and error)" (p. 60). Heuristic knowledge has limited transferability to other situations given it is "concrete, specific, and bound to a particular domain" (Padilla, 1991, p. 85). Padilla, Treviño, Gonzalez, & Treviño (1997) argued that heuristic knowledge is important because "students must acquire a certain amount of heuristic, or practical knowledge . . . to function competently on campus" (p. 126).

Action Taken

Action taken is defined as what Black students do, or a behavior they engage in, to

overcome a barrier or obstacle faced in college. Padilla (1999) distinguished heuristic knowledge from actions taken in that heuristic knowledge helps a student understand the nature of [a] barrier and possible solutions" (p. 142), whereas actions, informed by their heuristic knowledge, are "a set of behaviors...exhibited" (p. 142) by students to overcome a particular barrier. Ford-Edwards (2002) stated, actions are "details, or specific steps to be taken to prevent, address, or overcome a barrier" and that actions "detail how participants use the information about the barrier to overcome the barriers" (p. 103).

CHAPTER 2: LITERATURE REVIEW

This study will explore how Black students overcome barriers to be successful in engineering. This study will also examine how Black students' perceptions of themselves as successful students contributes to the development of a localized expertise model of successful Black students in engineering.

A Brief History of Research on Black Student Achievement

Historically, comparison of academic achievement between Whites and Blacks has been the focus of many educational researchers since Blacks were, for decades, the largest ethnic minority group in the United States (Jencks & Phillips, 1998). The achievement gap between White and Black students has been attributed to many factors including racial segregation (Massey & Denton, 1998; Orfield, 2003), socioeconomic opportunities (Diemer & Li, 2012; Roksa & Potter, 2011), stereotype threat (Aronson et al., 2001; Steele & Aronson, 1995), physiological health (Currie, 2005; National Center for Healthy Housing, n.d.), parental factors (Diemer & Li, 2012; Roksa & Potter, 2011), and the unequal distribution of funding in K-12 school districts (Coleman et al., 1966; Orfield, 2003). The debates around how these factors, separately or combined, impact the academic achievement of Black students continues.

Following the landmark 1954 *Brown v. Board of Education* Supreme Court decision, understanding "critical factors" (Coleman et al., 1966, p. 1) related to the education and achievement of minority children became a national priority. Coleman et al. (1966) released a seminal report (The Coleman Report) for the National Center for Educational Statistics on a national survey of students in 3rd, 6th, 9th, and 12th grades. The study found public schools that White and Black children attended were still highly segregated. Black students had fewer resources related to academic achievement (e.g., access to physics and chemistry courses and

laboratories, library books, textbooks, college preparatory and accelerated programs, etc.) and were less likely to attend regionally accredited public schools (Coleman et al., 1966). Reviewing "culture bound" (p. 20) standardized achievement test results, Coleman et al. (1966) found the achievement gap between Whites and Blacks in first grade progressively widened on through 12th grade.

Relatedly, Okada, Stoller and Weinfeld's (1968) report for the U.S. Department of Health, Education and Welfare found significant gaps in achievement between White and Black students in reading comprehension, verbal ability, and mathematics, in 6th through 12th grades. Reporting standardized achievement test scores for students in grades 1, 3, 6, 9 and 12, Okada et al. (1968) also found Blacks had the largest achievement gap compared to Whites in mathematics, reporting in at 5.5 years behind White students in mathematics upon completing high school.

The "Nation's Report Card" or the National Assessment of Educational Progress (NEAP**)**, obtains nationally-representative samples of U.S. students to assess what they "know and can do in various subject areas" (NEAP Glossary, 2019, p. 1). NEAP long-term trend (LTT) assessments have determined student achievement in reading (since 1971) and mathematics (since 1973) using samples of students aged 9, 13 and 17. The average scale scores of Black students in mathematics from 1978 to 2012 was the lowest among ethnic groups studied (i.e., Blacks - not Hispanic, Asian American or Pacific Islander, nor American Indian or Alaska Native), except in 1990, when the average scores of Hispanics were slightly lower (NEAP, 2019).

The NEAP findings over the past three decades support the earlier findings of Coleman et al. (1966) and Okada et al. (1968)—namely, suggesting there is a White-Black achievement gap.

Results also suggest the presence of a gap between Black students and other ethnic groups (NEAP, 2019). Such national reports have guided the narrative of Black student achievement at the national, state, and local levels. These findings have prompted initiatives to improve the educational outcomes of underrepresented ethnic groups including Black students to lessen this achievement gap.

Black Student Achievement in Engineering

Despite the narrative provided in national reports and long-term trend data, Boyd (1980) argued that previous attempts to aggregate the educational experiences of Black students were inadequate. Boyd (1980) studied almost 800 black undergraduates at 40 predominantly white, four-year colleges in 1973, 1975, and 1977. Graduates of high schools with less than 25% black enrollment were found almost twice as likely to have had excellent or good academic pre-college preparation, were more likely to have achieved high grade averages in college and had plans to attend graduate school, compared to graduates of high schools with more than 75% black enrollment. These findings suggested that the racial or ethnic make-up of high school environments may be a factor impacting Black student achievement in college. However, Boyd (1980) challenged labeling Black students as low achieving or lacking the ability to succeed based on the demographics of the high schools they attended. Other research suggested that Black high school students had achievement deficits in physics, chemistry, and mathematics (Coleman et al., 1966; Okada et al., 1968; NEAP, 2019). However, Boyd (1980) found a noticeable growth in Black undergraduates pursuing majors in STEM areas (i.e., biological sciences, engineering, and math) during the three-year period. This finding supports his argument that Black students are a diverse group with varying interests and capabilities to succeed in STEM.

Although Boyd (1980) reported an increase in Black undergraduates pursuing STEM majors, Berryman (1983) reported an underrepresentation of Blacks in STEM areas. Berryman (1983) focused on trends regarding the representation of degrees earned by women and ethnic minorities in "quantitatively based disciplines" (p. 11). Survey analysis suggested the pool for students pursuing quantitative degrees reached maximum size prior to senior year in high school, then subsequently declined in size through graduate school. Following the progress of cohorts through this educational pipeline, Black and Hispanic students were found to leave the STEM pipeline much earlier than White and other ethnic minority groups (Berryman, 1983). Results showed Blacks were the most underrepresented among quantitative degrees at all degree levels (i.e., Bachelor, Masters, and Doctorate), which was attributed to the loss of Black students at each point in the pipeline to degree attainment. These findings imply there is a window of time URMs will enter the STEM pipeline, that unique factors may influence Black and Hispanics students' paths to earning STEM degrees, and that these factors may continue to affect Black students throughout the pipeline.

Relatedly, Seymour and Hewitt (1997) examined factors that most influenced minority Science, Mathematics, and Engineering (SME) students' decisions to leave the STEM pipeline. They found the most influential reasons minority students mentioned for switching to non-SME majors were not indicated by non-minority students who also switched to non-SME majors. Minority students switched out of SME majors because their SME major proved inappropriate, they had conceptual difficulties with one or more SME subject(s), or they wanted to shift to more appealing non-SME career options (Seymour and Hewitt, 1997). These findings suggest, like Boyd (1980) and Berryman (1983), that unique cognitive and/or non-cognitive factors may

impact achievements and subsequently the persistence of minorities in science and engineering majors.

Researchers have also examined GPA as an achievement factor impacting the retention of women and ethnic minorities in engineering. Borrego et al. (2005) used the Southeastern University and College Coalition for Engineering Education (SUCCEED) longitudinal database to examine "first-time-in-college" student records from 1996 through 2001 at nine SUCCEED institutions. Findings indicated a significant difference between the GPAs of minority and non-minority students; also, the average GPA of minority students leaving engineering was lower than that of non-minority students. In a sample comprising 19 percent URMs, Sheppard et al. (2010) also examined GPAs among first year and senior URMs and non-URMs. They noted the GPA gap between URM and non-URM women widened to reach significance among seniors. In contrast, a significant GPA difference in the first year narrows and loses significance among seniors for men. Collectively, these findings suggest differences in the GPAs of racial/ethnic minorities in engineering compared to non-minorities, GPA variations that may be influenced by gender and undergraduate classification (i.e., first year or senior), and factors related to GPA which may contribute to URMs leaving engineering.

Additional cognitive (e.g., SAT) and non-cognitive (e.g., ethnicity) achievement factors have also been examined regarding URM retention in engineering. Min et al. (2011) used a database similar to Borrego et al. (2005) to examine the impact gender, ethnicity, and SAT (math and verbal) scores have on retention rates of undergraduate engineering majors. The Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) was used to perform a "survival analysis" (Min et al., 2011, p. 354) using student academic records from nine Southwestern universities between 1987 and 2004. Students who had lower SAT math

scores tended to leave engineering at a higher rate than the students with higher SAT math scores (Min et al., 2011). SAT math scores also proved to be better predictors of those at risk of leaving the engineering pipeline than SAT verbal scores (Min et al., 2011).

The National Center for Education Statistics (2018) reported mean SAT math scores for Asian (612), White (553), Hispanic (489), American Indian/Alaska Native (477), and Black (462) high school students. The National Center for Education Statistics' mean SAT math scores combined with Min et al.'s (2011) predictive SAT math findings suggest that Black students are most at risk and leave engineering more often as predicted by SAT math scores. Additional findings contradict these results by suggesting that White students tend to leave engineering slightly more than minority (i.e., African Americans, Hispanics, Native Americans, Alaskan Natives, and Native Pacific Islanders) students, who leave engineering more than Asian students, who leave engineering more than "Other" (including international) students (Min et al., 2011).

The environmental factors at Predominantly White Institutions (or PWIs) have also been found to influence URM achievement. Kuh et al. (2006) found that the strong support systems at Historically Black Colleges and Universities (HBCUs) yielded better academic performance and higher graduation rates for African American students compared to African American students at PWIs. Fries-Britt et al. (2010) noted students attending HBCUs were more likely to describe a family-type environment among peers and faculty than students at PWIs. Strayhorn et al. (2013) found that undergraduate African American and Latin American male STEM majors at PWIs experienced alienation and invisibility, lack of support from same-race peers and faculty, difficulty applying theory and curriculum to practice in introductory engineering courses, and a lack of pre-college preparation for college STEM coursework.

Black student achievement in STEM, specifically engineering, is impacted by different cognitive, non-cognitive, and environmental factors. Boyd (1980) found that pre-college learning environments can affect the academic achievement of Black undergraduates while not dissuading them from pursuing STEM majors. Berryman (1983) along with Seymour and Hewitt (1997) suggested that URMs pursuing STEM majors may face unique achievement barriers resulting in their early departure from the STEM pipeline. A connection between low scores on measures of academic achievement (i.e., GPA and SAT math scores) for Black students and their lack of persistence in engineering was also suggested (Borrego et al., 2005; Min et al., 2011; Sheppard et al., 2010). Kuh et al. (2006), Fries-Britt et al. (2010), and Strayhorn et al. (2013) agreed that environmental factors at PWIs can create more barriers to achievement for racial/ethnic minorities.

Minoritized students continue to be underrepresented in STEM fields despite findings which challenge the notion of achievement disparities between Black, White, and other racial/ethnic minoritized groups. Unique factors likely also impact the achievement and persistence of minorities in science and engineering. Examining how educational systems define and measure success may also be important to understanding Black student achievement disparities within these contexts.

How URM Success Has Been Historically Defined and Operationalized

Student success, an outcome of interest in educational research, has yielded more ambiguity than clarity regarding a definition of what student success is, factors that impact student success, and how it can or should be measured. Yet, the focus on student success in higher education has increased amid mounting pressures for institutions to provide evidence of

student learning, development, retention, and graduation (Castellanos & Gloria, 2007; Kuh et al., 2006; Wade, 2019; York et al., 2015).

Researchers have attempted to define success in several ways. Focused on underserved students, Kuh et al. (2006) provided a seminal report for the National Postsecondary Education Cooperative which synthesized relevant literature and findings related to student success. This report defined student success as "academic achievement, engagement in educationally purposeful activities, satisfaction, acquisition of desired knowledge, skills and competencies, persistence, attainment of educational objectives, and postcollege performance" (Kuh et al., 2006, p. 7). Examining racial/ethnic and socioeconomic gaps in student success, Perna and Thomas (2006) defined student success as the "completion or effective exercise of" (p. 2) college readiness (including educational aspirations and academic preparation); college enrollment (including college access and choice); college achievement (including academic performance, transfer, and persistence); and post-college attainment (including post-bachelor's enrollment, income and educational attainment). May and Chubin (2003) defined success as "satisfactory preparation for, recruitment and admission into, and completion of a baccalaureate engineering degree for members of underrepresented minority populations" (p. 28) in their retrospective on undergraduate engineering success for underrepresented minority students. These definitions illustrate the complexity and range of perspectives that inform definitions of success for underrepresented, racial, and ethnic minoritized groups in educational research.

Student achievement, a construct of student success (Kuh et. al., 2006; Perna & Thomas, 2006), is a familiar term in engineering education research. Within the field of engineering education, student achievement (particularly for URMs) has been an important topic related to national efforts to increase the success of URMs in STEM fields. To understand the mechanisms

responsible for student success, student achievement has been studied within various STEM environments (Lam et al., 2005; Maton et al., 2000; Maton et al., 2016; Ohland & Zhang, 2002). Lam et al. (1999) studied URM participation in a minority engineering program (MEP) and operationalized success as achievement in two ways: 1) retention (or completion of the MEP) and subsequent graduation from the University; and 2) GPA at graduation only for students that completed the MEP. Maton et al. (2000) and Maton et al. (2016) examined the academic outcomes of African American students in a minority scholarship program (MSP) for STEM majors. Both studies focused on bachelor-level retention, graduation rates in STEM majors, STEM GPA, overall GPA, and STEM graduate and professional school admission rates as markers of achievement and overall success.

Lam et al. (1999), Maton et al. (2000), and Maton et al. (2016) each illustrated that a common way to measure URM student success in engineering has been to use standard outcome-based measures of achievement (i.e., GPA, retention, graduation rates) despite student success consisting of several other components (Castellanos & Gloria, 2007; Kuh et al., 2006; May & Chubin, 2003; Perna & Thomas, 2006). Using outcome-based measures of achievement alone, or focusing on just a single aspect of student success (i.e., academic output) fails to account for students' personal qualities that may also influence student success. The disconnect between definitions and measurements of success, primarily as specific achievement variables for URMs, unfavorably leaves any definition of URM success in engineering widely open to interpretation, especially when using only academic outputs.

Despite the ambiguity that exists in the distinction between success and achievement, numerous approaches have been developed to improve URM success in engineering such as initiatives focused on addressing factors related to URM success through pre-college preparation,

recruitment programs, and sources of financial support (May & Chubin, 2003). Discussing each approach found in the literature is beyond the scope of this proposal; instead, three approaches designed to improve URM success in engineering are highlighted: bridge programs, minority scholarship programs, and minority engineering programs.

Approaches to Improve Minority Success in Engineering

Approaches aimed at improving URM success in engineering seek to address achievement factors illuminated by past research. Bridge programs, minority scholarship programs, and minority engineering programs are three approaches that are focused on URM success in engineering.

Bridge Programs

Bridge programs encompass a wide variety of terms (e.g., pre-college, transition) used to describe "programs [that] are designed to help transition students into the college learning environment" (Ashley et al., 2017, p.1). Engineering focused bridge programs seek to expose URMs to university, engineering, and/or STEM culture prior to their first semester in college through participation in structured learning activities (Ashley et al., 2017). These structured learning activities seek to address well-documented challenges faced by URMs in engineering programs (Borrego et al., 2005; Carter, 2006; Doolen & Long, 2007; Marra et al., 2012; Min et al., 2011; Seymour & Hewitt, 1997). For example, national Advanced Placement (AP) score distributions by ethnic groups showed overall AP scores for URMs across all AP tests to be lower than for White students (College Board, 2018). When examining AP scores in calculus, chemistry, and physics, white students' average AP score was 3.07 compared to scores by Native American (2.63), Mexican American (2.22), and Black (2.21) students. These findings suggest URM consistently score lower than white students in AP subjects required in engineering

curricula—if URMs gain access to AP courses in these subjects at all during high school. Bridge programs can offer URMs a pre-college review of core engineering subjects and exposure to engineering related activities to lessen challenges they may face in their transition to college learning environments.

Minority Scholarship Programs (MSPs)

Financial assistance is one feature of MSPs that sets them apart from other URM success approaches. Ushomirsky and Williams (2015) found "districts serving the most students of color...tend to receive less state and local funding than districts serving the fewest" (p. 8). These findings illustrate the need for MSPs to address the potential ripple effect the lack of K-12 funding can have on URM college persistence in engineering, especially for students coming from high poverty and under-resourced high schools—schools which have historically educated minority students (Boyd, 1980; Coleman et al. 1966; Massey & Denton, 2003; Orfield, 2013). Low-income youth are also less likely to attend school or persist to degree completion (Diemer & Li, 2012; Roderick et al., 2011). Research suggests that if offered financial incentives to pursue postsecondary education, low-income youth are more likely to attend college (Goldrick-Rab et al., 2016; Roderick et al., 2011). In addition, financial incentives also give students more time to focus on academic obligations rather than finding ways (e.g., work study) to maintain their financial status while in college (Leonard et al., 2013). The consistent financial support provided by MSPs can lessen the financial burdens engineering majors often incur (e.g., lab fees). In doing so, financial incentives have the potential to positively affect the mobility rates of URMs and potentially break the cycle of poverty and achievement gaps for future generations (Chetty et al., 2017).

Minority Engineering Programs (MEPs)

MEPs were created to increase the enrollment and retention of minority engineering students by making the undergraduate college experience smoother academically and socially (Lam et al., 1999; Van Aken et al., 1999). MEPs were developed when the need to diversify predominantly white engineering programs was viewed as a crucial step for URM success in engineering (Landis, 1988). Institutions that once excluded students of color from their campuses utilized MEPs to diversify their campuses. They did so by offering cultural environments where student identities were supported within predominantly white institutions (Newman, 2016). The MEP model aimed to "accomplish three objectives: build MEP students into a supportive academic community, deliver appropriate academic support, and facilitate the personal and professional growth of MEP students" (Landis, 1988, p. 759).

The distinguishing feature that sets MEPs apart from bridge or MSP approaches is they are housed within colleges/schools of engineering, which are directly responsible for fiscal support and administrative control, and who work directly with admissions offices to recruit and admit URMs for their programs. Similar to bridge programs and MSPs, MEPs greatest emphasis should be on the first-year transition (Landis, 1988). MEPs also help identify barriers minority students face in engineering, promote a high level of student involvement, provide a sound administrative structure controlled by colleges/schools of engineering, and encourage direct engineering faculty involvement with MEP students (Landis, 1988).

Bridge programs, MSPs, and MEPs are three approaches developed to improve URM success in engineering. These approaches aim to address factors including the transition to college academic environments, students' socioeconomic backgrounds, and support resources focused on improving URM retention in engineering. In the next section, the critique of past

research focuses on the use of deficit perspectives, the use of research methods that lead to the invisibility of Black students, and the use of graduation rate and GPA as the primary bases for defining URM student success.

Critique of Past Research

A synthesis of past research, critique points presented in this section, how this study addresses these critique points, and implications for this study are presented in Table A1 (see Appendix A).

Critique point 1: The implicit or explicit use of deficit approaches promotes stereotypes and misconceptions about the achievement of Black students

The Coleman Report (Coleman et al., 1966) established a framework for viewing their research on minority K-12 students from a deficit achievement approach when they introduced their study as "a survey of inequality of educational opportunity" (p. 549). This assertion was followed by a discussion of results heavily focused on Black students in terms of "deficiencies in achievement" (p.21) and in terms of the "degree of education disadvantage" (p. 218) of racial/ethnic groups. Their discussion of results confirmed that inequalities in education negatively impacted Black students. Coleman et al. (1966) also acknowledged that the standardized measures used were culturally biased and that results could favor White students. The measures aimed to assess performance to the "degree to which a child has assimilated a culture appropriate to modern life in the U.S." (Coleman et al., 1966, p. 218) implying that students who did not assimilate were at a deficit. Yet, Okada et al. (1968) used the same standardized measures to highlight the achievement deficits of Black students when Coleman et al. (1966) had already established the cultural disadvantages that such standardized measures may be more prevalent for Black students.

The reliability of the NEAP assessments of student achievement gaps or deficits is also questionable. The NEAP acknowledges "students do not receive enough questions about a specific topic to permit reliable estimates of individual performance" (National Center for Education Statistics [NCES], 2005, p. 109). Yet, based on these unreliable assessments, students were placed in varying achievement levels (i.e., basic, proficient, and advanced), and such achievement gaps were seemingly confirmed when "one group of students outperform[ed] another group and the difference in average scores for the two groups [was] statistically significant" (NEAP Achievement Gaps, 2019, p. 1). More specifically, for over 30 years, Black students had been identified as having a deficit in mathematics compared to other ethnic groups studied based on NEAP data.

National reports or the collection of data commissioned by the U.S. government such as the examples described above should be critically examined and challenged. The results presented in Coleman et al. (1966), Okada et al. (1968) and the National Assessment of Educational Progress (2019) are concerning when the achievement deficits between White and Black students are historically established, maintained, and widely accepted by both stakeholders with the power and social influence to guide educational reform in the U.S. as well as by teachers working in classrooms. Findings based on questionable methods, measures, and intentions can have widespread consequences across generations when research is accepted regardless of the political, cultural, and historical impact framing results solely from a deficit perspective can have on racial/ethnic students (Mejia et al., 2018).

Deficit perspectives' use in examining URM achievement in engineering education research has been present in the language of introductions, research questions, and/or in the discussions of findings (Mejia et al., 2018). For example, Min et al. (2011) stated in their

introduction that risk profiles for students dropping out of engineering among groups with different characteristics (e.g., ethnicity) would be the basis of their study; then, they supported their deficit line of inquiry by categorizing engineering students in deficit terms of "failure" (i.e., those who leave engineering) and "non-failure" (i.e., students who stay in engineering) (p. 354). They also highlighted that URMs were more likely to fail in engineering around their sixth semester compared to White and Other (i.e., international, ethnicity unknown) students, thereby suggesting that URM survival in engineering is doomed to "failure" in later semesters (Min et al., 2011).

Stereotypes and misconceptions about the ability of Black students are fostered when deficit perspectives are explicitly (Coleman et al., 1966; Okada et al., 1968) or implicitly (Borrego et al., 2005; Min et al., 2011) used in engineering education research. As a result, many programs, support resources, and/or initiatives like bridge programs, minority scholarship programs, and minority engineering programs aimed at increasing URM success in engineering are based on remediating achievement deficits. For example, Lam et al. (2005) described that one aspect of a bridge program is to provide diagnostic testing to determine high school students' deficiencies prior to college enrollment. Reisel et al. (2012) stated an aspect of their bridge program was to address deficiencies in the mastery of lower-level math skills.

Inescapable narratives of URMs lacking or in need of what non-URMs seem to inherently possess can be damaging to URM academic performance and ultimately their success in engineering. Steele and Aronson (1995) found that when African American college students feel vulnerable to negative stereotypes about their racial group's intellectual ability, their standardized test performance decreases relative to White students. Attempting to combat the impact that stereotype threat has on performance, Aronson et al. (2001) found that controlling for

stereotype threat did not fully eliminate the gap in performance and engagement between African American and Caucasian college students. These findings suggest that stereotype threat may not be the only factor influencing URM students' sometimes irredeemable feelings of intellectual inferiority (Aronson et al., 2001).

In sum, deficit narratives of Black student achievement have been historically supported by educational research with damaging, long term consequences. Few researchers have challenged these deficit narratives as social constructs in engineering education research, resulting in these narratives becoming constructed realities for URM in engineering (Mejia et al., 2018). Incorporating critical perspectives into engineering education research is needed to examine URM experiences, to critique research that maintains the status quo of engineering as a White, male-dominated field, and to challenge the complex social and institutional structures that perpetuate the inaccuracies of Black student achievement negating narratives of success (Mejia et al., 2018). The use of anti-deficit and expertise models of student success as critical frameworks in this study are needed to engage in asset-based research, provide frameworks to counter the socially-constructed deficiencies in Black student achievement, and acknowledge the expertise Black students bring to engineering contexts—all of which can directly challenge the use of deficit perspectives in engineering education research.

Critique point 2: Research methods that combine URM data within samples heavily populated with White students leads to the invisibility of Black students in engineering

Aggregating the experiences (Seymour & Hewitt, 1997) and achievement (Min et al., 2011; NEAP 2019; Sheppard et al., 2010) of minoritized students is problematic, but done frequently in engineering education research (Borrego et al., 2005; Zhang et al., 2004). In doing so, individual achievement as well as the understanding of variations within and across ethnic

groups are lost. Research methods that result in generalizations across URM samples created by aggregating URM data can lead to inaccurate narratives of URM experiences and achievement (Boyd 1980; Ohland et al., 2011). To decrease inaccurate generalizations influenced by aggregated URM data, this study focused solely on examining Black engineering students within a single university context.

In examining metrics of success in engineering (e.g., achievement, retention, graduation rates, etc.) where data is aggregated and averages (or means) are used can skew results toward majority trends when samples are heavily populated with white students (Ohland et al., 2011). Min et al. (2011) provided an example of distorted trends that emerge when using a majority White sample. They found White students (75% of the sample) leave engineering more than minority students (15% of sample). These results should be expected in a sample composed primarily of White students, which statistically increases the probability that students identified as leaving engineering would be White as reported. Research methods that use statistical analyses and which rely on averages are less likely to illuminate the experiences and successes of Black students as a result of their low representation in engineering unless Black students are the focus of the analysis. The low representation of Black students is also a reason researchers using quantitative methods are unable to obtain statistically significant results for Black students in engineering. Therefore, this study did not recruit White students or students from other racial/ethnic minoritized groups for participation. Instead, we intentionally focused on Black student success in engineering. This focus on a single ethnic group highlighted important relationships within and between Black engineering students that are often missing in engineering research.

Critique point 3: Using only graduation rates and GPA as the basis for defining URM student success ignores the harmful limitations of these assessments

Institutions often measure academic success by assessing whether or not students graduate or if they earn a certain level of GPA. York et al. (2015) found academic achievement, measured via GPA, to be the most commonly assessed aspect of academic success. Many view these indicators of student academic success as evidence of positive qualities that should correlate with their future academic and professional success. Graduation rates and GPA are often used as the primary basis for comparing the academic success of majority and URM students.

However, if we accept that the path to graduating or to earning a certain GPA is more challenging for URM students than majority students (Berryman, 1983; Fries-Britt et al., 2010; Kuh et al., 2006; Strayhorn et al., 2013), then we must also consider that what that measure of success indicates about these students may also be different. For example, Kim et al. (2014) found all racial/ethnic groups in their study reported significant gains in cognitive skills from their freshman to their junior or senior year. However, their college GPA showed a negative change (i.e., decrease) compared with their high school GPAs (Kim et al., 2014). These findings suggest that the cognitive skills (e.g., strategic thinking, resilience, resourcefulness) students from racial/ethnic backgrounds felt they gained in college were not accurately reflected in their GPA (York et al., 2015) and other factors may influence GPA. Granted, a URM student and majority student may both graduate and attain similar GPAs. However, the personal qualities - effort, persistence, resilience, resourcefulness, strategic thinking, awareness, and so on - required to achieve this success may be quite different for each. Importantly, it is these personal qualities -

not the fact that they graduated or earned a particular GPA - that will be most important to these students' future success.

Thus, using only graduation rates and GPA as the bases for defining student success has three harmful consequences. First, it fails to highlight qualities of successful students that really matter. Second, when used to compare groups, graduation rates and GPA tend to suggest that one group is better when this is not necessarily the case. Third, when using graduate rates and GPA, URMs, particularly Black students, will inevitably appear to be less successful, thereby reinforcing racist stereotypes.

The points being made here are not that institutions should never use graduation rates or GPA as indicants of student success. Instead, the points we are arguing are:

1. When comparing majority and URM students' graduation rates and GPA, keep in mind that the paths to each of these markers of success are probably more challenging for URM students, even more so for Black students.
2. Lower graduation rates or GPAs do not necessarily indicate lower academic aptitude, especially for Black students.
3. We should strive to understand more about students who manage the challenging path that Black students typically face. It is likely inaccurate and harmful to assume that Black students are similar to successful majority students. This is one of the central rationales for this study.

This study sought to better understand how Black engineering students navigate their path to graduation. By specifically examining the barriers Black students face in engineering, the heuristic knowledge needed to address these barriers, and actions students take to overcome these barriers, these variables are used to develop a local expertise model illustrating how Black

students successfully progress in engineering. The local expertise model of successful Black engineering students provides a context for understanding their experiences, reveals the specific challenges Black students face in engineering and highlights the qualities successful Black students possess to succeed in engineering.

How this study addresses these critique points.

Given these critiques of prior research, this study is different in that it:

1) used anti-deficit and expertise models of student success as critical frameworks to counter deficit narratives of Black student achievement in engineering;

2) used research methods that illuminate the experiences and achievements of Black students by recruiting only Black students for participation in the study and highlighting similarities, differences, and relationships among Black engineering students in the analysis phase;

3) defined Black student success as being able to navigate unique challenges and examines the specific barriers, heuristic knowledge, and actions of Black students in engineering to reveal how they navigate their path to graduation.

Therefore, below is an alternative approach that highlights how Black students develop their personal qualities to be successful in the engineering pipeline. This study expands Padilla's (1991, 1994) works which examined the success of minority students in higher education by exploring specifically how Black students' perceptions of themselves as successful engineering students contribute to the development of a localized expertise model of successful Black engineering students.

By challenging the use of deficit perspectives when examining Black students, using research methods that illuminate and center the experiences of Black students, and going beyond

GPA and graduation rates to examine how Black students navigate their path to graduation, what follows is an alternative approach that conceptualizes Black student success in engineering. The theoretical frameworks that grounds this study are discussed in the next section.

Frameworks

Anti-Deficit Achievement Framework (ADAF)

The Anti-Deficit Achievement Framework [ADAF] (Harper, 2010, 2012) guides researchers away from deficit-based theories and models to highlight the achievement of students of color. Focused on the entry points into the collegiate pipeline, this framework aids researchers in developing asset-based questions related to "pre-college socialization and readiness, college achievement and/or post college success" (Harper, 2010, p. 68). Using findings from 51 STEM majors in the National Black Male College Achievement Study (Harper, 2012), Harper adapted the ADAF to reframe deficit inquiries to examine how students of color succeed in STEM.

The ADAF addresses research investigating factors impacting URMs in engineering, but which does so through a deficit lens. For example, research suggests URMs are at greater risk of leaving engineering before their third semester (Borrego et al., 2005; Marra et al., 2012; Min et al., 2011), leaving engineering more often compared to Asian and Other (including international) students (Min et al., 2011), and having lower six-year graduation rates (Ohland et al., 2011). These factors impacting URM retention in engineering were all examined through the deficit perspective of the researchers.

Harper (2010) called for researchers to challenge deficit perspectives with asset-focused theories, models, and research questions when studying students of color in STEM. Since we know little about how Black students successfully navigate their way into and through the STEM pipeline (Harper, 2010), this study uses the ADAF to conceptualize Black students in

engineering as experts in their own success. This study seeks to understand how Black students overcome college achievement barriers to succeed in engineering.

Expertise Model of Successful College Students

Padilla (1991, 1994) also addressed the shortcomings of deficit-based research by focusing on minority students' successes rather than failures. Grounded in expert systems thinking, Padilla (1994) posits that college students develop heuristic (campus-specific), theoretical (content-specific) and total (compiled) knowledge over the course of their undergraduate careers in order to overcome barriers. Theoretical (or book) knowledge is learned through coursework, while heuristic knowledge is "locally defined and is acquired experientially" (Padilla 1994, p. 126). Padilla et al. (1997) developed a local (institutional specific) expertise model of successful minority students by identifying campus specific knowledge and actions successful minority students utilized to overcome barriers. Focusing on heuristic knowledge, the expertise model suggests that "students must acquire a certain amount of heuristic, or practical, knowledge that is necessary to function competently on campus" (p. 126).

The historical underrepresentation of ethnic minorities in engineering often leads the experiences of URMs (and especially Black students) to lack statistical significance making them difficult to validate. For example, the low representation of URMs in engineering research often leads researchers to fold URMs into the larger engineering (Li et al., 2009; Meyers & Mertz, 2011) or general STEM populations (White et al., 2006), or to group ethnic minorities into a single variable such as "ethnic" (Borrego et al., 2005; Zhang et al., 2004) or "non-Caucasian" (Marra et al., 2012). Using the Expertise Model of Successful College Students to guide the development of a local model of Black student success, the proposed study will provide a means

to obtain and validate the successful pathways of Black students in engineering.

The Anti-Deficit Achievement Framework and the Expertise Model of Successful College Students guide this study. By reframing the focus from deficit to asset-based thinking, this framework and model provide a structure in which to conceptualize Black student success in engineering. The research questions are presented in the next section.

Research Questions

The anti-deficit and the expertise models are the critical frameworks of student success that guided the development of asset-based research questions in this study. Such frameworks provide mechanisms to counter the socially constructed deficit narratives of Black student achievement. They also challenge the use of deficit perspectives in engineering education research. It is important to facilitate authentic reflections on the processes that allow Black engineering students to develop the personal qualities needed to navigate a successful path to graduation. Reflecting on the process of overcoming the barriers Black students face in engineering, using heuristic knowledge acquired to address the barriers experienced, and by taking actions to overcome these barriers, a local expertise model of successful Black students in engineering emerges. To better understand how Black engineering students successfully navigate their path to graduation, the following questions guided this study:

RQ1. What barriers do Black engineering students experience?

RQ2. What heuristic knowledge do Black engineering students need to overcome barriers?

RQ3. What specific actions do Black engineering students take to overcome barriers?

CHAPTER 3: METHODS

Positionality Statement

I have worked in higher education for 20 years. During my career, I spent 11 years as a professional academic advisor for first-year, undergraduate, engineering students. My experiences advising underrepresented students of color in engineering was the motivation for this study. As a Black female, I am more sensitive to the experiences Black students share with me and felt uniquely positioned to conduct this study.

Engineering administrators at the site institution and across higher education often use common key performance indicators (i.e. GPA, retention, and graduation rates) to gauge and/or predict the success of students - who will stay and who will leave. Speaking with many Black students over the years, I know these common indicators do not explain how some Black engineering students' progressed through their engineering programs while other Black students did not. Engineering research often tells us statistical tests often lack the power to produce statistically significant results in small Black student samples. Meaning that to be included in engineering research, Black students must disappear into larger minoritized samples. The focus of this study was to bring the experiences of Black students to the forefront illuminated and described through their own words.

The many advising interviews I have conducted with Black students honed my interviewing skills to incorporate pre-interview information while asking meaningful, open-ended questions to elicit details about the first-hand experiences during my interviews. The power of Black students' stories of truth, success, and struggle will shed light on the voices and experiences of Black engineering students at a single-site institution where they are marginalized within engineering are currently overlooked.

Setting

This study took place at a medium sized, private, Midwestern university. In fall 2019, the undergraduate population (N = 8,732) consisted of 47.9% women (n = 4,181) and 25% minority students, including Black or African American students (3.61%) (Anonymous Institutional Research, 2020). In the fall of 2020, the College of Engineering undergraduate population (N = 1,406), excluding first year students, consisted of 34.9% women (n = 491) and 18% minority students, including Black or African American (2%). (Anonymous, personal communication, July 22, 2020).

Sample

The sample for the study was chosen from the target population of Black undergraduate students (excluding first year students) currently in the College of Engineering or who were in the College of Engineering and left to pursue a non-engineering major at the site institution. Criterion-purposive sampling identified eligible participants based on the following criteria: 1) identified by the University as being Black or African American; 2) had confirmed enrollment in one of the five engineering departments (i.e., Aerospace/Mechanical, Civil, Environmental & Earth Sciences, Chemical & Biomolecular, Computer Science & Computer Engineering or Electrical) as of fall 2020 or changed from an engineering major to a major outside of the College of Engineering during or after their second semester; 3) were in or past their third semester (i.e., sophomores, juniors and seniors); and 4) were "United States Citizens" or "Permanent Residents." First year students were not included in the target sample because they may not have the experiences needed to provide the data requested (Padilla et al., 1997). In Fall 2020, 29 Black or African American students in the College of Engineering at the site institution fit this criteria. Eleven current Black engineering students and five former engineering majors at

the site institution participated in the study. The sample consisted of a representative sample of Black males and females pursuing majors in each of the five engineering departments or other colleges at the site institution. Former engineering students majors were Business Analytics, Industrial Design, Political Science, Chemistry, or Psychology. The summary of demographics for the 16 participants can be found in Table B1 (see Appendix B). All participants were at least 18 years of age.

Recruitment

Participants were identified with the assistance of the university Registrar. The researcher sent an email (see Appendix E) to students on the list during the fall 2020 semester inviting them to participate in the study. After sending at least three follow-up emails, the study invitation was put in the National Society of Black Engineers (NSBE) Group Chat to elicit additional participants. In each email invitation and group chat message, participants were informed they would receive a $20 gift card for their participation in each phase of the study.

Measures

This study took an explanatory sequential mixed methods approach where data was collected in two phases (Creswell & Creswell, 2018). Data collection happened first using an online Qualtrics survey, then through semi-structured Zoom follow-up interviews with all participants. The online survey included a consent form, demographic questions, and student experience items.

Phase 1: Engineering Experience Online Survey

Demographic Questions

The demographic questions focused on obtaining basic participant information relevant to the study (see Appendix G). Additional items highlighted participants' pre-college experiences

such as “I am the first in my family to attend college.” Participants’ first names, last names, and email data were collected only for notifications related to the proposed study (i.e., gift card delivery, request for participation in a follow-up interview, post-study debriefing, and dissemination of results if requested). The survey has nine demographic questions.

Survey Items of Note

Black Engineering Student Experience Items

The student experience items were grouped into eight sections (see Appendix G). The sections focused on participants' goals, confidence, barriers experienced, knowledge needed and actions taken to overcome barriers, engineering outcome expectations, and engineering-related interests. The items in these sections were guided by Padilla’s (1994, 2010) student success modeling approach, as well as previous research that also examined Black students in engineering (Blount, 2018; Felder Thompson, 2005; Ford-Edwards, 2002; Henley & Roberts, 2016; Myers, 2008; Robinson, 2016;), alongside Lent and Brown’s (2005) Engineering Fields Questionnaire.

Padilla’s Student Success Model Items

Three sections (i.e., Parts IV, V, and VI) were informed by Padilla’s (1994, 2010) student success modeling approach. Padilla’s Qualitative Student Success Modeling (QSSM) approach used an unfolding matrix technique to generate a general student success model (GSSM) and a local student success model (LSSM) (Wirth & Padilla, 2008). Padilla (1994) introduced the unfolding matrix technique to collect and analyze qualitative data using focus groups. This study created a way to gather similar information as Padilla through a survey rather than focus groups from the perspective of a horizontal matrix illustrated in Figure 1. It utilized Padilla’s QSSM approach as a framework to create survey items that focused on assessing barriers, knowledge,

and action components (Wirth & Padilla, 2008). Findings from previous research—that also used Padilla's framework to guide their qualitative studies and had Black engineering students as their primary sample—helped to create specific items that could assess barriers Black engineering students experienced, as well as the knowledge needed and actions taken to overcome these barriers.

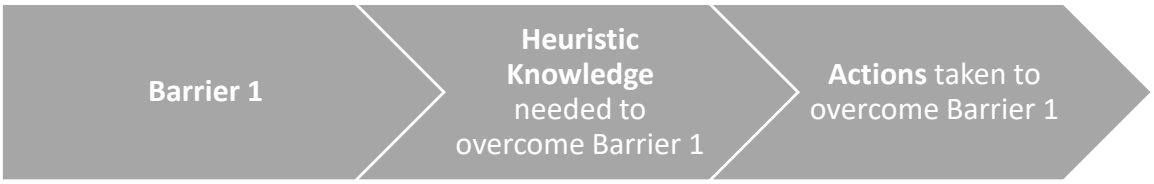

Figure 1: Example of a matrix for assessing the barriers, heuristic knowledge, and actions of successful college students (adapted from Padilla, 1999).

Development of Categories for Black Students Experience Items

Ford-Edwards (2002), Felder Thompson (2005), Myers (2008), Henley & Roberts (2016), Robinson (2016) and Blount (2018) also used Padilla's framework to guide their qualitative studies. Findings from their research identified specific events that Black or other students of color described having experienced. To create each section in Parts IV, V, and VI, findings from these qualitative studies were first grouped into academic, social, personal, or psychological categories; then, findings in these categories were placed into the appropriate barrier, knowledge, and actions section of the survey. Parts IV, V, and VI of the survey are composed of items that correspond to one of these categories. For example, the item "difficulty finding study groups for my engineering courses" was categorized as an academic subcomponent on the barriers scale; the item "know how to navigate the social environment in

engineering" was categorized as a social subcomponent on the knowledge scale. These items were also revised to align with what students at the site institutions in this study may experience.

Barriers Black engineering students' experienced were measured using items on the academic (7), social (8), personal (9), and psychological (5) barrier subscales. Heuristics were measured using items on the academic (5), social (6), personal (6), and psychological (5) knowledge subscales. Actions taken were measured using items on the academic (6), social (6), personal (6), and psychological (6) action subscales. There are additional items (12) at the end of each section [barriers (4), knowledge (4), action (4)] to gather information on how participants feel the main components are unique to themselves and other engineering students, and to understand how the main components impacted their thoughts about leaving engineering. In total, there are 87 items in these three sections.

Lent & Brown's (2005) Engineering Fields Questionnaire Items

Five sections (i.e., Parts I, II, III, VII and VIII) were taken directly from Lent & Brown's (2005) Engineering Fields Questionnaire or slightly revised to fit this study. The Engineering Fields Questionnaire establishes measures administered to students similar to this study's target Black engineering student population. Lent's Social Cognitive Career Theory (SCCT) also focuses on "relatively dynamic and situation-specific aspects of people (e.g., self-views, future expectations) and their environments" (Lent & Brown, 2006). Relatedly, the current study sought to understand aspects of Black students' progress and situation-specific experiences in engineering. Parts I, II, III, VII and VIII on the Engineering Experience Survey align with the core constructs of SCCT (i.e., Part I - Goals, Part II and III - Self-efficacy, Part VII - Outcome Expectations, and Part VIII - Interests). The core construct related to contextual supports and

barriers (i.e., Part V of the Engineering Fields Questionnaire) was integrated with more significant revisions into two of the sections discussed in the previous section (i.e., Part IV: Barriers and Part V: Knowledge). The contextual supports and barriers scale on the Engineering Fields Questionnaire aligned most with the primary focus of the current study and are described in more detail below.

Lent et al. (2003) focused on perceived environmental supports and barriers in the pursuit of an engineering major using a modified version of measures used by Lent et al. (2001). This barrier scale had a reliability coefficient (α) of .94 (excellent). Similarly, Lent et al. (2005) assessed supports and barriers that included engineering students at HBCUs using an adapted scale (α = .86) consisting of social, instrumental, and gender barrier subscales (α = .84). Lent et al. (2010) examined the function of social cognitive variables over time in a predominantly African American sample at two HBCUs using the Lent et al. (2005) scales. Flores et al. (2020) used the Engineering Supports and Barriers Scale (Lent et al., 2005) to examine how perceived supports, perceived barriers, and coping efficacy developed across time. In that study, the engineering barriers scale reliability coefficient (α) was .83, .85, and .77 for each time point with findings indicating perceived barriers increased over time.

Using items from Lent & Brown's (2005) Engineering Fields Questionnaire, Black engineering student goals in Part I were measured using 4 items; self-efficacy in Part II had 4 items and Part III had 7 items; outcome expectations in Part VII had 10 items; and engineering-related interests in Part VIII had 7 items. There are 32 items across these five sections. None of the scales discussed on Lent & Brown's (2005) Engineering Fields Questionnaire or the Engineering Supports and Barriers Scale (Flores et al., 2020) looked at the students' process (i.e., the how and what did they do) to resolve barriers. Acknowledging this point, Flores et al. (2020)

suggested exploring actual barriers experienced by engineering students, investigating the sources attributed to actual students' experiences, and conducting individual interviews with students with different levels of perceived barriers, all of which are the intent of this study.

Phase 2: Semi-Structured Follow-up Interviews

The semi-structured interview schedule (see Appendix I) was informed by the items on the Engineering Experience Online Survey. The interview schedule provided a framework for initial questions that built on the initial analysis of survey results for each participant (Creswell & Creswell, 2018). The semi-structured interview schedule allowed the researcher to incorporate her own knowledge and experience with Black engineering students and ask non-scripted questions in response to information provided by participants during the interview. The interviews also allowed the researcher to gather vivid, in-depth descriptions from Black students to illuminate their complex experiences and convey how those experiences influenced their progress while also giving a voice to their truth in how they experienced engineering.

The interview schedule was broken into seven sections that aligned to many of the sections in the Engineering Experience Online Survey. Table 1 provides an overview of each interview section.

Table 1

Semi-Structured Interview Sections

Section: Title	Focus
Section 1: Background Experiences	students' pre-college experiences, how they defined their racial identity, and how both informed their perspectives and experiences
Section 2: Goal Orientation	students' current goal orientations related to completing students' degrees
Section 3: Self-Efficacy Early in Engineering	students' early confidence or lack of confidence in engineering
Section 4a: Barriers (or Obstacles) Experienced in Engineering	students describing their personal experiences with the barriers below based on the groups indicating a high or low magnitude of agreement these barriers hindered their progress toward a degree in engineering.
Section 4b: Barriers - Personal Perspectives	students describing their personal perspectives related to the magnitude these barriers impacted themselves and others
Section 5a: Knowledge	students describing the impact of having and not having this knowledge while in engineering
Section 5b: Knowledge - Personal Perspective	students describing their personal perspectives related to how their knowledge informed themselves and others
Section 6a: Actions	students describing the impact of taking or not taking these actions while in engineering
Section 6b: Actions - Personal Perspectives	students describing their personal perspectives related to how the actions they took or did not take compared to other engineering
Section 7 - Outcome Expectations	students' beliefs about the outcomes of performing particular behaviors related to pursuing an engineering major

Procedure

Phase 1: Engineering Experience Online Survey

An email invitation was sent to students inviting them to participate in the Engineering Experiences Study after reading and submitting their response to the consent form (see Appendix D). After submitting their consent to participate in the study, participants were contacted by the researcher to schedule a one-on-one Zoom meeting to complete Phase 1: Engineering Experiences Online Survey. During the Phase 1 Zoom meeting, the researcher allowed

participants to ask questions they had regarding the consent form and/or any aspect of the Engineering Experiences Study before beginning the online survey. After the initial open question portion of the Phase 1 Zoom meeting, the researcher put the link to the online survey in the Zoom Chat. During each Zoom meeting, the researcher informed participants that they would stay on during the Zoom meeting but gave the participants an opportunity to turn off their camera and mute themselves while completing the online survey. Participants were instructed that they could ask the researcher questions at any time while taking the online survey. Participants were asked to turn their camera back on after they had completed the survey. After clicking on the online survey link, the participants were reminded of the "Online Survey Consent Form" they reviewed prior. Once participants turned their cameras back on, the researcher offered each participant the opportunity to debrief Phase 1 by allowing them to ask any additional questions they had after submitting the online survey. After the researcher secured the participant's online survey in Qualtrics, the Phase 1 Zoom meeting ended and the participant was sent a $20 Amazon eGift Card.

Phase 2: Semi-Structured Follow-up Interviews

Before submitting the online survey in Phase 1, participants were asked in the "Post-Survey Confirmation Questions" section if they could be contacted by the researcher for a follow-up interview. Participants who were willing could next participate in Phase 2: Semi-Structured Follow-up Interviews, which were contacted at least seven days following their participation in Phase 1; they were asked to schedule a one-on-one Zoom interview. Due to the small sample size (n = 16), all participants that agreed to a follow-up interview were included in Phase 2.

Initial survey analysis was used to "plan" (Creswell & Creswell, 2018, p. 374) the focus

of the semi-structured follow-up interviews for each participant. Planning for each participants' Phase 2 Zoom interview involved the researcher reviewing and making notes on each participants' responses to the online survey questions. From those notes, the researcher conducted an interview with each participant guided by the interview schedule in Appendix I. Each session was recorded and notes were taken. After the researcher ended the interview and secured the participant's Zoom recording, the participant was sent their $20 Amazon eGift Card.

Analysis

The Engineering Experiences Online Survey was analyzed first followed by the semi-structured interviews. Integrating the data in this way allowed each source of data to help explain the other yet remain independent from each other during analysis (Creswell & Creswell, 2018).

Phase 1: Engineering Experiences Online Survey

In Qualtrics, the survey responses were re-coded to align with the researcher's numerical codes for each response option on the survey. The Engineering Experiences Online Survey data was then downloaded from Qualtrics into SPSS using the Legacy SPSS format. Once in SPSS, the data was cleaned up as documented in Appendix H.

SPSS generated descriptive statistics. Frequency was used to obtain a summary of the sample demographics, while a summary of frequency showed how often participants "agreed" or "strongly agreed" they experienced a certain barrier, felt that specific knowledge was needed to overcome barriers, and what actions they most often took to overcome barriers in engineering. This analysis also gauged the magnitude or level of impact certain barriers, knowledge, and actions may have had on the participants. An analysis of means compared means for engineering students and former engineering students across all eight scales (while missing cases were coded

as -99 and excluded from analysis). For items on the barrier, knowledge, and action scales, data was excluded from analysis for participants who indicated they "Did not Experience" (barrier scale), "Did not Know This" (knowledge scale), or "Did not Do This" (action scale).

Phase 2: Semi-Structured Follow-up Interviews

The research questions in this study took an anti-deficit approach to "[explore the] personal, interpretive meanings found within the data" (Saldana, 2016, p. 70). With this approach in mind, the interview data was analyzed for emergent themes in three cycles (see Table 2) culminating with the identification of main themes. Themeing the data is the process of "labeling and thus analyzing portions of data with an extended thematic statement" (Saldana, 2016, p. 198). The process for themeing the data "consisted of 1) extracting verbatim significant statements, 2) formulating meanings about them through the researcher's interpretation, and 3) clustering these meanings into a series of organized themes" (Saldana, 2016, p. 200). Before the first cycle of analysis, each interview was transcribed, reviewed, and checked for accuracy.

The first cycle of analysis followed a phenomenological process to see what initial themes appeared in the data (Saldana, 2016). "A theme is an extended phrase or sentence that identifies what a unit of data is about and/or what it means" (Saldana, 2016, p. 199). Verbatim statements or exemplars from each interview noted by the researcher were given an initial theme that gave meaning to these statements (Saldana, 2016) as shown in Table 2.

The second cycle of analysis included clustering initial themes into categories from the first cycle based on similarities, differences, and/or possible relationships (Saldana, 2016). Thematic categories were used "to develop researcher-generated theoretical constructs [by]...clustering a set of related themes and labeling each cluster with a thematic category"

(Saldana, 2016, p. 202) as illustrated in Figure 2. Each time a thematic category was identified in the second cycle, it was given a number, name, and definition along with an example (if applicable) of that definition within the interview context. Clustering initial themes from the first cycle yielded 39 thematic categories in the second cycle of analysis.

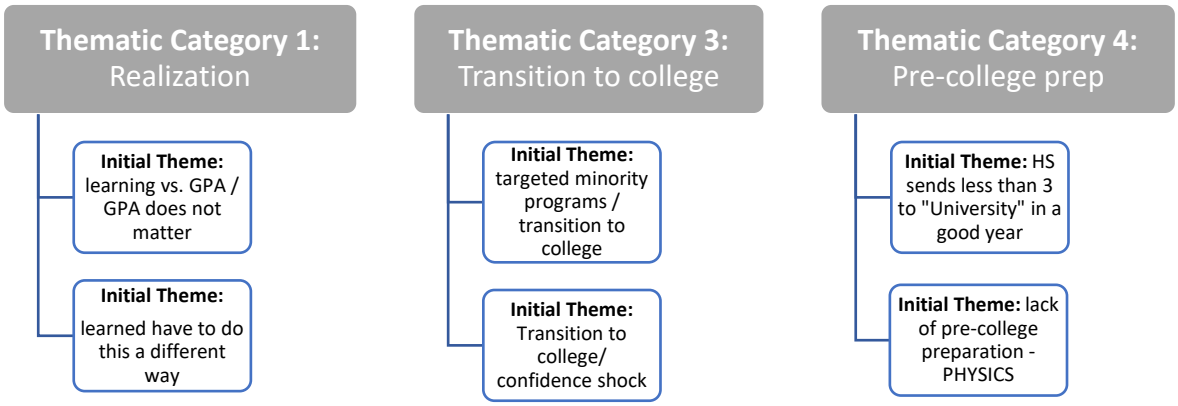

Figure 2: Example of process used to cluster a set of related initial themes and labeling each cluster with a thematic category (Saldana, 2016).

In the third cycle of analysis, the 39 thematic categories that emerged from the second cycle were further refined either by combining thematic categories or eliminating thematic categories from further analysis if discussed by less than three participants. For example, the "transition to college" and "pre-college prep" thematic categories were not identified as main thematic categories in the third cycle due to less discussion by participants compared to the recurring "realization" and "race in engineering" thematic categories with robust discussion by participants were identified as main themes. The outcome of the third cycle of analysis are the main barriers, main heuristic knowledge, and main action themes or thematic categories described in more detail in Chapter 4.

The three-cycle interview analysis process described was piloted and refined on the first three interviews, then repeated with each subsequent interview during analysis. This process continued with each interview across the barrier, heuristics, and action interview data until no

new main themes could be created.

Table 2

Examples of Initial Themes, Thematic Categories, Main Themes and Definitions during the Three Cycles of Theming the Data

Third Cycle	**Second Cycle (developed Thematic Categories)**				**First Cycle**	
Main Thematic Category Name	**Thematic Category Name**	**Thematic Category Number**	**Thematic Category Definition**	**Example(s) of the Thematic Category**	**Initial Theme**	**Exemplar**
realization	realization	1	insight gained or new understanding as a result of personal experience or observation of others	personal learning; what I thought	learning vs. GPA / GPA does not matter	"GPA was always something I was worried about…but slowly I am learning GPA does not matter as much as people always make it out to be - what's more important is am I learning what I need to learn"
	transition to college	3	period between senior year in high school and end of 2nd semester in college		targeted minority programs / transition to college	"same material, same pace - no academic benefit but helped me transition in to what college is like, these are the kinds of people that will be in my classes (Scholars Program)"

Table 2 (cont'd)

	pre-college prep	4	education before college		HS sends less than 3 to "University" in a good year	Only 2 people from my university [HS school] came to [site institution] says a lot. Where the other nearby school had almost 20 every year, where my school sends less than 3 and that is on a good year."
race in engineering	race in engineering	5	treated differently because of race	Black Girl in engineering; visible lack of representation; Blacks understood common experience	race in engineering - feeling alone	"OK so I don't have somebody in class will look like me and so when like you just looking around it's just you're just alone. You know it's kinda hard."

Validity, Reliability, and Trustworthiness

Validity and reliability was established, first, by using the same participants in each phase, which contributed to the consistency of the data collected (Creswell & Creswell, 2018). In addition, a script was established and followed in the collection of survey and interview data for each participant to improve reliability. After the survey data was collected, notes were taken on a print copy of each participant's survey to identify topics for follow-up during the interview phase. This process contributed to the accuracy of the findings by identifying points for follow-up in advance, then allowed participants an opportunity to clarify their survey responses and/or address any discrepancies noted by the researcher between participants' survey responses and

their interview responses (Creswell & Creswell, 2018). The script used in the semi-structured interview phase also contributed to the reliability of the questions asked to each participant while giving the researcher and participants flexibility to discuss topics that developed based on the natural flow of the interview.

Analyzing participants' survey data separately, then along with themes that emerged in the semi-structured interviews strengthened the validity and reliability through triangulation. Triangulation in this study allowed the researcher to gain an in-depth understanding of participants' lived experiences as Black engineering students through three methods - first, closed-ended choices on the survey, second, open-ended interview questions, and finally, through the integration of the survey and interview data. The triangulation process also allowed for the analysis of each student independently from their engineering group, within their respective continuing or former engineering group, and a comparison across each engineering group. Although participant feedback was not obtained to confirm themes that emerged during the final analysis phase, the systematic and consistent collection and analysis of the data described in this section aided in establishing trustworthiness in this study.

CHAPTER 4: RESULTS

The explanatory sequential mixed methods approach in this research followed such that the survey data was collected first and the interview data second (Creswell & Creswell, 2018). This process continued in the analysis phase; survey data was analyzed first followed by interview data for each research question related to Barriers, Heuristics, and Actions. The results from this analysis are presented in this section.

Research Question 1: What Barriers do Black Engineering Students Experience?

The research question addressed in this section is what barriers do Black engineering students experience? A barrier is defined as an obstacle (e.g., a person, place, thing, or event) Black students experienced, which they perceived hindered their progress while pursuing an engineering degree (Padilla, 1999). Barriers discussed by participants were expressed as being external or internal to them. In other words, participants discussed barriers as perceived obstacles that happened to them as a result of actions or conditions external to them they felt were out of their control. Or, participants discussed perceived obstacles as individual conditions they felt more personal control over and personally needed to address or manage.

This section will summarize main findings from the survey data and semi-structured interviews. First, findings from Part IV: Barriers that Hindered Progress in Engineering of the online survey are presented, followed by findings from the semi-structured interviews focused on barriers.

Survey Results

Participants responded to 28 barrier survey items (see Appendix G) on a 6-point Likert Scale that included 0 = Did not Experience, 1 = Strongly Disagree, 2 = Disagree, 3 = Unsure; 4 = Agree, and 5 = Strongly Agree. Do Black students in engineering experience barriers? If so, what

are these barriers? Top-ranked barriers that Black students perceived "hindered" their progress in engineering were identified as those items with an average rating of 4.5 (agree) or greater. The main three findings from the survey are presented in this section.

Barriers: Continuing versus Former Engineering Students

Top-ranked Barrier Items for Continuing and Former Engineering Students.

Of the 28 barriers items on the survey, continuing and former engineering students agreed (4.5 or greater) that two different barriers hindered their progress in engineering. The top-ranked action items and items with the largest differences between the groups (-0.5 or greater and 0.5 or greater) are presented. In Table 3, continuing engineering students agreed (4.5 or greater) upon "feelings of being an 'imposter' in engineering" (4.5) and former engineering students agreed upon "difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities" (4.5) as barriers that hindered their progress in engineering. Barrier items ordered by percent of agreement for all participants can be found in Appendix J.

Table 3

Top-ranked Barrier Items for Continuing and Former Engineering Students
Prompt for items: "My progress in engineering was hindered due to…"
0= Did not Experience; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group.

Barrier Item	**Continuing Engineering Students (n=11)**		**Barrier Item**	**Former Engineering Students (n=5)**
Feelings of being an "imposter" in engineering	4.5[1] (4.0)		Difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities	4.5[1] (4.1)

Note. Superscripts indicate number students excluded from average because they "did not experience" this barrier

Barrier Items with Largest Difference

In Table 4, continuing and former engineering students had the largest difference related to the barriers that they "experiencing negative perceptions or stereotypes of students of color in engineering" (1.7), "experience[d] racial discrimination in engineering" (1.6) and "receiving negative comments or discouragement about my engineering major from family members" (-1.4). A comparison of barrier items by percent of agreement for former and continuing students can be found in Appendix J.

Table 4

Barrier Items with Largest Difference

Prompt for items: "My progress in engineering was hindered due to…"
0= Did not Experience; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Barrier Item	Difference of agreement = continuing - former engineering students
Experiencing negative perceptions or stereotypes of students of color in engineering	1.7
Experiencing racial discrimination in engineering	1.6
Feelings of alienation and invisibility in engineering	1.5
Difficulty working in teams/group work in my engineering classes	1.4
Difficulty accessing an engineering "mentor" who could offer me advice and encouragement	1.3
Difficulty finding study groups for my engineering classes	1.3
A lack of support from professors or my academic advisor	0.8
Lack of faculty that looked like me in engineering	0.8
The lack of pre-college preparation for STEM coursework in college	0.8
Difficulty accessing a "role model" in engineering (i.e., someone I can look up to and learn from by observing)	0.7
Difficulty finding ways to study effectively for engineering courses despite having competing demands for my time	0.7
Experiencing gender discrimination in engineering	0.6

Table 4 (cont'd)

Communication problems with professors or teaching assistants	0.6
Financial pressures related to completing a degree in engineering	0.6
Feeling that, socially, the environment in engineering classes was not very welcoming	0.6
Feelings of being an "imposter" in engineering	0.5
Feeling pressure from parents or other important people to change my major to some other field	-0.9
Worrying that an engineering career path would require too much time or schooling	-0.8
Difficulty engaging in my engineering classes	-0.7
Feeling excluded from engineering clubs/organizations	-1.1
Not feeling well-liked by engineering classmates or professors	-1.1
Receiving negative comments or discouragement about my engineering major from family members	-1.4

The assumption would be that former engineering students experienced more barriers, thereby suggesting their reasons to leave engineering. The results in this section suggested similarities in that both continuing and former engineering students were hindered by barriers. However, the type of barriers continuing engineering students agreed upon which hindered their progress were different from the barriers largely identified by former engineering students.

Barriers: Continuing Males versus Continuing Female Engineering Students

Top-ranked Barrier Items for Continuing Males versus Continuing Female Engineering Students.

When continuing male and female engineering students were compared in Table 5, males agreed (4.5 or higher) upon one barrier whereas females agreed that three barriers hindered their progress in engineering.

Continuing males agreed that their "feelings of alienation and invisibility in engineering" (4.5) was a barrier. In contrast, continuing female engineering students agreed that "difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities" (4.8), "difficulty finding ways to study effectively for engineering courses despite having competing demands for my time" (4.8), and "feelings of being an 'imposter' in engineering" (4.7) were all barriers.

Table 5

Top-ranked Barrier Items for Continuing Male and Continuing Female Engineering Students

Prompt for items: "My progress in engineering was hindered due to…"
0= Did not Experience; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Barrier Item	**Males (n=5)**		**Barrier Item**	**Females (n=6)**
Feelings of alienation and invisibility in engineering	4.5[1] (4.0)		Difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities	4.8[1] (3.4)
			Difficulty finding ways to study effectively for engineering courses despite having competing demands for my time	4.8[1] (4.0)
			Feelings of being an "imposter" in engineering	4.7 (4.3)

Note. Superscripts indicate number students excluded from average because they "did not experience" this barrier

Barrier Items with Largest Difference

In Table 6, continuing males and females had the largest difference of agreement in "experiencing negative perceptions or stereotypes of students of color in engineering" (1.4), "feeling that, socially, the environment in engineering classes was not very welcoming" (1.3), encountering "limited tutoring assistance for engineering classes when I felt I needed such help"

(-1.3), and ongoing "difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities" (-1.4) as barriers.

Table 6

Barrier Items with Largest Difference
Prompt for items: "My progress in engineering was hindered due to…"
0= Did not Experience; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Barrier Item	**Difference of agreement = continuing males - continuing females**
Experiencing negative perceptions or stereotypes of students of color in engineering	1.4
Feeling that, socially, the environment in engineering classes was not very welcoming	1.3
Experiencing racial discrimination in engineering	1.2
Feeling that I don't fit in socially with other students in engineering	0.8
Feeling excluded from engineering clubs/organizations	0.8
Financial pressures related to completing a degree in engineering	0.7
Feeling pressure from parents or other important people to change my major to some other field	0.7
Feelings of alienation and invisibility in engineering	0.5
Difficulty accessing a "role model" in engineering (i.e., someone I can look up to and learn from by observing)	-0.6
Difficulty accessing an engineering "mentor" who could offer me advice and encouragement	-0.7
A lack of support from professors or my academic advisor	-0.8
Difficulty finding ways to study effectively for engineering courses despite having competing demands for my time	-0.8
Limited tutoring assistance for engineering classes when I felt I needed such help	-1.3
Difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities	-1.4

The assumption would be that being a female in the currently-male dominated field of engineering while also being women of color means that Black females would experience more barriers. Although continuing male and female engineering students both experienced barriers they perceived hindered their progress in engineering, these findings confirmed this assumption in that continuing females had a higher level of agreement with more barriers compared to continuing males. However, the types of barriers experienced by continuing males and females differed.

Barriers: Continuing Females versus Former Female Engineering Students

Top-ranked Barrier Items for Continuing Females versus Former Female Engineering Students.

Comparing agreement by females only in Table 7, continuing engineering students agreed (4.5 or higher) that three barriers and former engineering students (all females) agreed upon one barrier which hindered their progress in engineering.

Female continuing (4.8) and former (4.5) engineering students agreed that "difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities" were barriers that hindered their progress in engineering.

Continuing female engineering students also agreed that "difficulty finding ways to study effectively for engineering courses despite having competing demands for my time" (4.8) and "feelings of being an "imposter" in engineering" (4.7) were common barriers in engineering.

Table 7

Top-ranked Barrier Items for Continuing Female and Former Female Engineering Students

Prompt for items: "My progress in engineering was hindered due to…"
0= Did not Experience; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Barrier Item	**Continuing Females Engineering Students (n=6)**		**Barrier Item**	**Former Engineering Students (all female; n=5)**
Difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities	4.8[1] (4.5)		Difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities	4.5[1] (4.8)
Difficulty finding ways to study effectively for engineering courses despite having competing demands for my time	4.8[1] (3.8)			
Feelings of being an "imposter" in engineering	4.7 (4.0)			

Note. Superscripts indicate number students excluded from average because they "did not experience" this barrier

The results in this section suggest differences in levels of agreement of perceived barriers experienced between continuing female engineering and former (all female) engineering students. The assumption would be that former engineering students experienced more barriers suggesting reasons to leave engineering. However, the opposite was found, as continuing female engineering students who remained in engineering experienced more barriers.

Barrier Items with Largest Difference.

In Table 8, continuing females and former engineering students (all female) had the largest difference of agreement in "difficulty accessing an engineering 'mentor' who could offer me advice and encouragement" (1.7), "difficulty working in teams/group work in my

engineering classes" (1.4), "feeling excluded form engineering clubs/organizations" (-1.4), and "receiving negative comments or discouragement about my engineering major from family members" (-1.6) as barriers.

Table 8

Barrier Items with Largest Difference

Prompt for items: "My progress in engineering was hindered due to…"
0= Did not Experience; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Barrier Item	**Difference of agreement = continuing females - former females**
Difficulty accessing an engineering "mentor" who could offer me advice and encouragement	1.7
Difficulty working in teams/group work in my engineering classes	1.4
A lack of support from professors or my academic advisor	1.3
Difficulty finding study groups for my engineering classes	1.3
Feelings of alienation and invisibility in engineering	1.3
Difficulty finding ways to study effectively for engineering courses despite having competing demands for my time	1.1
Experiencing negative perceptions or stereotypes of student of color in engineering	1.1
Experiencing racial discrimination in engineering	1.1
Difficulty accessing a "role model" in engineering (i.e., someone I can look up to and learn from by observing)	1.0
The lack of pre-college preparation for STEM coursework in college	0.9
Lack of faculty that looked like me in engineering	0.8
Feelings of being an "imposter" in engineering	0.7
Experiencing gender discrimination in engineering	0.6
Communication problems with professors or teaching assistants	0.6
Difficulty engaging in my engineering classes	-0.6
Worrying that an engineering career path would require too much time or schooling	-0.9

Table 8 (cont'd)

Not feeling well-liked by engineering classmates or professors	-1.0
Feeling pressure from parents or other important people to change my major to some other field	-1.3
Feeling excluded form engineering clubs/organizations	-1.4
Receiving negative comments or discouragement about my engineering major from family members	-1.6

The survey reveals barriers Black engineering students experienced. The most interesting survey findings from the results in this section are highlighted in the next section.

Barriers: Most Interesting Survey Findings

Continuing engineering students' barriers focused on race while former engineering students' barriers focused on discouragement in engineering from family members.

An analysis of results in Tables 3 and 4 suggested continuing engineering students differed from former engineering students on the types of barriers each agreed (4.5 or greater) they experienced in engineering. Continuing engineering students had the largest difference of agreement compared to former engineering students; they largely experienced barriers related to negative perceptions of being a student of color in engineering (1.7) and racial discrimination (1.6). Former engineering students had the largest difference of agreement compared to continuing engineering students, especially related to discouragement about their engineering major from family members (-1.4).

Continuing males experienced barriers related to being alienated and invisible whereas continuing females experienced barriers related to study time and uncertainty as to if they were good enough for engineering.

Another interesting finding came from the analysis of Tables 5 and 6. Survey data suggested that continuing males agreed they experienced barriers related to their perception of

being left out and/or not seen in engineering. While continuing females experienced barriers related to the time they perceived was needed to study for engineering and questioned if they were good enough or cut out for engineering. These levels of agreement focused on different types of barriers was also evident in the largest differences in agreement between continuing males and females. Males "experience[d] negative perceptions or stereotypes of students of color in engineering" (1.4), and felt "that, socially, the environment in engineering classes was not very welcoming (1.3), and that they "experience[d] racial discrimination in engineering" (1.2) at a higher level of agreement compared to continuing females. In contrast, females experienced the largest difference of agreement compared to males in their "difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities" (-1.4) and "limited tutoring assistance for engineering classes when I felt I needed such help" (-1.3) as barriers.

Female engineering students had difficulty balancing studying with their desire for free time but differed in their difficulty accessing mentors and discouragement from family members about engineering.

Further analysis of survey data in Tables 7 and 8 found a high level of agreement (4.5 or higher) for continuing female and former engineering students (all female) and that "difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities" was a barrier for females in engineering.

Also interesting was the large difference of agreement between continuing females and former engineering students (all female). Continuing females differed from former engineering students (all female) in their agreement they had "difficulty accessing an engineering 'mentor' who could offer me advice and encouragement" (1.7). In contrast, former engineering students

(all female) differed from continuing females in their agreement they "receive[d] negative comments or discouragement about my engineering major from family members" (-1.6).

Survey analyses of barriers yielded interesting findings. But, were these barriers Black engineering students experienced also expressed in interviews? Informed by participants' responses to survey items, semi-structured interviews provided an opportunity to gain additional insight into Black students' experiences with barriers in engineering.

Barriers: Main Interview Themes

In the analysis of the interviews, Black students'common examples or experiences in engineering described in interviews yielded 39 initial themes. Barrier themes were organized into broad supporting barrier thematic categories that yielded two main barrier themes - racial discrimination and academic contexts. The main themes are connected in that they each provide a broad categorization of the recurring barriers Black engineering students experienced at the site institution. The supporting themes in this section will provide examples that illustrate the interpretation of the main themes (Saldana, 2016).

Main Theme 1: Racial Discrimination as a Barrier.

Racial discrimination is defined as Black students in engineering being treated differently or perceived they were treated differently because they are racially visible and/or identified as Black. My analysis of interviews yielded examples of this theme discussed in relation to racial discrimination.

One reasonable hypothesis would be that many if not all Black students in engineering would agree that racial discrimination is a barrier they experienced. Another reasonable hypothesis would be that students who left engineering perceived racial discrimination more as a barrier than those who persisted. However, survey findings suggested that—for continuing

engineering students specifically—male engineering students agreed racial discrimination was a barrier. The emergence of racial discrimination as a supporting theme in the interviews was not expected given the survey findings. The interview data suggested the survey results alone did not provide a complete understanding of the racial discrimination experiences of Black students in engineering. In fact, interview findings demonstrated that both continuing and former engineering students experienced racial discrimination.

Former and continuing engineering students described experiences of racial discrimination in about the same proportion: two of the five former engineering students, and five of the eleven continuing engineering students as shown in Table 9. In addition,

Table 9

Survey and Interview Responses on Experiencing Racial Discrimination for Each Student

Participant	**Student Type** Continuing Engineering Student (CEG) or Former Engineering Student (FEG)	**Survey Response**	**Interview Response**
AW1	CEG	Strongly Agree	Yes
AA2	CEG	Unsure	Yes
LN5	CEG	Unsure	Not Discussed
TN7	CEG	Agree	Yes (Intersected with Gender)
IM8	CEG	Strongly Agree	Yes
AE9	CEG	Did not Experience	Not Discussed
OE10	CEG	Unsure	No - Not directly
LA12	CEG	Agree	Yes (Intersected with Gender)
VM14	CEG	Disagree	Not Discussed
SC15	CEG	Strongly Disagree	Not Discussed
AW16	CEG	Unsure	Not Discussed
LO3	FEG	Disagree	Not Discussed
CO4	FEG	Disagree	Yes
LA6	FEG	Disagree	No
SH11	FEG	Strongly Disagree	No
MG13	FEG	Did not Experience	Yes

racial discrimination was expressed primarily around instances of academic socialization with White peers resulting in feeling alienated and/or invisible in engineering and through experiences of being a "Black girl in engineering," thereby illustrating the intersection of race and gender for some females in engineering. See Appendix K for example interview responses related to experiencing racial discrimination.

Fostered Alienation and/or Feeling Invisible in Engineering.

Four continuing engineering students either "agreed" or "strongly agreed" on their survey responses and described incidents of racial discrimination in their interviews. Continuing engineering males also described instances of racial discrimination in terms of feeling alienation and/or invisibility in engineering. For example, AW1 and IM8 described feeling alienated and/or invisible in engineering after interactions with their white peers. AW1 described one of the first times in college they felt they were being treated differently for being Black. His statement "I was like wow like they came in a row like just didn't wanna sit next to you" suggests he knew his classmates did not want to sit next to him because he was Black. This statement also illustrates how the actions of his classmates surprised him.

IM8 describes a similar experience of being treated differently when meeting new people in his major. He states, "they were all white...that was not the issue, the issue was when I tried to talk and speak they would be like 'ha ha ha' then they would turn away." IM8 acknowledges that he had no issue with his classmates being white, but suggests they had an issue with him because he was Black.

In addition, a former engineering student described incidents of racial discrimination, which did not align with her survey responses. CO4 indicated that she "disagreed" racial discrimination was a barrier that hindered her progress but described incidents in classes where

"the only person who would want to partner with me is like another black person." In her description, she implies that she did experience racial discrimination but she may not have believed this incident hindered her progress while in engineering.

Being a "Black Girl" in Engineering.

Continuing engineering students, TN7 and LA12, both described instances of racial discrimination in terms of being a "Black girl in engineering." During her interview, TN7 was asked to clarify her survey responses where she agreed racial discrimination was a barrier and strongly agreed alienation and invisibility, feeling like an impostor, and gender discrimination were also barriers. She clarified stating,

> I don't think it was necessarily gender...because I saw a lot of other girls in the room and they were doing just fine. So, I was like it's like oh it's not because you are a girl. There weren't as many black people in my class…maybe it was being a Black Girl I more want to say.

In addition, she mentioned,

> I might not remember everything like I might forget a concept and it's not that I'm not listening, but I just forget things...This is why I say I think it's being a Black Girl 'cause I remember like this black guy was in the class and he can joke around with the professor and it's like fine but when I did it's kind of like what's going on like you're not trying hard enough.

LA12 was asked to expand on her experiences being the only female in her computer science cohort as part of a scholar's program aimed at helping "minorities basically get acquainted into the STEM." In her response she stated,

> I was the only girl in my cohort so it was really weird because I guess the boys they were click and connect. But I will always feel weird because one, I was I was black, and two, I was a girl so I couldn't connect on the same level of all the other guys...But just with that, I felt like I really had to be two steps ahead of everyone because I had to prove that I was there for reason and not just because I was in minority and they had to reach a specific quota.

TN7 and LA12's statements referencing being a "Black Girl" in engineering suggests their perception of an intersection between being Black and being a woman and how it influenced their experiences while in engineering.

SC15, also a continuing engineering student, did not specifically discuss racial discrimination but suggested being viewed differently as a black woman in engineering. SC15 defined her racial identity as a "black woman in STEM," then later mentioned how people perceived her as a "black girl" in that,

> Definitely like when people see you in the beginning, they're like, all right, black girl you know whatever, but you definitely have to like prove yourself in some way shape or form, which is like honestly disgusting, like awful, but that's just the way the world is really, in some cases.

This passage suggests SC15 understood that she was or will be perceived differently as a black woman and relatedly as a black woman pursuing STEM.

CO4, a former engineering student, described anticipating instances of racial discrimination as a result of being a "Black woman in engineering." She stated,

> Sophomore year I really started my courses in computer science and then that sense of belonging really stemmed from the fact that it's...overwhelmingly, male dominated and of course it's a PWI, so either way, like I'm going to be in the minority, so as a black woman...Yeah, there is kind of...a novelty, like I'm kind of the only one, of course I wasn't the only one that's an exaggeration. But yeah, there are literally three of us.

These comments by CO4 suggest her perception of the intersection of being Black, a woman, and majoring in a male dominated STEM field put her in an undesirable position of being minority based on her personal characteristics - race, gender, and major.

"Did Not Experience" or "Unsure."

One continuing engineering student, AA2, responded that he was "unsure" on his survey, but discussed incidents of racial discrimination during his interview. By contrast, another

continuing student, OE10, responded that she was “unsure” on the survey and indicated during her interview that she did not experience racial discrimination directly.

Four continuing engineering student surveys and interview responses were not clear if they experienced racial discrimination or not. These participants responded either “strongly disagree, disagree, unsure, or did not experience” on their survey responses and they were not asked directly about their experiences (n = 3) or they acknowledged general racism but not specific instances related to engineering (n = 1).

Two former engineering students indicated during their interviews they did not experience racial discrimination, which aligned to their survey responses. For example, SH11 stated she “never experienced racial things.” Similarly, LA6 said, “Well I think in general, for me I always feel like I’ve never experienced racial discrimination…” However, this participant also added, “even like if I were to describe a situation where it's clear racial discrimination, I don't even feel like I would identify it as that.” This comment suggests LA6 may not acknowledge racial discrimination directed at her even if it were pointed out to her. This is an interesting insight given that she acknowledged being aware of a lack of representation of students and professors of color stating, “I had a black professor in one of my engineering classes. But, I and one other student, I think were the only black people in the class. And I notice that because I mean I'm grown up with that not necessarily being the case.” She also agreed that “feelings of alienation and invisibility” were barriers she experienced, yet she didn't experience “negative perceptions of students of color” in engineering. It could be that LA6 may have categorized her experiences in terms of alienation or invisibility rather than racial discrimination. This would be in line with a few other participants where their descriptions of alienation and invisibility were difficult to distinguish from racial discrimination.

Former engineering student, MG13, indicated she "did not experience" racial discrimination, but stated, "I wouldn't, maybe I wouldn't say 'discrimination,' but a racial awareness," then goes on to describe how for one group project it seemed like "everything [she] said came across as hostile" and how she would use a "fake high pitch voice and end with like a question or if [she] like wanted [her group members] to do something." It is interesting that MG13 described her experience of being treated differently because she is Black yet would not call this racial discrimination but instead racial awareness. Her naming her experience as racial awareness may be similar to how other participants such as LA6 viewed her experience of being treated differently in engineering because of her race. This may be why LA6 stated, "I would not identify it as that" if racial discrimination was pointed out to her.

Main Theme 2: Academic Contexts as a Barrier

In addition to racial discrimination, barriers described by Black students during the interviews were also associated with aspects of the academic context. These aspects included coursework demands, professor interactions, and peer interactions.

Coursework Demands Highlight Inadequate Student Preparation.

Describing her difficulty understanding engineering concepts, SC15, a continuing engineering student, discussed how long it takes her to learn engineering course material stating,

> You know like I have no idea how all the other students do that so quickly and so easily, you know like, like, oh, boom, done you know like everything's fine you know like I understood the information for me it's no it's like I really have to like keep understanding it and I feel like I really just don't grasp it information as easily. I didn't get that it takes a lot of work and a lot of effort to like really understand the material which is kind of a bad thing but, you know, it's only two more years of the degree so I think I could do it.

The challenges that SC15 described illuminates the challenges she experiences regularly in her engineering classes and suggests her limited prior exposure to similar course material may be a contributing factor.

Similarly, CO4, a former engineering student, stated, **"**I started taking like Gen Chem and calculus and stuff like that and that definitely was a blow to confidence." LO3, also a former engineering student mentioned:

> It wasn't even it wasn't even like I didn't have support or anything because I had friends in engineering as well that I knew, like were also struggling, but I just was like it's not like worth the struggle for me that was that was mainly it, yeah.

The "blow to confidence" CO4 described and engineering "not worth the struggle" mentioned by LO3 suggests their experiences impacted their confidence and motivation which may have been factors in their decision to leave engineering.

Also, reflecting on her collective challenges in engineering, MG13, a former engineering student, stated,

> So I do think that's my only regret is not switching out faster 'cause you know GPA and just how I feel now I don't know. You can add to the relationship curve but it's kind of like when you're in a toxic or abusive relationship and you can't leave yet because you're so scared of what life will be like I believe that relationship compared to when you get out and you're like wow. I wish I hadn't wasted all that time in this abusive relationship.

MG13's comparison of her experiences in engineering to an abusive relationship illustrates not only how her limited preparation for engineering courses may have impacted her GPA, but also the larger influence remaining in engineering may have had on her mental wellbeing.

Professor Interactions Fostered Inaccurate Comparisons.

Professor interactions that lead to inaccurate academic comparisons to engineering peers were also described as barriers in interviews. For example, a continuing engineering student, TN7, described an incident with their physics professor:

> I come in. I just failed the first exam. I literally got a 20 I think or a 30 out of 100, I come in crying and he is like "yeah well you need to go through the book and just do more problems." And I'm like what? That, oh yeah…that devastated me.

Later in the interview, TN7 described another experience trying to get help on problems during office hours following an exam:

> I guess the picture I am trying to paint is some kids would come in and be questioning they 70 out of 100 like you know you want to get back those points. I'm sitting there with a 20 you don't even want to speak. You don't want any of the other people in that room to know. So I know that kinda made me want to drop the major. Wow, all these kids, you're not even the same level as them. That was a huge thing. And then, like the way my professor was like just try harder. That was not helpful at all.

These comments by TN7 illustrate the emotional devastation and psychological impact her experiences with some of her professors made her consider dropping the major.

AW16, also a continuing engineering student, discussed her professor's comments regarding working on a project with another female engineering student. She stated,

> We both were working on a database project and we went up to the professor because we wanted to use a certain technology to accomplish this project. It was specifically something that I had learned outside of class, like with an internship. Uhm, and at first like when we like told him…his comment was oh OK, what you're probably going to need some other team members to like do the back end work and I thought that was very interesting because, well, [my friend] was really offended by it. I also have become desensitized…I kinda was like Oh, maybe he meant like you know we need more members, but when you think about it, he was just saying that he didn't think we were qualified to do what we were trying to do and that we should get some more. You know some other people on our team to help us out with that.

AW16 comments that she had become "desensitized" to gender discrimination comments from her instructors suggests that in her four years in engineering, she may have experienced many similar incidents to the point where they seem commonplace.

AA2, a continuing engineering student, discussed barriers in seeking help for difficult classes:

> And just like the difficulty of the classes. And not really feeling like I, like someone that had any help. Even when I went to office hours sometimes professors would really kind of be like, I'm not gonna say names like once a professor he's like, Oh yeah, this is easy. You can go ahead and do this and I didn't even know what it was, but he said it was easy. So like, I felt like I had to do it, but I don't know like things like that would happen and it had just made me feel like you know this. Maybe question if this was really worth it and if I should just switch my major.

These comments highlight how the professor assumed AA2 had prior knowledge of course material that should have made it "easy" for him, but in reality this interaction seemed to make AA2 more insecure about what he was supposed to know but did not.

Peer Interactions and Social Isolation.

Other interviews described barriers of academically-related peer interactions that resulted in feelings of social isolation and/or exclusion. For example, AA2, a continuing engineering student, felt that socially the environment in engineering classes was not very welcoming:

> Like in my engineering classes I . . . when it comes time for like teamwork assign or group work like it's kind of like you know that last kid who gets picked in baseball or fly kickball and that's basically how I feel in those kind of classes. And yes, that means like and when I, even when I'm in class, sometimes like I sit by myself constantly. Walk to class by myself.

Relatedly, MG13, a former engineering student, was asked about obstacles experienced in engineering and stated, "Group work was definitely one; it was a nightmare for me." CO4, a former engineering student, similarly stated,

> When I mainly felt that way, of course there were the times in freshman year when I had my science labs and there was stuff regarding that and I would have some friends in my classes but and they wouldn't help me. But then I just realized things like, you know, the class would make. Like students in the class would make like a study group chat or something like that and it's like, OK, certain people weren't added to that.

The experiences these students described provides valuable insight into how required engineering group assignments or projects and voluntary study group opportunities make Black students feel excluded.

Students' Lack of Interest in the Subject.

Former engineering students discussed a lack of interest or disengagement from their engineering courses. For example, when asked if CO4 wanted to provide additional context regarding her response of "strongly agree" to the questions regarding difficulty engaging in your engineering classes, she responded,

> Yeah, that was definitely just a lack of interest. Well, I tried my best to get myself to be interested, but it just wasn't something that resonated with me, so it was difficult for me to really pay attention enough and focus enough to grasp all the information I needed.

Similarly, LO3 stated about her confidence in pursuing engineering,

> Even if, like I wasn't worried as much about like if I would struggle with it, but I was still hoping like, well maybe like my interests or whatever. By growing and then I'd be willing to, like you know, put in the work to really like succeed in it, but I just later on found out that it's not really like an effort thing. It's more of just an interest thing and then I kind of just like lost interest like really halfway through the [first] semester."

In addition, LO3 provided a specific example from her first-year engineering course explaining:

> The format of the class was like all group projects and group work and I think probably
>
> like the first project we had. I know like what we were doing, I was like I mean it's, it in itself is interesting, but I wasn't really like, I don't know really engaged with the project.

When asked to expand on her survey response related to feeling that I don't fit in socially with other engineering students, LA6 mentioned

> The group of engineering students that I knew were all very different and some of them it seemed like we're much more interested in the topic than I would like in engineering than I was, which made me feel like maybe this isn't for me because I'm not. I don't have like a passion for let's just say solar energy. And so it made me feel like this wasn't

something for me.

These comments from former engineering students demonstrate how they realized they were not as interested in the engineering topics taught in class that manifested as a lack of focus (CO4), lack of engagement (LO3), and a lack of passion in engineering classes (LA6).

Building on the results discussed in the barriers section, the next section will discuss the results of the research question 2: What heuristics do Black engineering students need to overcome barriers experienced?

Research Question 2: What Heuristics do Black Engineering Students Need to Overcome Barriers Experienced?

Heuristics are defined as information Black engineering students acquired through first-hand experience, observation, or through others that aids their ability to overcome barriers faced in college (Felder Thompson, 2005; Myers, 2008; Padilla, 1991, 1994; Padilla et al., 1997). The research question discussed in this section is: What heuristics do Black engineering students need to overcome barriers experienced? Participants expressed heuristics which focused on information they felt they needed to know to help them overcome barriers discussed in the previous section. Findings from Part V: Heuristics of the survey are discussed followed by interview results.

Survey Results

Participants were asked to respond to 22 heuristic survey items (see Appendix G) on a 6-point Likert Scale that included 0 = Did not Know This, 1 = Strongly Disagree, 2 = Disagree, 3 = Unsure; 4 = Agree, and 5 = Strongly Agree. Questions this study sought to answer include: Are there specific heuristics Black students in engineering believe are needed to overcome barriers in engineering? If so, what kind of heuristics are needed? Top-ranked heuristics that “helped” Black

students overcome barriers faced in engineering were identified as those items with an average rating of 4.5 (agree) or greater. The main three findings from the survey are discussed below.

Heuristics: Continuing versus Former Engineering Students

Top-ranked Heuristic Items for Continuing and Former Engineering Students.

Of the 22 heuristic items, former engineering students agreed (4.5 or greater) that six types of heuristics were needed while continuing engineering students agreed that three types of heuristic were needed to overcome barriers. The top-ranked heuristic items (4.5 or higher) and items with the largest differences between the groups (-0.5 or greater and 0.5 or greater) are presented.

In Table 10, former and continuing engineering students had a similar level of agreement (4.5 or greater) that they needed to "know how to communicate with engineering faculty" (4.6 and 4.5 respectively), "know about academic support resources for assistance in engineering classes" (4.6 and 4.5 respectively), and "know how to deal with group dynamics for team/group work in engineering classes" (4.5 and 4.6 respectively). Additionally, former engineering students also agreed that they needed to "know how to address racial discrimination" (4.8), "know how to address gender discrimination" (4.8), and "know how to advocate for myself in instructional/classroom environments" (4.6). Heuristic items ordered by percent of agreement for all participants can be found in Appendix L.

Table 10

Top-ranked Heuristic Items for Continuing and Former Engineering Students

Prompt for items: "To overcome barriers I faced in engineering, I needed to…"
0= Did not Know This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Heuristic Item	**Continuing Engineering Students (n=11)**		**Heuristic Item**	**Former Engineering Students (n=5)**
Know how to deal with group dynamics for team/group work in engineering classes	4.6 (4.5)		Know how to address racial discrimination	4.8 (4.2)
Know how to communicate with engineering faculty	4.5[1] (4.6)		Know how to address gender discrimination	4.8 (4.0)
Know about academic support resources for assistance in engineering classes	4.5 (4.6)		Know how to communicate with engineering faculty	4.6 (4.5)
			Know about academic support resources for assistance in engineering classes	4.6 (4.5)
			Know how to advocate for myself in instructional/classroom environments	4.6 (4.3)
			Know how to deal with group dynamics for team/group work in engineering classes	4.5[1] (4.6)

Superscripts indicate number students excluded from average because they "did not experience" this barrier

Heuristic Items with Largest Difference.

On which heuristic items did the continuing and former engineering students differ the most in terms of rating its importance? In Table 11, continuing and former engineering students had the largest difference - by far – in assessing whether or not they needed to "know how to

solve financial aid problems - who to contact and when" (1.6), "know that my friends encourage me to pursue an engineering major (-0.9), and "know how to address gender discrimination" (-0.8). A comparison of heuristic items by percent of agreement for former and continuing students can be found in Appendix L.

Table 11

Heuristic Items with Largest Difference

Prompt for items: "To overcome barriers I faced in engineering, I needed to…"
0= Did not Know This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Heuristic Item	**Difference in agreement = continuing - former students**
Know how to solve financial aid problems - who to contact and when	1.6
Know that close friends or relatives are proud of me for making the decision to pursue engineering	0.7
Know how to find engineering students that look like me	0.7
Know how to address racial discrimination	-0.6
Know about the mental health support resources on campus	-0.6
Know how to address gender discrimination	-0.8
Know that my friends encourage me to pursue an engineering major	-0.9

In the barrier findings previously discussed, continuing engineering students experienced more barriers compared to former engineering students. Therefore, the assumption would be that

continuing engineering students would identify additional heuristics that were needed to overcome these barriers compared to former engineering students. The opposite was found, which suggests that former engineering students needed additional heuristics to overcome barriers while in engineering.

Heuristics: Continuing Males versus Continuing Female Engineering Students

Top-ranked Heuristic Items for Continuing Males and Continuing Female Engineering Students.

Comparing continuing male and female engineering students in Table 12, both groups agreed (4.5 or higher) that five types of heuristics were needed to overcome barriers. Males and females both agreed that they needed to "know how to deal with group dynamics for team/group work in engineering classes" (4.8 and 4.5, respectively). Males also agreed they needed to "know that close friends or relatives are proud of me for making the decision to pursue engineering" (4.8), "know how to advocate for myself in instructional/classroom environments" (4.6), "know that my family members support my decision to pursue engineering" (4.6), and "know how to address racial discrimination" (4.5). By comparison, females agreed they needed to "know how to communicate with engineering faculty" (4.6), "know how to manage feelings of alienation and invisibility" (4.6), "know about academic support resources for assistance in engineering classes" (4.5), and "know how to find engineering students that look like me" (4.5).

Table 12

Top-Ranked Heuristic Items for Continuing Male and Female Engineering Students
Prompt for items: "To overcome barriers I faced in engineering, I needed to…"
0= Did not Know This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Heuristic Item	**Males (n=5)**		**Heuristic Item**	**Females (n=6)**
Know how to deal with group dynamics for team/group work in engineering classes	4.8 (4.5)		Know how to communicate with engineering faculty	4.6[1] (4.4)
Know that close friends or relatives are proud of me for making the decision to pursue engineering	4.8 (3.5)		Know how to manage feelings of alienation and invisibility	4.6[1] (4.0)
Know how to advocate for myself in instructional/ classroom environments	4.6 (4.0)		Know about academic support resources for assistance in engineering classes	4.5 (4.4)
Know that my family members support my decision to pursue engineering	4.6 (4.2)		Know how to deal with group dynamics for team/group work in engineering classes	4.5 (4.8)
Know how to address racial discrimination	4.5[1] (4.0)		Know how to find engineering students that look like me	4.5 (4.0)

Note. **Superscripts indicate number students excluded from average because they "did not experience" this barrier**

Heuristic Items with Largest Difference.

In Table 13, continuing males and females had the largest difference of agreement that they needed to "know that close friends or relatives are proud of me for making the decision to pursue engineering" (1.3) and "know how to navigate the social environment in engineering" (0.9).

Table 13

Heuristic Items with Largest Difference
Prompt for items: "To overcome barriers I faced in engineering, I needed to…"
0= Did not Know This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Heuristic Item	**Difference in agreement = continuing male - female students**
Know that close friends or relatives are proud of me for making the decision to pursue engineering	1.3
Know how to navigate the social environment in engineering	0.9
Know how to advocate for myself in instructional/classroom environments	0.6
Know how to address racial discrimination	0.5
Know how to find engineering students that look like me	-0.5
Know how to manage feelings of alienation and invisibility	-0.6

Continuing engineering students experienced distinct barriers based on gender in findings previously discussed. A reasonable assumption would be that continuing males and female engineering students would identify different heuristic areas needed to overcome barriers in engineering. This was the case regarding heuristics needed. The results suggested continuing male and female engineering students differed in types of heuristics each group perceived they needed to overcome barriers in engineering.

Heuristics: Continuing Female versus Former Female Engineering Students

Top-ranked Heuristic Items for Continuing and Former Female Engineering Students.

Comparing continuing and former female engineering students in Table 14 reveals that

Table 14

Top-Ranked Heuristic Items for Continuing and Former Female Engineering Students
Prompt for items: "To overcome barriers I faced in engineering, I needed to…"
0= Did not Know This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Heuristic Item	**Continuing Female Engineering Students (n=6)**		**Heuristic Item**	**Former Engineering Students (all female; n=5)**
Know how to communicate with engineering faculty	4.6[1] (4.6)		Know how to address racial discrimination (ac)	4.8 (4.0)
Know how to manage feelings of alienation and invisibility	4.6[1] (4.0)		Know how to address gender discrimination	4.8 (4.0)
Know about academic support resources for assistance in engineering classes	4.5 (4.6)		Know how to advocate for myself in instructional/ classroom environments	4.6 (4.0)
Know how to deal with group dynamics for team/group work in engineering classes	4.5 (4.5)		Know how to communicate with engineering faculty	4.6 (4.6)
Know how to find engineering students that look like me	4.5 (3.6)		Know about academic support resources for assistance in engineering classes	4.6 (4.5)
			Know how to deal with group dynamics for team/group work in engineering classes	4.5[1] (4.5)

Note. **Superscripts indicate number students excluded from average because they "did not experience" this barrier**

former engineering students (all female) agreed (4.5 or higher) that six types of heuristics were needed compared to continuing females, who agreed that five types of heuristics were needed to overcome barriers. Continuing and former female engineering students had the same level of agreement that they needed to know "know how to communicate with engineering faculty" (4.6), and "know how to deal with group dynamics for team/group work in engineering classes" (4.5), while continuing female engineering students also agreed they needed to "know how to manage

feelings of alienation and invisibility" (4.6) and "know how to find engineering students that look like me" (4.5). Former engineering students also agreed they needed to know "how to address racial discrimination" (4.8), "how to address gender discrimination" (4.8), "about academic support resources for assistance in engineering classes" (4.6), and "how to advocate for myself in instructional/classroom environments" (4.6).

Heuristic Items with Largest Difference.

Table 15 shows that continuing and former female engineering students had the largest

Table 15

Heuristic Items with Largest Difference

Prompt for items: "To overcome barriers I faced in engineering, I needed to…"
0= Did not Know This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Heuristic Item	Difference in agreement = continuing female - former female
Know how to find engineering students that look like me	0.9
Know how to manage feelings of alienation and invisibility	0.6
Know how to advocate for myself in instructional/classroom environments	-0.6
Know about the mental health support resources on campus	-0.6
Know how to navigate the social environment in engineering	-0.7
Know how to address racial discrimination	-0.8
Know how to address gender discrimination	-0.8
Know how to address gender discrimination	-0.8
Know that my friends encourage me to pursue an engineering major	-1.1

difference of agreement when it came to if they needed to "know that my friends encourage me to pursue an engineering major" (-1.1), "know how to find engineering students that look like me" (0.9), "know how to address racial discrimination" (-0.8), and "know how to address gender discrimination (-0.8).

Continuing female engineering students experienced more barriers than former engineering students in findings previously discussed. A reasonable assumption would be that continuing female engineering students also identify additional heuristics needed to overcome barriers in engineering. However, the opposite was found. These results suggested differences in the level of agreement regarding heuristics continuing and former female engineering students perceived they needed to overcome barriers. Overall, former female engineering students had higher level of agreement that certain heuristics were needed to overcome barriers in engineering. The survey provided some insight into understanding what heuristics Black engineering students felt they needed to know. But, how were these heuristics expressed during interviews if expressed at all? The most interesting survey findings discussed in the previous section will be discussed in combination with initial themes from the interview data in the next section.

Heuristics: Most Interesting Survey Findings.

Former engineering students needed to know how to deal with discrimination and learn self-advocacy while continuing engineering students needed to know how to solve financial aid problems.

An analysis of results in Tables 10 and 11 suggested some similarities in agreement between continuing and former engineering students on heuristics. However, former engineering students had a higher level of agreement than continuing engineering students as to if they

needed to know how to address racial and gender discrimination and advocate for themselves in classroom environments. It was also interesting that the largest difference of agreement between continuing and former engineering students was that continuing students had a higher level of agreement in that they needed to know how to solve financial aid problems (1.6).

Continuing males and females had a single heuristic in common and differed on other heuristics they needed to know to overcome barriers.

Another interesting finding came from the analysis of Tables 12 and 13. Continuing male and females were similar on only one heuristic: "knowing how to deal with group dynamics for team/group work in engineering classes." They differed on other top-ranked heuristics which they felt they needed to know to overcome barriers. In addition, the largest difference of agreement was that males needed to "know that close friends or relatives are proud of me for making the decision to pursue engineering" (1.3) at a higher level of agreement compared to continuing females.

Female engineering students had heuristics in common and differed on other heuristics they needed to know to overcome barriers.

Further analysis of survey data in Tables 14 and 15 compared continuing and former female engineering students. Survey findings suggested that female engineering students had the same level of agreement, that they needed to know both "how to communicate with engineering faculty" (4.6) and "how to deal with group dynamics for team/group work in engineering classes" (4.5). But, the largest difference of agreement (-1.3) between these groups was "know[ing] that my friends encourage me to pursue an engineering major," a response that suggested former engineering students (all female) perceived this heuristic to be more important than continuing female engineering students.

In the interview analyses, Black engineering students provided rich data in their discussion of heuristics needed to overcome barriers in engineering. Their common examples or experiences yielded 7 initial heuristic themes that were duplicates from the 39 initial barrier themes, plus one additional theme: “academic knowledge.” These heuristic themes were organized into broad supporting heuristic themes that yielded two main heuristic themes discussed in the next section - how to sustain mental health and how to do well in engineering and related courses.

Heuristics: Main Interview Themes

Black students often discussed heuristics they needed to know in conjunction with barriers they experienced in engineering. In their discussion of barriers, Black students highlighted heuristics or things they learned about themselves that seemed to manifest as realizations. *Realizations* are defined as insight gained or new understandings obtained about oneself through deep reflection or introspection as a result of personal experiences. The main themes in Table 16 that emerged from the interviews related to heuristics Black engineering students felt they needed to know to help them overcome barriers were expressed as realizations related to self-preservation, realizations that aimed to sustain mental health and heuristics gained to help them do well in engineering and related courses.

Table 16

Main Themes from Interviews by Student

Numbers indicate amount each student discussed each main theme

Participant	**Student Type** Continuing Engineering Student (CEG) or Former Engineering Student (FEG)	**Main Theme 1: How to Sustain Mental Health**	**Main Theme 2: How to Do Well in Engineering and Related Courses**
AW1	CEG	1	1
AA2	CEG		2
LN5	CEG		1
TN7	CEG	1	
IM8	CEG	1	1
AE9	CEG		2
OE10	CEG	1	
LA12	CEG		1
VM14	CEG	1	
SC15	CEG		1
AW16	CEG		1
LO3	FEG	1	
CO4	FEG		1
LA6	FEG	1	1
SH11	FEG	1	1
MG13	FEG		1
	Totals	8	15

Main Theme 1: How to Sustain Mental Health

Black students discussed realizations they gained related to personal changes or adjustments they needed to make in order to preserve their mental health and well-being. A continuing engineering student, IM8, discussed adjusting his thoughts regarding “failing.” For

example, instead of thinking “I failed,” they “[tried] to not bring myself down anymore bc I know that the first time I failed I was devastated…now I can fail three or four times and still walk away with a B is what I realize.”

Similarly, continuing engineering student AW1 mentioned,

> Not getting to not being too hard on yourself 'cause when you're too hard on yourself and you're in your head it comes back up during the next exam. Was like Dang, like I fail this one. Am I gonna fail this one because of this, this and this? And now you're not really focused on the test that you study so hard for.

OE 10, also a continuing engineering student, discussed the mindset to maintain her mental health to succeed in engineering:

> I'd say just one thing. One piece of knowledge. I think that even still sticks with me now, is just knowing that like no individual is like better than you just because they came from a different background or they're not better than you because of the background that that they came from. And I think that definitely really helped me throughout these past 3 1/2 years. Just like even when it came down to getting a grade and knowing that someone else got something higher than me, that it doesn't make them any better of a student than you or any better of a person. It just literally means that they got a higher score than you and that's literally it. So, I think just remembering that or knowing that definitely has helped me too. I would yeah to help me like succeed and just keep going with the engineering thing.

The comments show how these continuing engineering students learned pushed past academic failures and/or low test scores through realizing IM8 could still pass the course, AW1 needed to let go of past failed exams to focus on the present exam or OE10 need to remind herself that one exam does not make you less than a peer with a higher score.

Black students also discussed the need to find a balance to preserve their mental health and well-being. For example, continuing engineering student TN7 mentioned she needed to find joy outside of engineering stating,

> I'll still be able to find joy. No, I guess that just you know, just in general, to be able to find joy. And I guess my life. I look at my professors and I see that this is what drives

> them everyday to wake up and I realize that's not for me and I'm OK with that and I could still find joy with whatever I'm studying every day, even if it's not like the reason that I come into work every day.

And continuing engineering student VM 14 stated,

> We have a lot of math and you have a lot of science. And it's also important that you do something that's not necessarily math or science, that you figure out ways to like cultivate your other side of the brain, because that's also important. But like it's also important for your mental health to do that because, like, you need to. Engineering is sometimes rigid, especially like when you're just learning the courses. Like you're just like learning how to do these things, but then it's also important to just be free for your mind of that and like. Learn how to do that and that's what I'm like.

These comments illustrate that these students needed to give themselves permission to shift their minds or daily activities to something other than engineering from time to time.

Similar to continuing engineering students, former engineering students discussed their perspective on how to sustain mental health. For example, SH11 mentioned the importance of,

> realizing that you must take time out for yourself…[because] at the end of the day a broken child with good grades is worse than a person that's really, really doing like good mentally getting through like all the trials and tribulations of college that may have a little bit lower grades—like, I've come to that conclusion an I'm 100% happy with that.

Providing a related, but different perspective, former engineering student, LO3, discussed the need to reflect on whether engineering is the right fit as a way to sustain mental health. She stated,

> I'd also say like take time to reflect 'cause I feel like that's what I had to do 'cause I really had to evaluate for myself. Whether like I don't want to do engineering just because. Like I felt like it would get too hard with like all the like math and science courses that I struggled with in the past, or if I really like just did not see myself doing it in the future. So I'd also say probably the last thing I'll say like take time to like really reflect and think about like if this is what you want to do.

These comments by former engineering students highlights the process of reflecting on their own experiences to find what was best for them to sustain their mental health.

Main Theme 2: How to Do Well in Engineering and Related Courses

Develop Study Habits and Skills.

Black students discussed information they need to know related to the development of study habits and/or skills pre-college or early in their college careers. For example, a continuing engineering student, AA2, mentioned the importance of "developing studying habits" and that "those study habits would have been formed if I had more rigor, rigorous courses in high school." LA12, also a continuing engineering student, mentioned,

> I really had to learn how to study and how to actually be a good student. I just realized that you have to be really organized and know, the importance of studying because if you don't prepare yourself beforehand, you can just get lost within the whole lifestyle or college.

Similarly, continuing engineering student, AE9 stated the importance of "being like honest to myself" as "it took me some time to admit that my study method wasn't really working at this stage because…if you're used to something for so long, it's kind of hard to change." AW1, also a continuing engineering student, stated,

> I say learn, make sure you like have good study habits or develop them pretty early because it will pick up that first semester is a lot of…review for most people. But that second semester can hit you hard and it hit me hard and make sure you develop good study habits.

Speaking more generally, continuing engineering student SC15 stated,

> I would say the main two things are just time management and how to ask for help. Those are the two most important thing because I feel like those are two things that I have wildly struggled with just in my life in general, you know, so definitely I feel this semester is kind of like a time for me to kind of like scale back a little bit and definitely trying to like figure things out and kind of like start with a routine like a consistent system.

A departure from what continuing engineering students expressed, LA6, a former engineering student, spoke about pre-college skills that she felt were needed in engineering:

> I definitely think that like advanced math was kind of like a critical component in like engineering because it applied to most of the classes like math was present in the majority of the classes that were taught.

In addition, she stated, “I think like AP chemistry…would have helped a lot in engineering. I don't even remember high school chemistry, though to like definitively say that, but I feel like it definitely would've helped.” These comments provide insight into the importance Black students put on needing knowledge to develop study habits and skills early in the academic careers.

Understand What Engineers Do.

Black students also discussed information they need to know related to understanding what engineers do. For example, when asked what she needed to know, a former engineering student, CO4 stated a need to “know what EGs do on a daily basis.” Relatedly, continuing engineering student, IM8 stated that they needed to “know what engineering you want to do - the sooner you figure that out the sooner you know what you need to work on and what you should be prepared for.” According to continuing engineering student AA2:

> I guess having a full understanding of what exactly, what, uh, what mechanical engineering really is like? The limits of having a mechanical engineering major or the limits having or whatever major. So, like I think maybe in our first year courses we can cover if you do. If you go, if you go in this route you can't do it. I mean not can't like you're more likely to do this when you graduate or you're more likely to do this when you graduate. Having something like that. Well, I may be like. I guess I understood exactly what having that degree entails.

These comments demonstrate that it was important for these students to know what engineers do to aid in deciding if engineering was the right for them.

Communicate with Faculty and Peers.

Black students also discussed information they need to know related to communicating with faculty and peers. For example, a continuing engineering student, AE9, said he needed to know and be "willing to ask for help from professors and students alike." Similarly, continuing engineering student LN5 discussed the moment when he understood he needed to communicate with peers around him about needing help:

> You need to communicate a bit more with the people around [you]. I wasn't talking to anybody and I felt like, me not communicating with a big issue if I was if I was going to sit there and do nothing. It's not like anybody's gonna help me. So when I started communicating with…people in my dorm, they're like 'Oh yeah, I'm in trouble. I went through the same classes that you went through here. My notes here. My notes from the classes before. You know, study them, take them.' And when I when I started getting the help it was like…magic, like I started doing a whole lot better [in] my classes. So, if I had known this before I went up, I don't think I would have gone through the…I think I wouldn't have suffered as much as I needed to if I had just communicated.

Continuing engineering student AW16 discussed gaining heuristics related to emailing professors:

> Like the one about like that you could like email professors like about like you know how when you're registering for classes and the class looks full. Like you can just like you know, be bold and like send the professor an email. [Anonymous Student] had told me this. And she was like, well, what's the worst thing that could happen? They just tell you no, right?

AW16 also discussed the consequence of not having the heuristic related to communicating with faculty related to her course sequencing:

> I think something that I was kind of missing was I didn't know that you could like...I was kind of following like the normal trajectory for classes to take…like, there's [a] page on the CS website, that's like, oh, this is what a normal schedule for CS over four years looks like. So I'm thinking, 'OK, I'm just going to follow this, right?' But for one semester, I'd followed that advice and I took…like they were basically the hardest classes of our career altogether really. And that was just really stressful and I wish I had kind of understood that I could switch. I can switch things around like I don't have to take

exactly what that page said.

In communicating with faculty, former engineering student, SH11, discussed the need to know when to "[explain] to your professors like you don't like don't be afraid to say you don't know what's going on like that you don't understand." Another former engineering student, MG13, discussed how communicating with a faculty member helped her learn by providing her with what she called a "cheat sheet":

> I would say having a cheat sheet definitely helped me in terms of my mentor and everything, and him telling me do this and do that. It kept me from a lot of the holes that my peers who didn't have that fell into so it was like not being able to finish my exams on time and things like that is kind of what I would see is when I didn't have the cheat sheet.

These comments by continuing and former engineering students provide insight into the benefits of communicating and the unnecessary challenges when they did not communicate their questions or needs with their professors and/or peers.

Building on the results discussed in the heuristic section, the next section will discuss the results of the research question 3: What specific actions do Black engineering students take to overcome barriers experienced?

Research Question 3: What Specific Actions do Black Engineering Students take to Overcome Barriers Experienced?

Actions are defined as what Black students did, or a behavior they engaged in, to overcome a barrier or obstacle faced in college (Ford-Edwards, 2002; Padilla, 1999). The research question discussed in this section is: What specific actions do Black engineering students take to overcome barriers experienced? The actions taken by participants focused on behaviors they felt helped them overcome barriers discussed previously. Findings from Part VI: Actions of the online survey are discussed below followed by interview results.

Survey Results

Participants were asked to respond to 24 action survey items (see Appendix J) on a 6-point Likert Scale that included 0 = Did not Do This, 1 = Strongly Disagree, 2 = Disagree, 3 = Unsure; 4 = Agree, and 5 = Strongly Agree. Are there specific actions Black engineering students engaged in to overcome barriers in engineering? If so, what are these actions? Top-ranked actions that helped Black students overcome barriers faced in engineering were identified as those items with an average rating of 4.5 (agree) or greater. The main three findings from the survey are discussed below.

Actions: Continuing versus Former Engineering Students

Top-ranked Action Items for Continuing and Former Engineering Students.

Of the 24 action items, former engineering students agreed (4.5 or greater) upon nine actions, and continuing engineering students agreed upon six actions, which helped them overcome barriers in engineering. The top-ranked action items (4.5 or higher) and items with the largest differences between the groups (-0.5 or greater and 0.5 or greater) are presented.

In Table 17, continuing and former engineering students had similar levels of agreement (4.5 or greater) in that: they "built friendships/ relationships with engineering students that looked like me" (4.7 and 5.0 respectively), "contacted or followed up with the Office of Financial Aid" (4.6 and 4.5 respectively), "leaned on friends and family for emotional support" (4.5 and 4.6 respectively), and "researched engineering majors to find the best fit" (4.4 and 4.5 respectively). Action items ordered by percent of agreement for all participants can be found in Appendix M.

In addition, continuing engineering students agreed they "told friends and family when I needed to prioritize school" (4.7), "made my education a priority" (4.6), and "built friendships/

relationships with engineering students that did not look like me" (4.5). Former engineering students also agreed they "used mental health resources on campus" (5.0), "found a 'mentor' who could offer advice and encouragement" (4.8), "developed relationships with engineering faculty" (4.6), "learned how to manage my feelings of alienation and invisibility" (4.5), and "established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)" (4.5).

Table 17

Top-ranked Action Items for Continuing and Former Engineering Students

Prompt for items: "To overcome barriers I faced in engineering, I…"
0= Did not Do This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Action Item	**Continuing Engineering Students (n=11)**		**Action Item**	**Former Engineering Students (n=5)**
Told friends and family when I needed to prioritize school	4.7[2] (3.0)		Used mental health resources on campus	5.0[1] (3.6)
Built friendships/ relationships with engineering students that looked like me	4.7 (5.0)		Built friendships/ relationships with engineering students that looked like me	5.0 (4.7)
Made my education a priority	4.6 (4.0)		Found a "mentor" who could offer advice and encouragement	4.8[1] (3.5)
I contacted or followed up with the Office of Financial Aid	4.6[3] (4.5)		Leaned on friends and family for emotional support	4.6[3] (4.5)
Leaned on friends and family for emotional support	4.5[2] (4.6)		Developed relationships with engineering faculty	4.6 (3.9)

Table 17 (cont'd)

Built friendships/ relationships with engineering students that did not look like me	4.5[1] (3.7)		Learned how to manage my feelings of alienation and invisibility	4.5[3] (4.3)
			I contacted or followed up with the Office of Financial Aid	4.5[3] (4.6)
			Established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)	4.5[1] (4.3)
			Researched engineering majors to find the best fit	4.5[1] (4.4)

Note. Superscripts indicate number students excluded from average because they "did not experience" this barrier

Action Items with Largest Difference.

In Table 18, continuing and former engineering students had the largest difference - by far - related to the actions that they "told friends and family when I needed to prioritize school" (1.7), "gained confidence in my engineering abilities (1.7), "found a 'mentor' who could offer advice and encouragement" (-1.3), and "used mental health resources on campus" (-1.4). A comparison of action items by percent of agreement for former and continuing students can be found in Appendix M.

Table 18

Action Items with Largest Difference

Prompt for items: “To overcome barriers I faced in engineering, I…”
0= Did not Do This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Action Item	**Difference of agreement = continuing - former students**
Told friends and family when I needed to prioritize school	1.7
Gained confidence in my engineering abilities	1.7
Developed study skills	0.9
Built friendships/ relationships with engineering students that did not look like me	0.8
Made my education a priority	0.6
Developed relationships with engineering faculty	-0.7
Found a "mentor" who could offer advice and encouragement	-1.3
Used mental health resources on campus	-1.4

In the findings previously discussed, former engineering students needed additional heuristics to overcome barriers while in engineering compared to continuing engineering students. Similarly, these findings suggested former engineering students took additional actions to overcome barriers while in engineering compared to continuing engineering students. In addition, findings suggested noticeable differences in the level of agreement between the actions continuing and former engineering students took to overcome barriers in engineering.

Actions: Continuing Males versus Continuing Female Engineering Students

Comparing continuing male and female engineering students in Table 19, males agreed (4.5 or higher) that eight actions were needed whereas females agreed 10 actions were needed to overcome barriers.

Males and females had similar levels of agreement. They both “built friendships/ relationships with engineering students that looked like me” (4.8 and 4.7, respectively), “developed study skills” (4.6 and 4.7, respectively), “built friendships/ relationships with engineering students that did not look like me” (4.5 and 4.5, respectively), “researched engineering majors to find the best fit” (4.5 and 4.4, respectively), and “set realistic academic expectations regarding the demands of my engineering workload” (4.4 and 4.5, respectively). Additionally, continuing males agreed they “leaned on friends and family for emotional support” (4.6), “used mental health resources on campus” (4.5), “joined engineering focused student clubs or organizations” (4.5), and “told friends and family when I needed to prioritize school” (4.5).

Continuing females also agreed they “told friends and family when I needed to prioritize school” (4.8), “contacted or followed up with the Office of Financial Aid” (4.8), “made my education a priority” (4.8), and “established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)” (4.7), “made a strategic plan for my four (4) years at site institution” (4.7), and “learned from other engineering students about the "good" engineering faculty” (4.5).

Table 19

Top-ranked Action Items for Continuing Male and Female Engineering Students

Prompt for items: “To overcome barriers I faced in engineering, I…”
0= Did not Do This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Action Item	**Males (n=5)**		**Action Item**	**Females (n=6)**
Built friendships/ relationships with engineering students that looked like me	4.8 (4.7)		I contacted or followed up with the Office of Financial Aid	4.8[1] (4.3)
Leaned on friends and family for emotional support	4.6 (4.3)		Told friends and family when I needed to prioritize school	4.8[1] (4.5)

Table 19 (cont'd)

Developed study skills	4.6 (4.5)		Made my education a priority	4.8 (4.4)
Used mental health resources on campus	4.5[3] (3.0)		Established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)	4.7[3] (4.0)
Researched engineering majors to find the best fit	4.5[1] (4.4)		Built friendships/ relationships with engineering students that looked like me	4.7 (4.8)
Joined engineering focused student clubs or organizations	4.5[1] (4.0)		Made a strategic plan for my four (4) years at site institution	4.7[4] (4.3)
Built friendships/ relationships with engineering students that did not look like me	4.5[1] (4.5)		Set realistic academic expectations regarding the demands of my engineering workload	4.5[2] (4.4)
Told friends and family when I needed to prioritize school	4.5[1] (4.8)		Learned from other engineering students about the "good" engineering faculty	4.5[2] (3.3)
			Built friendships/ relationships with engineering students that did not look like me	4.5 (4.5)
			Developed study skills	4.5 (4.6)

Note. **Superscripts indicate number students excluded from average because they "did not experience" this barrier**

Action Items with Largest Difference.

In Table 20, continuing males and females had the largest difference of agreement for answers including "used mental health resources on campus" (+1.5), "learned from other engineering students about the 'good' engineering faculty" (-1.2), and "developed relationships

with engineering faculty" (-1.4).

Table 20

Action Items with Largest Difference
Prompt for items: "To overcome barriers I faced in engineering, I…"
0= Did not Do This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Action Item	**Difference in agreement = continuing males – continuing female students**
Used mental health resources on campus	1.5
Developed time management skills	0.9
Found academic support resources on campus (e.g., tutoring, professor's office hours, etc.)	0.9
Joined engineering focused student clubs or organizations	0.5
I contacted or followed up with the Office of Financial Aid	-0.5
Established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)	-0.7
Learned from other engineering students about the "good" engineering faculty	-1.2
Developed relationships with engineering faculty	-1.4

In the findings previously discussed, continuing male and female engineering students differed in types of heuristics they perceived they needed to overcome barriers in engineering. The current findings suggest differences in the level of agreement between actions taken by continuing male and female engineering students. Findings also suggest that continuing female engineering students took additional actions to overcome barriers while in engineering compared to continuing male students.

Actions: Continuing Female versus Former Female Engineering Students

Comparing continuing female and former female engineering students in Table 21, continuing females agreed (4.5 or higher) that 10 actions were needed, whereas females agreed nine actions were needed, to overcome barriers.

Continuing and former females had similar, higher levels of agreement in that they "contacted or followed up with the Office of Financial Aid (4.8 and 4.5 respectively), "built friendships/ relationships with engineering students that looked like me (4.7 and 5.0, respectively), and "established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)" (4.7 and 4.5, respectively). Additionally, continuing females agreed they "told friends and family when I needed to prioritize school" (4.8), "made my education a priority" (4.8), "made a strategic plan for my four (4) years at site institution" (4.7), "set realistic academic expectations regarding the demands of my engineering workload" (4.5),"learned from other engineering students about the 'good' engineering faculty" (4.5), "built friendships/relationships with engineering students that did not look like me" (4.5), and "developed study skills" (4.5).

Former females also agreed in other ways. They "used mental health resources on campus" (5.0), "found a 'mentor' who could offer advice and encouragement" (4.8), "leaned on friends and family for emotional support" (4.6), "developed relationships with engineering faculty" (4.6), and "learned how to manage my feelings of alienation and invisibility" (4.5), and "researched engineering majors to find the best fit" (4.5).

Table 21

Top-ranked Action Items for Continuing and Former Female Engineering Students

Prompt for items: "To overcome barriers I faced in engineering, I…"
0= Did not Do This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Top ranked is defined as greater or equal to 4.5; Scores in (parentheses) are from the comparison group

Action Item	**Continuing Female Engineering Students (n=6)**		**Action Item**	**Former Engineering Students (all female; n=5)**
I contacted or followed up with the Office of Financial Aid	4.8[1] (4.5)		Used mental health resources on campus	5.0 (3.0)
Told friends and family when I needed to prioritize school	4.8[1] (3.0)		Built friendships/ relationships with engineering students that looked like me	5.0 (4.7)
Made my education a priority	4.8 (4.0)		Found a "mentor" who could offer advice and encouragement	4.8[1] (3.3)
Established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)	4.7[3] (4.5)		Leaned on friends and family for emotional support	4.6 (4.3)
Built friendships/ relationships with engineering students that looked like me	4.7 (5.0)		Developed relationships with engineering faculty	4.6 (4.4)
Made a strategic plan for my four (4) years at site institution	4.7[3] (4.0)		Learned how to manage my feelings of alienation and invisibility	4.5[3] (4.4)
Set realistic academic expectations regarding the demands of my engineering workload	4.5[2] (4.0)		Contacted or followed up with the Office of Financial Aid	4.5 (4.8)

Table 21 (cont'd)

Learned from other engineering students about the "good" engineering faculty	4.5[2] (4.3)		Established connections with other engineering students through social media platforms (e.g., TikTok, Instagram, GroupMe, etc.)	4.5[1] (4.7)
Built friendships/ relationships with engineering students that did not look like me	4.5[1] (3.7)		Researched engineering majors to find the best fit	4.5[1] (4.4)
Developed study skills	4.5 (3.6)			

Note. **Superscripts indicate number students excluded from average because they "did not experience" this barrier**

Action Items with Largest Difference.

In Table 22, continuing and former engineering females had the largest difference of agreement - by far - related to the action that they "used mental health resources on campus" (-2.0), in addition to, "found a 'mentor' who could offer advice and encouragement" (-1.5), "gained confidence in my engineering abilities" (+1.7) and "told friends and family when I needed to prioritize school" (+1.8).

Table 22

Action Items with Largest Difference
Prompt for items: "To overcome barriers I faced in engineering, I…"
0= Did not Do This; 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree
Largest difference is defined as greater or equal to +/- 0.5

Action Item	Difference in agreement = continuing females - former females
Told friends and family when I needed to prioritize school	1.8
Gained confidence in my engineering abilities	1.7
Developed study skills	0.9

Table 22 (cont'd)

Made my education a priority	0.8
Built friendships/ relationships with engineering students that did not look like me	0.8
Made a strategic plan for my four (4) years at site institution	0.7
Set realistic academic expectations regarding the demands of my engineering workload	0.5
Developed time management skills	-0.5
Found academic support resources on campus (e.g., tutoring, professor's office hours, etc.)	-0.7
Found a "mentor" who could offer advice and encouragement	-1.5
Used mental health resources on campus	-2.0

In the heuristic findings previously discussed, continuing and former female engineering students differed in the heuristics they perceived they needed to overcome barriers in engineering. Current findings also suggest differences in the level of agreement between actions taken by continuing and former females. Findings also suggest that continuing female engineering students took additional actions to overcome barriers while in engineering compared to former female students.

The survey provided some insight into understanding what actions Black engineering students took to overcome barriers in engineering, but were these actions also expressed during interviews? The most interesting survey findings discussed in the previous section will be discussed in combination with initial themes from the interview data in the next section.

Actions: Most Interesting Survey Findings

Continuing engineering students took actions to prioritize school and gain confidence in engineering while former engineering students utilized mental health resources and mentors to overcome barriers.

An analysis of results in Tables 17 and 18 found that although both continuing and former engineering students had similar levels of agreement on some actions items, the largest difference of agreement were actions continuing engineering students took when they "told friends and family when I needed to prioritize school" (1.7) and "gained confidence in my engineering abilities" (1.7), especially when compared to former engineering students. Former engineering students also had the largest difference of agreement compared to continuing engineering students in that they "found a 'mentor' who could offer advice and encouragement" (-1.3) and "used mental health resources on campus" (-1.4).

Continuing males took actions to use mental health resources while females engaged in actions to identify and develop relationships with their faculty.

Another interesting finding came from the analysis of Tables 19 and 20. Continuing males and females had similar levels of agreement for several actions, but the largest difference of agreement came from males who "used mental health resources on campus" (1.5) at a higher level of agreement compared to females. In contrast, females had a higher level of agreement in that they "developed relationships with engineering faculty" (-1.4) and "learned from other engineering students about the 'good' engineering faculty" (-1.2) compared to continuing males.

Female engineering students had heuristics in common and differed on other heuristics they needed to know to overcome barriers.

Further analysis of survey data in Tables 21 and 22 found that the largest difference in agreement - by far - was that former engineering students (all female) “used mental health resources on campus” (-2.0) at a higher level than continuing females. Continuing female engineers had the largest difference when they “told friends and family when I needed to prioritize school” compared to former engineering females. In addition, continuing females’ actions seemed to be related to engaging in specific action needed to remain in engineering while former engineering students' actions seemed focused on seeking resources to provide emotional support to get through engineering.

Survey analysis provided insights into the actions Black engineering students took to overcome barriers in engineering. But, were these findings supported in interview data? In the analysis of the interview data, Black students’ examples or experiences in engineering described in interviews yielded 4 initial heuristic themes that were duplicates from the 39 initial barrier themes, plus one additional theme: “time management.” These action themes were organized into broad supporting action themes that yielded two main action themes discussed in the next section - engaged in help seeking behaviors and engaged in behaviors toward sustaining mental health.

Actions: Main Interview Themes

Similar to the discussion of heuristics, Black students often discussed the actions they took or behaviors they engaged in while discussing the barriers they experienced in engineering. The main themes in Table 23 emerged when students were asked about the actions they took to address barriers they experienced in engineering. Students often expressed their actions in terms of engaging in help-seeking behaviors related primarily to connecting with academic support resources and engaging in behaviors to sustain their mental health and well-being.

Table 23

Main Themes from Interviews by Student

Numbers indicate amount each student discussed each main theme

Participant	**Student Type** Continuing Engineering Student (CEG) or Former Engineering Student (FEG)	**Main Theme 1:** Engaged in Help Seeking Behaviors	**Main Theme 2:** Engaged in Behaviors Toward Sustaining Mental Health
AW1	CEG	2	
AA2	CEG		1
LN5	CEG		
TN7	CEG	1	3
IM8	CEG	2	
AE9	CEG	1	
OE10	CEG	1	1
LA12	CEG		2
VM14	CEG	1	1
SC15	CEG	1	2
AW16	CEG	1	
LO3	FEG	1	1
CO4	FEG		1
LA6	FEG		1
SH11	FEG	1	3
MG13	FEG		1
	Totals	**12**	**17**

Main Theme 1: Engaged in Help Seeking Behaviors

Academic Support Resources: Tutoring, Help Sessions, Study Groups and Professor's Office Hours.

Continuing engineering students discussed behaviors they engaged in related to seeking academic support resources. For example, a continuing engineering student, IM8 stated,

> Finally my sophomore year, I was like cut that out - you need to go get help; you need to go ask for a tutor; you need to attend tutor sessions; you need to do something bc if you keep going down this path you are going to get similar grades in every single math class, then you are gonna be screwed. That was when I was like I need help.

Similarly, a continuing engineering student, SC15 mentioned,

> Oh, yeah, I don't know, but I need to definitely check out the math help room, sometime this week or next week because we have an exam coming up, you know, and so yeah it's kind of like me, taking the time and the opportunity to kind of like, go for these extra resources you know like I'm saying this right now like okay, I'm going to do this I'm going to do that, you know, kind of instilling that.

When asked about specific action she took, TN7, a continuing engineering student, stated,

> To overcome the barriers, go to more tutoring sessions, go to more. Um, like go to every single help session 'cause then yeah, that's the number one thing that I did like. I would always whenever the professor had office hours I would always go to them. I would always go to like whatever thing like if that TA was having a help session.

Relatedly, IM8 also discussed attending professors' and/or teaching assistants' office hours:

> I learned oh shoot I don't understand this, I need to ask a question or I need to go to office hours, like, I need to go find help if I am not going to ask questions in class I have to do this a different way.

OE10, a continuing engineering student similarly stated,

> I really just went to my professors and I think they helped me. In the best way that they could, and I felt that their help was enough with any of the issues that I that I brought to their attention.

These continuing engineering students' comments illustrated their belief that taking action to seek out academic help through tutoring and professor office hours was important to their success in engineering.

Communicated with Professors & Peers for Assistance.

Continuing and former engineering students discussed the need to communicate with professors and peers while in engineering. For example, continuing engineering student, AW1, mentioned,

> Like you know, the most semester I've built relationships just because, uh, I'm more into it after I guess it's more necessary like I need to do that like that was something I didn't do that I needed to do, like sitting office hours so you can build the relationship with the professors 'cause they're only there to help you.

Another continuing engineering student, VM14, discussed opening up to talking more to her professors:

> I think one of the things that I've been able to do at least this semester I've been like Talking to my professors more. That's one thing that I've been able to do more often, especially my engineering professors…Being open and being more vulnerable to the fact that I can now is actually knowing everything, but talk to my professor is asking people going more office hours more regularly and 'cause I feel like like freshman year is like oh, I don't want to be that person that doesn't know it. But then now it's like OK. I'm probably not going to get better if I don't ask, so just asking more.

Similarly, SH11, a former engineering student, mentioned the importance of "explaining to your professors like. You don't like. Don't be afraid to say you don't know what's going on like that you don't understand."

Continuing engineering student, AW16, discussed the importance of communicating with their faculty advisor:

> One of the big ones is just being like upfront and like asking the questions to your advisor, like utilizing those people. And not thinking that you have to do it all by yourself, you know, like there's people to help you.

These students demonstrate the benefits of building relationships with professors by being open to communicating your questions and academic needs.

Also interesting, former engineering student, LO3, discussed talking to her mentor [also a faculty member] and upper class peers:

> I'd say I'd definitely like talk to a lot of people about my decision. I talked to my mentor that I had with the like [Anonymous] Scholars Program. And then I also talked to like some of my other like friends I like were like in the same class or like year as me. And then I also talked to like upperclassmen as well.

Similar to LO3, continuing engineering student AE9 also mentioned reaching out to a peer stating "I did reach out to an upperclassman who's also from Nigeria so forgot to add him" and VM14 also mentioned the importance of "finding connections with Upperclassmen and getting their advice about things." These students provided insight into understanding the role of communicating or connecting with peers for academic guidance and support.

Main Theme 2: Engaged in Behaviors Toward Sustaining Mental Health

Establishing Friendships in Engineering.

Continuing and former engineering students discussed the role of establishing friendships in engineering. TN7, a continuing engineering student, stated, "trying to make friends in your classes, I think that's super helpful…No, like you're just gonna have to work a little bit harder to find friends, which I kind of wish that I did looking back." She went on to also say:

> I think you just have to work harder to find your group of people and they won't come to you as easily as I would say they would if you were like a guy or if you were just like a white woman, but...you don't necessarily have to find other like people of color or like women of color in stem, but finding like there's other people that will be kind to you, but it's going to take time for you to find them, and I think that's something to realize and understand that. I and also just being more open an even if the first kid doesn't like you and talk with you, that's OK like move on.

Similarly, SC15, a continuing engineering student, mentioned when asked about if making friends is an important action to take:

> I would definitely say so because it's kind of cool because you get also like a broader array of like different. I guess like backgrounds and thoughts and experiences and kind of like how they've grown, you know, and just how who they are as a person, which is really cool. So, Yeah.

When asked about establishing connections with other engineering students through social media platforms (i.e., Tiktok, Instagram, GroupMe, etc.) OE10 stated,

> I'd say that helped in ways. Kind of just getting to know people like in my engineering classes beyond just sitting in class and seeing them and saying hi and bye. I know the people that I associate with the most in my engineering classes are the ones that like I follow on social media. Just because like you know, I comment on your pictures or on your videos and things like that so it's not as awkward or uncomfortable making that connection or associating and communicating with them in or outside of class.

TN7, SH15, and OE10 comments provided insight into the challenges, their motivations and benefits of building relationships with peers while in engineering.

> AA2, a continuing engineering student discussed opening up to new friendships:
>
> Oh so I started like opening up to like I think my first year I was more so looking for things that I was used to. Sought like people who were like me who like look like me or whatever. And I think like biggest realization was like I'm not gonna always have that so opening myself up to like you know learn about I don't know, just not learn about but just like opening myself up to meeting and becoming close or yeah or friends with people that I normally wouldn't be friends with Uh, and just like taking the time to understand, understand them, talk to them like setting up lunch, lunch dates with them, things like that I feel like really helped overcome some of the barriers that I faced in engineering.

VM14, a continuing engineering student, discussed the impact of making friends that look like her:

> Being with people and like a lot of people, especially people of color, I feel like [Site Institution] that I've talked to at least most of my peers, 'cause most of my closest friends at school are probably people of color. And so, like being able to just be with them and talk about things that we're facing and talk about those things...talking about with other

> people helped like feel like, OK, I'm not the only one that's going through this and feeling this and just uhm, going through that has also helped me like bring my confidence and also realize that like I'm not just the only one in not feels alienated or anything like that so.

According to former engineering student, LA6:

> I definitely think talking to my friends was big. Um, in terms of like. Kind of seeing if it was like shared experiences. Um was definitely important in terms of like overcoming them and kind of feeling like I wasn't in this by myself.

SH11, a former engineering student, also discussed the role of friendship:

> Also, just like making sure you have friends and peers and understand what you're going through, whether it be the same major or like a different major, just it really helped me like some of those late nights having to like having people around me, rather like just sitting in like my room by myself. I would get unmotivated like what forget it Let me just go to bed. But having a people that you see like working hard as well. Struggling with you as well the material so like 4:00 or 5:00 o'clock in the morning sometimes really helps. So just having a network of people. Is very, very important.

AA2, VM14, LA6, and SH11 comments revealed the personal impact being open to building relations with peers had on each of them while in engineering.

Time Management: Made the Commitment to Study.

Continuing and former engineering students discussed the time commitment to studying they engaged in while in engineering. For example, TN7, a continuing engineering student, mentioned that “the level of studying that I had to commit myself to doing it was...very stress inducing. Yeah it was. It was super stressful.” LA12, also a continuing engineering student, mentioned, they “really had to learn how to study and how to actually be a good student. Former engineering student, CO4, discussed what she felt she needed to do when she studied in engineering: “Pushing myself to absorb more information and being a more attentive student at all times.” Similarly, MG13, a former engineering student, stated,

> just putting my all in my all and everything else. The last semester I was in engineering. I, oh my God. I put everything I like all the effort I've ever put into school ever in my life went into that semester because. It was hard like it was hard, it was just computer science classes and also like math. Everything at once. Where I was only serving one challenge class and then the rest were OK. It was like every challenging class. Every class was like challenging separate one so. I had to put in all the study techniques I had, go to every office hour, meet with professors all the time. Sleep was just not a thing, so I would say.

MG13 went on to discuss specifically what she sacrificed at times to study while in engineering:

> I had to sacrifice pretty much all of my everything regarding like self-care, and like sleep and eating right to make sure like I can just survive. So, I don't really think that was like a tip on how to get through 'cause it's not like the healthiest thing I did, but now it's like the only way I was making it through that semester.

These students' comments helped to better understand the stress, focus, and sacrifice they felt was needed to dedicate themselves to their engineering coursework.

Time Management: Established a Daily Routine.

Many continuing and one former engineering student discussed managing their time by establishing a regular routine. TN7, a continuing engineering student, discussed the daily routine of believing in herself stating,

> I guess I would say like believing in myself. Me 'cause I think half of it is, I guess, like the tangible thing that I did is like going to these office hours, but I think a large portion of it is like a mental battle like you have to push yourself in order to. To achieve because I feel as if you relax a second you will the work will over flood you. You won't have. You'll fall behind, which is, you know then I would really want to drop the major.

SC15, a continuing engineering student, provided more specifics about how she allocated specific time in her daily schedule:

> So, definitely adjusting my schedules, the most important thing I would definitely say that because now I have class from 11 to five which is amazing. I mean obviously one to five but 11 is fine too. You know, and then yeah just kind of like cutting back I would say like with Office Hours I'm not on the day you know we're all the freshmen are trying to do their homework you know that's pretty good. And also, like I don't really have a

> section this time, or anything but I'm not like doing like multiple office hours I just said like, all right, just the set of office hours. You know this class that's it.

Similarly, LA12, a continuing engineering student discussed her daily schedule,

> I have a schedule right now, even for next semester. I have when I'm going to go to class when I'm going to study when I'm going to work out everything is laid out and then I have like a little bit of room to adjust it in case I want to work more or maybe hang out with friends.

OE10, another continuing engineering student, mentioned maximizing her free time,

> maximizing more of the time that maximizing more of my free time and doing as much work as I can during those little pockets of free time, so that when I'm like doing when I'm in the time that I've like allotted to do my homework. I'm not getting more done, but I've I'm ahead of schedule because I've like used my free time to do some work.

Relatedly, former engineering student, SH11, offered that,

> Changing my environment to something that's more calm that is a bit less high strung is what I'm used to really, really helps me because like at first I used to do like schoolwork homework, whatever it was seven days a week all the time and then realizing that you must take time out for yourself. I started doing it only six to five days a week so like after I get outta class on Friday I still stick to this because it makes me feel so much better. After I get out of class on Friday, I don't touch anything until Saturday or Sunday depending on how much homework I have. So like Friday is my detox, my me time. I'm like whatever I need to do I get it done like it done Saturday or Sunday. So that was one of the that's literally the main thing I would say in that like that has transitioned over even when I did change my major I will take that Friday.

The daily routines these students shared illustrate the various actions students have taken to maintain their mental health each day while in engineering.

Used Mental Health Resources.

Two former engineering students discussed specific mental health resources they used on campus, such as LO3:

> I think the biggest like resource I used that first year was at the [Anonymous] Center

> like I went there a decent amount. Uh, like that first semester 'cause I was also going through like other things that were kind of like difficult to get through at the time, or were just making like academics and like that whole major process like more stressful than it needed to be. Whether it's like taking a break and like playing like games or like using like the essential oils or like getting a snack or on the I think on the other floor they have like a massage chair, whether it was like any of those things just help to like help me like reflect and like clear my mind I'd say.

SH11, also mentioned the same on-campus resource:

> They tell us about like the [Anonymous] Center and I didn't really utilize it because I was like, oh like it's far away from my dorm like whatever, like it probably doesn't help anyway. It's probably for certain people. I went one time literally changed my life I made. I made it a point to make like appointments every Friday just as like a detox for me. And that was like my self-care. For that whole semester, so making it a point just to like whether they have they have like tea and berries. And just like either whether it be like sitting in a room and looking at something I need to study or watching TV in a room for an hour or whatever it was just taking time to like, change my environment and it's such a smoothing environment.

Continuing engineering students more generally discussed their mental health. However, these former engineering students were the only two that specifically named an on-campus center they felt was an important resource they used when they were in engineering.

CHAPTER 5: DISCUSSION

This section will present two revealing findings. First, the variation in student experiences and descriptions of racial discrimination highlights how some Black engineering students experienced racial discrimination, that some Black engineering students did not experience racial discrimination, and that other Black engineering students' experiences with racial discrimination were inconclusive. Second, a comparison of continuing engineering students versus former engineering students' experiences in engineering reveals that former engineering students experienced less racial discrimination than continuing engineering students, that former engineering students needed to know about and took actions to find mental health resources more often than continuing engineering students, and that continuing engineering students built friendships and relationships with engineering students who did not look like them more frequently than former engineering students.

Interesting Finding #1: Variation in Student Experiences and Description of Racial Discrimination

Some Black Engineering Students Experienced Racial Discrimination

In the current study, some Black engineering students experienced racial discrimination. I expected all Black engineering students to have experienced racial discrimination as a barrier. The discrimination these students described was expected.

On the survey, four continuing engineering students "strongly agreed" or "agreed" that racial discrimination was a barrier. One continuing engineering student was "unsure" he experienced racial discrimination. In their interviews, each of these students described barriers categorized as racial discrimination. AW1, a continuing engineering student, expressed feeling that he was intentionally physically isolated by his peers:

> I remember freshman year, you know. Big chemistry classes. I was sitting in the middle row—you just have to grab a seat in a lot of those—and nobody sat next to me. Everybody got filled in around me…and I mean like some empty seats and some people further down. I was like 'wow like they came in a row like just didn't wanna sit next to you.' Like, that has never happened…like, I've never seen that. Like, I've heard stories from like my older relatives about stuff like that, but I had never actually experienced something like that happen to me.

CO4, a former engineering student, expressed feeling excluded by her peers when preparing to partner for group work stating,

> [In] science classes and labs and stuff—it was kind of like clear that certain people tend to group together. So yeah, there were times where I would only like the only person who would want to partner with me is like another black person.

Why were these experiences of isolation and exclusion salient for these students? One reason might be that the peers they interacted with intentionally treated these students as described based on preconceived and inaccurate stereotypes of Black people. The students who expressed experiences with racial discrimination may have had similar, prior experiences in non-engineering contexts that could have increased their ability to identify and name their experience within a new context. Padilla et al. (1997) posits that all students arrive to college campuses with certain levels of heuristic knowledge, which may explain how prior experiences of racial discrimination could influence their experiences with racial discrimination within their new engineering context. These experiences may have also been salient because they may have been hyper aware of their underrepresentation in the classroom and/or more broadly within engineering, which aided in their attribution of their peers' behaviors to the students being Black. Padilla et al. (1997) findings also suggest students that experienced racial discrimination in the current study may have dealt with "lack-of-presence barriers" described as "institutional culture and practices that marginalized, devalued, and omitted ethnic minority students" (p. 131).

There may be many reasons why the racial discrimination expressed as isolation and exclusion was salient for these students. What is most concerning is that these students experienced racial discrimination while in engineering. Black students continue to experience racism in engineering through acts of isolation/invisibility (Strayhorn et al., 2013) and microaggressions (True-Funk et al., 2021) to name a few. Even in their interactions with faculty (Park et al., 2022) Black students cannot escape racial discrimination. For decades, national programs and initiatives have focused on retaining Black students in engineering. However, the racial discrimination Black students experience each day in engineering may continue to work against the efforts of these national programs and initiatives.

Some Black Engineering Students Expressed Not Experiencing Racial Discrimination

Some Black engineering students expressed they did not experience racial discrimination. Assuming all Black engineering students would have experienced racial discrimination as a barrier, the finding that some students suggested they did not feel like they experienced racial discrimination was surprising.

On the survey, one continuing engineering student was "unsure," one former engineering student "strongly disagreed," and another former engineering student "disagreed" that racial discrimination was a barrier they experienced in engineering. These engineering students also did not believe they experienced racial discrimination. How could they say they did not experience racial discrimination?

This group of engineering students interview conversations seemed different from the group in the next section that did not discuss racial discrimination. The students in this section seemed to actively process their experiences with racial discrimination before confirming that,

no, they did not experience racial discrimination. For example, OE10 a continuing engineer stated,

> I'd say it was different and that's why I don't think that it affected me as much as I saw it, or that they explained that it affected them because it didn't happen like directly to me…So I'd say it has been a little different for me. Been different for me, but I could definitely like understand like their struggles with that same thing, even though I didn't experience it directly.

In this instance, OE10 seemed aware of the possibility of racial discrimination in engineering. However, she expressed that what was described to her or what she observed happened to others did not in fact happen to her. Triangulating her "unsure" survey response that racial discrimination was a barrier she experienced in engineering and her interview description that "I I don't think that it affected me," suggested that, OE10, perceived racial discrimination indirectly through others, but expressed that she had not experienced racial discrimination directly.

Former engineering student LA6 seemed to process her experiences with racial discrimination a little differently. She first stated, "I always feel like I've never experienced racial discrimination…that's not something…I've ever had to worry about." She then added that "even like if I were to describe a situation where it's clear racial discrimination I don't even feel like I would identify it as that," which was interesting but somewhat confusing. The additional processing LA6 seemed to exhibit by her last comment is that even if someone told her she was being racially discriminated against, she would not "identify it as that," a response which suggests that she could not under any circumstances perceive racial discrimination. It is difficult to understand LA6's comments that also suggest the complete denial or lack of acknowledgement that racial discrimination has or could happen to her. However, triangulating her survey response that she "disagreed" racial discrimination was a barrier and her interview comments previously described suggests LA6 believes that she did not experience racial

discrimination. These comments were surprisingly different from OE10, who at least seemed to acknowledge the possibility she could experience racial discrimination.

Relatedly, MG13 a former engineering student stated, “I wouldn't say discrimination, but a racial awareness” during her interview. Triangulating her survey response that she “did not experience” racial discrimination as a barrier with her interview comments, I asked her to clarify what seemed to be a contradiction in her survey and interview responses. She added, “I definitely had to if I needed to just get something done in a group with like where nobody else was black, I would have to say it in a very in a way that basically coddled my classmates.” This additional processing of her experience led to her categorizing her experience as “racial awareness,” which is also interesting. MG13 specifically described the process of how she coddled her classmates: “Everything I said came across as hostile. And it didn’t matter what. It was like why? I'm literally just making a suggestion.” As a result, “it's kind of like I had to always have, like the fake high pitch voice and end with like a question or if I like wanted them to do something, I'd have to ask a question.” This was done “so that they think that you know it was their idea instead of discussing it. If I wanted to get it done, this stuff like that, that was very tedious.”

MG13 seemed to be suggesting that when racial discrimination was present she needed to have racial awareness to manage the situation. MG13 managed the situation by “basically [coddling her] classmates” in order to have her presence and contributions within the group acknowledged. Such findings suggest that these engineering students processed their experiences with racial discrimination and decided they had not experienced racial discrimination.

How were these students' experiences different from the “inconclusive” students discussed in the next section? The students that confirmed they did not experience racial discrimination may be further along in processing their racial/ethnic identity (Hall & Carter,

2006). This may be why their experiences were different from the "inconclusive" students. As a result of being further along in processing their racial/ethnic identity, these students may have been more confident or comfortable with who they were as Black students in engineering (Cross et al., 1991; Phinney, 1992; Scottham et al., 2010). This confidence or comfort may have allowed them to better differentiate whether or not they had experienced racial discrimination. The strength to which Black students affirm or acknowledge their racial/ethnic identity has been found to mediate their experiences with racial discrimination (Hall & Carter, 2006). Whether we want to admit it or not, race or skin color is one of the first features people notice about others around them. Black students see their black or brown skin in the mirror every day, which influences their perspectives and how they navigate life. The assumption that all Black engineering students would have experienced racial discrimination as a barrier was not the case in this study. It is important that researchers acknowledge where Black students are in their racial/ethnic identity development and how this development may influence their experiences or perspectives related to racial discrimination.

The literature provides two other explanations that may explain why these Black students did not experience racial discrimination. First, these students may believe they are living in a "post racial era" (Johnston et al., 2015, p. 227) or these students could be "resisting decolonization" (Alemána & Gaytán, 2017, p. 129) as a coping mechanism.

The election of President Barack Obama in 2008 signaled for some the beginning of a "post-racial era" according to Johnston et al. (2015), who stated that people who believe they are living in a post-racial era recognize race as having historical significance and importance, but also believe that "race does not matter as a way to help move past the historical oppression associated with race and racism in the US" (p. 230).

Second, Alemána and Gaytán (2017) defined resisting decolonization as "a reluctance to grapple with a critical race pedagogy that destabilizes mainstream ideologies about race, racism, and racial identity in schools" (p. 129). Alemána and Gaytán (2017) also found when some students were asked about their racialized experiences, their responses suggested their belief that the topic was "not about me" (p.139) or was "too much about me" (p. 140). In order to better assimilate and participate in their university community, were these black students trying to avoid recognizing and breaking away from historical and institutional discrimination - the hallmark characteristics of the decolonization perspective? Or, in order to protect themselves from additional emotional trauma, were these black students trying to forget or deny that any racial discrimination occurred? It is important that researchers acknowledge the different perspectives Black students may have regarding racial discrimination based on their personal experiences, as these perspectives may influence the confirmation of their experiences with racial discrimination.

Some Black Engineering Students Experiences with Racial Discrimination Were Inconclusive

Some Black engineering students did not discuss racial discrimination. As previously mentioned, I expected all Black engineering students to have experienced racial discrimination as a barrier. To discover that some students did not discuss or even mention experiences with racial discrimination in their interviews was unexpected.

On the survey, two continuing engineering students indicated they were "unsure" if racial discrimination was a barrier. Two continuing and one former engineering students "strongly disagreed" or "disagreed" that racial discrimination was a barrier, while one continuing engineering student indicated they "did not experience" racial discrimination. During their interviews, these engineering students did not discuss any instances of racial discrimination.

These findings together seemed to provide inconclusive evidence detailing experiences with racial discrimination.

Why wasn't racial discrimination mentioned? First, these students might be "unsure" how racial discrimination impacted or hindered their experience in engineering. Why might these students be unsure about their experiences with racial discrimination? These Black students may be at a different place in their experience with the processing of racialized interactions with their engineering peers. The unsure response might be an indication that these students have not decided on how to categorize what they have been experiencing in engineering as Black students. Second, these students might not want to acknowledge they experienced racial discrimination. What happens if these students acknowledge racial discrimination as a barrier? They would have to have to deal with it or come to terms with it in some way. It is reasonable to assume the fear, worry, and/or added anxiety associated with acknowledging racial discrimination could be too stressful to discuss. Third, perhaps some students "did not experience" racial discrimination and in turn did not discuss it during their interviews. How can this be? Robinson (2016) provides one explanation in their findings that African-American males that "appeared non-threatening or unraced" did not report negative encounters related to race (p. 119). These particular students may not attribute their experiences with engineering peers as related to race, or may not categorize their experiences as racial discrimination, but something else. Or, maybe in their prior experiences they have never felt that they were treated differently because they were perceived by others or self-identify as Black. Investigating these points more in-depth was beyond the scope of this study. These constructs could be useful in future studies that extend the findings discussed in the current study.

Regardless of whether these students were still processing, did not want to deal with the fear, worry, and/or added anxiety of discussing their experiences, or believed they did not have experiences with discrimination because they are Black, it remains important to highlight these students' experiences which may be different from the experiences of other Black engineering students.

It is reasonable to assume that these Black students may not want to acknowledge racial discrimination due to the added trauma it may cause them. Racial discrimination is a known predictor of negative psychological outcomes (Pieterse et al., 2010). Pieterse et al. (2010) found that "perceptions of discrimination contributed an additional 10% of variance in trauma-related symptoms for Black students" (p. 255), and that racial and/or ethnic discrimination was found to be a significant, positive predictor of trauma-related symptoms for Black students. It is also reasonable to assume these students were at different stages in processing their racial or ethnic identity. Research suggests a relationship between racial or ethnic identity status and perceived racial discrimination (Hall & Carter, 2006; Phinney, 2006; Scottham et al., 2010). Phinney (2006) suggested "people who perceive more discrimination are likely to engage in more exploration" (p. 130). Hall and Carter (2006) suggest a positive relationship between racial identity and perceived discrimination. Their findings indicated racial identity status accounted for 15% of the variance in perceptions of discrimination and was a significant predictor of discrimination for Afro-Caribbean adults over their lifetime. However, Seaton et al. (2012) found racial discrimination did not predict being in a specific racial identity status nor did it predict the specific racial identity trajectory for black adolescents over time. Although the literature on the topic does not provide definitive evidence to support the current study findings, Black students' willingness to discuss racial discrimination varied.

Interesting Finding #2: Continuing Engineering Students vs. Former Engineering Students

Former Engineering Students Experienced Less Racial Discrimination than Continuing Engineering Students.

Former engineering students experienced less racial discrimination than continuing engineering students. I assumed that former engineering students would have indicated racial discrimination as a barrier and confirmed discrimination as a reason they left engineering. This was unexpectedly not the case.

Continuing engineering students survey responses varied: some strongly agreed or agreed (n = 4), some were unsure (n = 4), some strongly disagreed or disagreed (n = 2), and one did not experience (n = 1) racial discrimination in engineering as a barrier. In contrast - and surprisingly - most former engineering students strongly disagreed or disagreed (n = 4) racial discrimination was a barrier. Interviews indicated variations in how students perceived racial discrimination, but again only one former engineering student expressed she experienced racial discrimination. How could this be?

First, former engineering students in the current study averaged 2.6 semesters in engineering with only one student remaining in engineering through her fourth semester. This suggests former engineering students did not stay in engineering long enough to experience racial discrimination. As a result, they may have had less opportunity for exposure to racial discrimination compared to continuing engineering students.

Second, most of the former engineering students participated in the same STEM retention program which could have also shielded them from experiencing racial discrimination during their first two semesters. Students mentioned two scholar programs during interviews: a scholars program coordinated through the College of Engineering & College of Science that provided

faculty mentoring and had specific STEM courses that students attended as a cohort their first two semesters in college, and another program which did not provide specific STEM courses by cohort, but provided additional tutoring and faculty mentoring support for historically marginalized scholars pursuing STEM majors throughout all four years of undergraduate courses. Students could not participate in both STEM-focused scholar's programs; however, four of the five former engineering students participated in the College of Engineering & College of Science scholar's program. The cohort only STEM courses during the first two semesters of this program may have contributed to these former engineering students not experiencing racial discrimination. In contrast, the only former engineering student not in the College of Engineering & College of Science scholars program indicated she did experience racial discrimination.

Third, former engineering students indicated other barriers that were more salient and impactful than racial discrimination, including "difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities." This answer suggests that former engineering students' focus may have been elsewhere—maybe just on trying to get academics done. Padilla et al. (1997) supports this notion that former engineering students may have been dealing with other barriers related to discontinuity barriers – "obstacles that hinder a student's transition from high school to college" (p. 130), lack of nurturing barriers – "absence of supportive resources on campus to facilitate adjustment and development" (p. 131), lack of presence barriers – "absence of minorities in the curriculum, university programs, and general university population" (p. 131) , and/or resource barriers – "lack of money and difficulties associated with financial aid" (p. 131).

This study demonstrates the complexity of just how racial discrimination impacts

Black engineering students' decisions to stay or leave engineering. The literature already documents Black student experiences with racial discrimination and self-esteem (True-Funk et al., 2021), the negative impact discrimination has on academics (Solorzano et al., 2000), and on academic motivation (Reynolds et al., 2010). The experiences expressed by some continuing engineering students in this study confirms that, yes, racial discrimination exists in engineering.

What can be learned from engineering students who experienced discrimination yet stayed in engineering? Do they experience more discrimination because they are in engineering longer? Do they develop more friendships with white engineering peers that leads to more discrimination? Are their mediating factors that lessen the impact discrimination has on their academic success?

This study highlights additional factors that impact Black students' reasons for leaving engineering; namely, four of the five former engineering students did not experience racial discrimination. If racial discrimination was not the reason they left engineering, why did they leave? Do some STEM retention programs isolate black students with other students of color thereby shielding them from discrimination? Are there more salient challenges that influenced their decision to leave? The fact that former engineering students did not experience racial discrimination does not mean the discrimination continuing engineering students experienced was not real. On the other hand, the assumption should not be made that racial discrimination experienced by continuing engineering students was the reason former engineering students left engineering.

Former engineering students needed to know about and took action to find mental health resources more often than continuing engineering students.

Former engineering students sought out mental health resources more often than continuing engineering students. I assumed that former engineering students would experience more mental health issues or concerns than continuing engineering students. Unexpectedly, all five former engineering students affirmed that they needed to know about mental health resources to overcome barriers in engineering. Additionally, seven of eleven continuing engineering students (63%) indicated needing knowledge about mental health resources. In addition, the highest agreement across former engineering students was they acted to utilize mental health resources. Could this be one reason why former engineering students decided to leave engineering?

Continuing engineering students strongly agreed (n = 3) or agreed (n = 4) they needed to know about campus mental health support resources to overcome barriers they experienced. All five former engineering students strongly agreed (n = 2) or agreed (n = 3) they needed to know about mental health resources. Another distinction between groups was that former engineering students indicated they took additional actions to utilize mental health resources (M = 5.0, SD = .000) compared to continuing engineering students (M = 3.6, SD = 1.517). This finding suggests that taking action to seek mental resources was important for former engineering students to manage barriers while in engineering.

Previously presented in results, former engineering student, LO3, identified the campus resource that helped her most during her first year: “I think the biggest like resource I used that first year was the [Anonymous Center] like I went there a decent amount.” SH11, a former engineering student, also described her experience with the same campus resource:

> They tell us about like the [Anonymous Center] . . . I went one time literally changed my life. I made it a point to make like appointments every Friday just as like a detox for me. And that was like my self-care.

In contrast, continuing engineering student OE10 explained why she did not seek out on-campus mental health resources:

> I usually just like cried and then got back to work. I mean, I didn't really feel like any of the mental health resources would have helped because I feel like most of my issues or most of the things I struggled with or that I was upset about was just It was just my grades really, and I didn't really think that going to like therapy or counseling was gonna help me like pick up my grade.

These examples highlight how former and continuing engineering students took different actions related to their mental health.

The current study suggests that 75% of continuing and former Black engineering students surveyed felt they needed knowledge about mental health resources to overcome barriers they experienced in engineering. The magnitude to which both continuing and former engineering students expressed needing information about mental health resources is noteworthy. Even more alarming is the higher percentage of former engineering students versus continuing engineering students who agreed mental health information was needed. Were mental health issues or concerns a factor that contributed to former engineering students' decisions to leave engineering? If mental health concerns were also indicated by some continuing engineering students, why did they remain in engineering? What unique stressors do Black students experience that may impact their mental health while in engineering?

Black students have to cope with unique stressors. Padilla et al. (1997) provides a categories of barriers successful students must overcome, but mental health is not addressed in any of the categories in their Expertise Model of Successful College Students. Padilla et al.’s (1997) resources barrier category should be expanded beyond “lack of money” and “financial aid

system" (p. 130) to include mental health. In the current study, the magnitude to which former engineering students expressed needing information combined with the high level of agreement that each of them took actions to seek out mental health resources should be warning signs. The fact that some continuing Black engineering students also expressed the need for mental health support is another warning sign that these students need mental health resources and support. These mental health concerns may have been factors in former engineering students leaving engineering. The unique stressors indicated in the literature may also continue to be a factor impacting the academic success and psychological health of continuing engineering students who remain in engineering.

Researchers have found these stressors include, but are not limited to, microaggressions/macroaggressions (Forestbank & Cuellar, 2018; True-Funk et al., 2021), minority status stress (McClain et al., 2016), stereotype threat (McGee & Martin, 2011; Steele, 1997; Steele & Aronson, 1995), isolation/invisibility (Strayhorn et al., 2013), and negative perceptions of university environments (Fries-Britt et al., 2010; Kuh et al., 2006; Wei et al., 2011). These specific constructs were not examined in the current study, but could be useful in future studies.

Continuing engineering students built friendships/relationships with engineering students that did not look like them more often than former engineering students.

Continuing engineering students built friendships/relationships with engineering students that did not look like them more often than former engineering students. This idea may be important because it suggests that having a broader social network may be associated with academic success in engineering.

Continuing engineering students' took actions to build friendships/relationships with engineering students that did not look like them (M = 4.5, SD = .527) to overcome barriers in engineering than did former engineering students (M = 3.7 , SD = 1.528). In contrast, former engineering students primarily took actions to build friendships/relationships with engineering students who looked like them (M = 5.0, SD = .000).

In interviews, continuing engineering students described the benefits of developing relationships with engineering students who did not look like them. AA2, a continuing engineering student, realized he needed to open up:

> Oh so I started like opening up to like I think my first year I was more so looking for things that I was used to. Sought like people who were like me who like look like me or whatever. And I think like biggest realization was like I'm not gonna always have that so opening myself up to like you know learn about I don't know. Just not learn about but just like opening myself up to meeting an becoming close or yeah or friends with people that I normally wouldn't be friends with. Uh, and just like taking the time to understand, understand them, talk to them like setting up lunch, lunch dates with them, things like that I feel like really helped overcome some of the barriers that I faced in engineering.

Similarly, when asked about building friendships with people who don't look like you, continuing engineering student SC15 responded,

> I would definitely say so because it's kind of cool because you get also like a broader array of like different, I guess, like backgrounds and thoughts and experiences and kind of like how they've grown, you know, and just how who they are as a person, which is really cool. So, yeah.

TN7, also a continuing engineering student said "trying to make friends in your classes, I think that's super helpful."

From the perspective of a Black girl in engineering, TN7 remarked, "you're just gonna have to work a little bit harder to find friends, which I kind of wish that I did looking back." When asked to provide a bit more detail regarding her response to strongly agreeing to

establishing connections with other engineering students through social media platforms, continuing engineering student, OE10, stated,

> I'd say that helped in in ways. Kind of just getting to know people like in my engineering classes beyond just sitting in class and seeing them and saying hi and bye. I know the people that I associate with the most in my engineering classes are the ones that like I follow on social media. Just because like you know, I comment on your on your pictures or on your videos and things like that so it's not as awkward or uncomfortable making that connection or associating and communicating with them in or outside of class.

In contrast to continuing engineering students, former engineering students' comments regarding friendships in engineering were more general. SH11 suggested that "having a network of people…is very important." LA6 concurred:

> I definitely think talking to my friends was big. Um, in terms of like. Kind of seeing if it was like shared experiences. Um was definitely important in terms of like overcoming them and kind of feeling like I wasn't in this by myself.

Continuing engineering students felt it was important to build relationships with peers who did not look like them. They described the benefits of taking these actions as allowing them to learn from those with "backgrounds and thoughts and experiences" different from their own. It was furthermore "helpful" in lessening the "awkward[ness] or uncomfortable[ness] making that connection or associating and communicating with them." These findings are supported in Padilla et al. (1997) as a way continuing engineering students addressed lack-of-nurturing barriers by knowing that "they had to nurture themselves or acquire nurturing from others" and "being persistent about meeting their own needs" (p. 131).

How would continuing engineering students use the knowledge gained from their diverse social networks? How might these diverse social networks facilitate continuing engineering students' academic success? As a result, did these diverse social networks aid in their decision to remain in engineering? Yosso's Model of Community Cultural Wealth (2005) discussed various

forms of capital that “are not mutually exclusive or static, but rather are dynamic processes that build on one another as part of community cultural wealth” (p. 79). Social capital includes “networks of people and community resources (Yosso, 2005, p. 79). Continuing engineering students may have used their diverse friendships/relationships with their peers that did not look like them to build social capital. According to Yosso (2005), continuing engineering students would have used this capital to gain education and access to other information and resources that may have enhanced their learning and academic success while in engineering. Navigational capital includes “skills of maneuvering through social institutions” (Yosso, 2005, p. 80). Continuing engineering students may have also used the social capital gained through their diverse friendships and relationships with peers to maneuver within and across institutional structures that were not built for or which currently benefit people of color. Successful students of color are then able to connect their social networks to facilitate continued movement through various places and spaces (Yosso, 2005).

It is assumed that diverse social networks aided in continuing engineering students' decisions to remain in engineering. Former engineering students did not seem to perceive the same benefits of building a diverse social network with peers that did not look like them. As a result, this may have been a contributing factor in why they left engineering while continuing engineering students persisted in engineering.

CHAPTER 6: IMPLICATIONS FOR RESEARCH AND PRACTICE

Examine unique variations in Black engineering students' experiences to avoid harmful generalizations across racial/ethnic student populations

It is important to understand how variations within Black student populations are distinct from each other and other racial/ethnic student populations. It is also important to learn how Black engineering students' experience**s** collectively and independently impact their success and retention in engineering. The variation in Black student experiences with racial discrimination in this study suggested individual factors within Black student populations may influence why some students discussed experiencing racial discrimination, some indicated they were unsure, and others expressed they did not experience racial discrimination at all. These findings provide further evidence that Black engineering students are not a homogenous group.

Black engineering students face unique barriers while pursuing undergraduate degrees in engineering. Yet, engineering education researchers (Borrego et al., 2005; Marra et al., 2012; Meyers & Mertz, 2011; Zhang et al., 2004) often aggregate Black student experiences to form a larger comparison group with other minoritized student populations to gain statistical significance. It is harmful to generalize experiences across all Black students. In the current study, some Black students did not experience racial discrimination.

This does not mean that we have progressed in engineering to the point where faculty researchers, administrators, and/or other stakeholders at the site institution can assume we have now moved beyond racial discrimination. Forty-three percent of Black students did experience racial discrimination to the point they perceived it hindered their progress in engineering. This is evidence that racial discrimination is still an issue.

Researchers should not use deficit-based methods with Black student populations (Borrego et al., 2005; Min et al., 2011) that perpetuate misconceptions about the ability of Black students, which is racist in the assumption that Black student achievement is inferior to White student achievement. Using their research as evidence, faculty researchers at the site institution should demand that engineering administrators create research-based, anti-racist environments that are inclusive of Black engineering students by critically examining the social and institutional structures that perpetuate engineering as a White, male-dominated field that ignores narratives of Black engineering student success (Mejia et al., 2018).

Investigate aspects of STEM retention programs as contributing factors some Black students leave engineering.

Former engineering students indicated other barriers that were more salient than racial discrimination compared to continuing engineering students.

Experiencing less racial discrimination still led former engineering students to leave engineering while continuing engineering remained. This study found that former engineering students averaged 2.6 semesters before leaving. Also, four of the five former engineering students participated in the same STEM retention program focused on retaining students of color in engineering at the Anonymous Institution. Former engineering students indicated other barriers that were more salient and might have been more impactful than racial discrimination on their decision to leave engineering.

Berryman (1983) posits there is a narrow window of time URMs will enter the STEM pipeline. STEM retention programs attempt to identify and support students of color during this window. Landis (1988) agreed the structure of Minority Engineering Programs (MEPs) that put the greatest emphasis of support on the first year transition increased the likelihood of keeping

students of color in STEM majors. However, the structure of STEM retention programs in early semesters may not address barriers experienced by some Black students who still left engineering after participating in these programs. In doing so, these engineering programs may be creating unnecessary barriers for Black students and contributing to their departure.

For example, do STEM retention programs assess Black students' racial identity development when they start the programs? We can assume that each student that self-selected to participate in these STEM programs has thought about their racial identity at some point to determine if they meet the specific program criteria aimed at recruiting students of color. The variation in Black students' racial identity development could explain their varied racialized experiences (e.g. racial discrimination), success, and retention in the program. Racial identity statuses "reveal the extent to which an individual has explored and committed to one's racial identity" and racial identity content "provides information about how important and what racial identity means to an individual" (Yip, Seaton & Sellers, 2006, p. 1506). If STEM retention programs do not assess and understand these aspects of racial identity development of the Black students' in their programs, these programs meant to lessen barriers could be creating more salient, unintended barriers for some Black students (e.g. feelings of being an imposter in engineering). Future research should examine racial identity development as a construct to understand variations present in the current study.

It is also important to critically examine how the structure of STEM retention programs may hinder the development of key social networks Black students need to succeed in engineering. This point is discussed further in the next section.

Continuing engineering students benefited from building friendships or relationships with engineering students that did not look like them compared to former engineering students

Establishing friendships or relationships with other students who did not look like them may have facilitated continuing engineering students' academic success and/or retention in engineering. Future research should also consider why former engineering students did not benefit from these same social networks.

One of the important findings of this study was that continuing engineering students agreed at a higher level than former engineering students that "building friendships/relationships with engineering students that did not look like [them]" helped them to overcome barriers faced in engineering. Continuing engineering students also described the benefits of taking actions to develop relationships with engineering students who did not look like them.

Another important finding of this study was that during their first-year, four of the five former engineering students participated in the same STEM retention program focused on retaining students of color in engineering at the Anonymous Institution. In contrast to continuing engineering students, former engineering students agreed at a higher level that "building friendships/relationships with engineering students that looked like [them]" helped them overcome barriers.

Continuing engineering students took actions to build broader social networks with students who looked like them and with students who did not. Strong support systems (Kuh et al., 2006) and family-type environments among peers and faculty (Fries-Britt et al., 2010) facilitate better academic performance and higher graduation rates for African American students. The current study supports the notion that continuing engineering students may have felt that they needed more supportive social connections to be successful in engineering so they

sought and created their own support systems. The actions continuing engineering students took to build their own social capital (Yosso, 2005) through diverse social networks highlights the additional effort they put in to stay in engineering that former engineering students did not.

In light of these findings, engineering administrators at the site institution should reevaluate the way targeted engineering programs or initiatives are structured to ensure that Black students are socially positioned to succeed in engineering. If bridge programs, minority scholarship programs, and minority engineering programs create racially or ethnically segregated environments where Black students are only learning alongside or creating social networks with other students who look like them, these programs may be setting some students up to fail in engineering after they leave these environments. These segregated environments may lead Black students to feel as if they experienced a bait and switch - made to believe that the social skills they had developed with only Black students in these programs will facilitate successful navigation in predominantly White engineering environments outside of these programs.

A key component of bridge programs, minority scholarship programs, and minority engineering programs should be creating spaces for intentional conversations and activities for Black students to build social networks with people who look like them as well as with those who do not. Measures of successful students participating in these types of programs have not typically included an assessment of how well these students build social networks. For example, Lam et al. (1999) operationalized success in a minority engineering program (MEP) as 1) retention (or completion of the MEP) and subsequent graduation from the University; and 2) GPA at graduation only for students that completed the MEP. Maton et al. (2000) and Maton et al. (2016) both measured student success based on bachelor-level retention, graduation rates in STEM majors, STEM GPA, overall GPA, and STEM graduate and professional school

admission rates. Black students benefit from building social networks with other Black students, but this limited social network may shield them from experiencing the reality of stressors like racial discrimination. Intentionally broadening these social networks to include non-Black peers may aid Black students in learning information and making the important social connections needed to successfully navigate majority spaces in engineering.

Psychological well-being should be prioritized as an important engineering outcome

Former engineering students' reasons for seeking out mental health resources differed from continuing engineering students. This study found that 63% percent of continuing students and 100% of former engineering students indicated they needed to know about mental health resources, while 100% of former engineering students agreed they needed to seek out mental health resources to help them overcome barriers.

Black engineering students need mental health resources. Black students in the current study sought to preserve their mental health and well-being by reframing their thinking to deal with varied academic success in engineering courses, by balancing engineering demands while pursuing other interests that gave them joy, establishing friendships with engineering peers, creating daily routines to manage their time more effectively, and seeking out on-campus mental health resources. Some Black students also described needing mental health resources to manage the stress of projecting the persona of a strong Black man/woman. The site institution should incorporate positive mental health within departmental and college learning outcomes.

Implement targeted mental health resources for Black engineering students

Mental health concerns may have been a contributing factor in why former engineering students in the current study averaged 2.6 semesters in engineering. Engineering research supports the trend that Black, Hispanic, and Native American students have a greater likelihood

of leaving engineering before their third semester (Marra et al., 2012; Min et al., 2011) but does not link their departure to mental health factors.

When former engineering students take action to seek out mental health resources, it suggests that these students may need a particular type of mental health support before, during, and after their engineering experience. The notion that continuing engineering students needed to know about mental health resources but were less likely to seek out these resources suggests these students may need a different type of targeted mental health support which encourages them to engage with campus mental health resources while they remain in engineering. This type of differentiated mental health support may increase continuing Black engineering student achievement, success, and retention.

In addition, student-facing professional academic advisors and faculty should be trained in intercultural competency and mental health awareness to support Black students who may be managing personal stressors such as those mentioned above that could impact their mental health while in engineering. Engineering schools or colleges should implement program-wide mental health assessments with an intentional focus on reviewing data from Black students. This type of layered mental health assessment and targeted support may help retain more Black students in engineering.

For decades, researchers have identified factors that impact Black engineering students' success in engineering including unique cognitive and/or non-cognitive factors such as GPA (Borrego et al., 2005; Sheppard et al., 2010), gender (Min et al., 2011), lack of campus support systems (Fries-Britt et al., 2010; Kuh et al., 2006; Strayhorn et al., 2013). Past research has underestimated the mental health needs of Black students. Findings from the current study suggest some Black engineering students have tried to address their mental health needs while in

engineering, yet they still left. Mental health concerns may not be the only reason Black engineering students face challenges while in engineering, but evidence from the current study indicates a strong need to prioritize mental health for Black engineering students. Researchers need to refocus efforts on understanding the mental health status of Black engineering students. In addition, researchers should explore the impact Black students' mental health status may have on their achievement and subsequently the persistence engineering to better support these students while in engineering.

CHAPTER 7: LIMITATIONS

Research Design Limitations

This study used an explanatory sequential mixed methods approach to collect data in two phases (Creswell & Creswell, 2018) - first using an online Qualtrics survey, and second through semi-structured Zoom follow-up interviews with all participants.

A limitation of the Qualtrics survey was that it was not pilot tested on a similar student population before being used in the current study. Pilot testing may have provided insight into how participants understood items on the survey, identified items that were unclear to participants, or identified items that should be removed. Pilot testing may have also increased the measure's validity and contributed to the reliability of the measure over time. Although the items were not pilot tested in the current study, these items were guided by Padilla's (1994, 2010) student success modeling approach, as well as previous research that also examined Black students in engineering (Blount, 2018; Felder Thompson, 2005; Ford-Edwards, 2002; Henley & Roberts, 2016; Myers, 2008; Robinson, 2016), alongside Lent and Brown's (2005) Engineering Fields Questionnaire. These items were revised slightly to better fit Black engineering students' experiences at the site institution. Moving forward, survey items should be further examined for external validity and reliability across other Black engineering student populations at other institutions.

Another limitation of the Qualtrics survey was the length of the survey (87 items). The survey length could have increased participant survey fatigue. Prior to administering the survey, the structure of the items did not appear to require reverse coding based on what seemed to be the neutral wording of each item. In future survey administration, reverse coding some items

may lessen the likelihood of survey fatigue impacting participant responses and would be an opportunity to check the consistency of participants' responses on similar items.

An additional survey limitation was the wording of the survey item: "Difficulty finding ways to study effectively for engineering courses despite having competing demands for my time." The wording of this item was an error that may have influenced participant responses by creating confusion on how to respond to this item. The original item on the Lent and Brown (2005) Engineering Fields Questionnaire read "find ways to study effectively for engineering courses despite having competing demands for your time." In the future, a revision of this question could read "Difficulty finding ways to study effectively for engineering courses *because* of competing demands for my time" to lessen potential confusion and guide participants to consider whether the difficulty finding ways to study effectively for engineering courses because of competing demands for my time is a barrier they experienced.

A limitation of the interviews was that the data was collected during a global pandemic. This required interviews to be conducted via Zoom in various environments chosen by each participant. These varied environments, even if perceived as more or less private, may have influenced participants' willingness to respond to certain questions. In addition, the personal toll of the global pandemic on each participant may have influenced responses in an attempt to lessen additional trauma already experienced as a result of the pandemic. Future replications of this study should take place ideally not during a global pandemic in order to have in-person interviews and to lessen the impact of a pandemic as a confounding variable.

An additional limitation of the interviews was not following up with participants to share an initial analysis of their interview to compare with their actual intending meaning. Following up with participants would have strengthened the validity of participants' responses during the

interviews. However, in the current study, survey data was used to support or challenge themes that emerge in the semi-structured interviews and vice versa to enhance the reliability or trustworthiness of the data. Moving forward, following up with participants to confirm theme analysis has captured their intent as well as an independent comparison of survey and interview themes would increase the trustworthiness of the data.

Data or Statistical Limitations

The sample was chosen from a target population of Black undergraduate students currently in the College of Engineering or who were in the College of Engineering and left to pursue a non-engineering major at the site institution.

A limitation of the study was the small target population and actual sample size. The small target population of upper-class Black students at an anonymous institution did not allow for pilot testing of the survey on similar students. As previously discussed, pilot testing may have contributed to the validity and reliability of the measure over time. Small sample size also limited the type of statistical analysis performed on the data. Although quantitative data analysis was restricted to descriptive statistics (including mean, frequency, and standard deviation), the current study provided meaningful contributions to understanding the experiences of Black engineering students. Finally, the small sample size did not allow for qualitative responses to the point of data saturation. Future research should aim for a larger sample size to address these limitations to improve validity and reliability of the measure. A larger sample size would allow for more powerful statistical analysis that may lessen the influence of outliers.

Impact Limitations

This study took place at a medium sized, private, Midwestern university in fall 2020. A limitation of the single-site study design is that the findings cannot be generalized beyond the

anonymous institution of this current study. Another limitation is that findings cannot be generalized to non-Black engineering populations at the single-site anonymous institution or to Black students in other STEM majors at the same institution. Although generalization is limited, the intention of the current study was to only explore the experiences of Black continuing and former engineering students. Future research may include Black students from other STEM majors to allow for the generalization of findings.

CHAPTER 8: CONCLUSION

The purpose of this study was to explore how Black undergraduate engineering majors navigate barriers by gaining knowledge from their experiences and taking action to succeed in their program. This study addressed critiques of past research, including: implicit or explicit use of deficit approaches promote stereotypes and misconceptions about the achievement of Black students; research methods that combine URM data within samples heavily populated with White students leads to the invisibility of Black students in engineering; and that using only graduation rates and GPA as the bases for defining URM student success ignores the harmful limitations of these assessments.

This study utilized anti-deficit and expertise models of student success as critical frameworks to counter deficit narratives of Black student achievement in engineering. The explanatory sequential mixed methods approach illuminated the experiences and achievement of Black students by focusing only Black continuing and former engineering students to answer the following main research questions:

RQ1. What barriers do Black engineering students experience?

RQ2. What heuristic knowledge do Black engineering students need to overcome barriers?

RQ3. What specific actions do Black engineering students take to overcome barriers?

An interesting finding with barriers experienced was that variation in students' experiences and descriptions of racial discrimination suggested the racialized experiences of Black engineering students are not all the same. Some Black students still perceive racial discrimination in engineering while factors beyond the scope of this study may continue to influence the perception of discrimination for other Black students. Other interesting findings

suggested key differences between continuing and former engineering students. Former engineering students experienced less racial discrimination and needed to know about and took action to find mental health resources more often, while continuing engineering students built friendships/relationships with engineering students that did not look like them more often than former engineering students. These differences may have influenced continuing engineering students' success while former engineering students found success in areas outside of engineering.

Moving forward, research should continue to explore the unique racialized barriers Black engineering students face while pursuing an undergraduate engineering degree. Diversity, equity, and inclusion-focused assessments should be a part of strategic planning to ensure that engineering colleges and schools foster environments that eliminate barriers rather than create more barriers for Black students. These assessments should specifically explore aspects of STEM retention programs as contributing factors in some Black students leaving engineering. Finally, the role of Black engineering students' mental well-being as a factor in their decision to stay or leave engineering should be of particular importance for researchers and engineering administrators.

This study provided findings that support defining Black student success in engineering as being able to navigate unique barriers, identify heuristic knowledge needed to address these barriers, and taking action to manage these barriers in order to move forward on their path in engineering. However, the experiences of Black students while in engineering are complex. This study only touched the surface in further highlighting the complexity of Black engineering students' experiences. To meet the increased demand for more engineers in the U.S. workforce, national efforts continue to focus on keeping Black and other students of color in engineering

pipelines. These pipelines will continue to lose Black students if their unique lived experiences are not acknowledged as invaluable to their success in the field of engineering.

REFERENCES

Alemán, S. M., & Gaytán, S. (2017). 'It doesn't speak to me': understanding student of color resistance to critical race pedagogy. *International Journal of Qualitative Studies in Education, 30*(2), 128–146. https://doi.org/10.1080/09518398.2016.1242801

Aronson, J., Fried, C. B., & Good, C. (2001). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of Experimental Social Psychology, 38*(2), 113–125. https://doi.org/10.1006/jesp.2001.1491

Ashley, M., Cooper, K. M., Cala, J. M., & Brownell, S. E. (2017). Building better bridges into stem: A synthesis of 25 years of literature on stem summer bridge programs. *CBE Life Sciences Education, 16*(4). https://doi.org/10.1187/cbe.17-05-0085

Berryman, S. E. (1983). Who will do science? Trends, and their causes in minority and female representation among holders of advanced degrees in science and mathematics. A Special Report. A Special Report: The Rockefeller Foundation, 148. http://files.eric.ed.gov/fulltext/ED245052.pdf

Blount, L. (2018). The key to academic success: A qualitative phenomenological study on first-generation African American students who successfully graduated from a predominantly white institution. *Education Doctoral*. Paper 370. https://fisherpub.sjfc.edu/education_etd/370

Borrego, M. J., Padilla, M. a., Zhang, G. Z. G., Ohland, M. W., & Anderson, T. J. (2005). Graduation rates, grade-point average, and changes of major of female and minority students entering engineering. Proceedings Frontiers in Education 35th Annual Conference, 1–6. https://doi.org/10.1109/FIE.2005.1611931

Boyd, W. M. (1980). Black undergraduates at predominantly white colleges, 1971-77: A report on three nationwide surveys. https://files.eric.ed.gov/fulltext/ED212231.pdf

Bryer, J. & Speerschneider, K. (2016). Likert: Analysis and Visualization Likert Items. R package version 1.3.5. https://CRAN.R-project.org/package=likert

Burrell, J. O., Fleming, L., Fredericks, A.C., & Moore, I. (2015). College Experiences of Black Males Majoring in Engineering at an HBCU. *Journal of Negro Education, 84*(1), 40–55.

Carter, L. (2006). Why students with an apparent aptitude for computer science don't choose to major in computer science. In Proceedings of the 37th SIGCSE technical symposium on Computer science education (SIGCSE '06). Association for Computing Machinery, New York, NY, USA, 27–31. https://doi.org/10.1145/1121341.1121352

Castellanos, J., & Gloria, A. M. (2007). Theoretical application for best practices in higher education Latina/os achieving success. *Journal of Hispanic Higher Education, 6*(4), 378–396. https://doi.org/10.1177/1538192707305347

Chetty, R., Friedman, J. N., Saez, E., Turner, N., Treasury, U. S., & Yagan, D. (2017). Mobility report cards: The role of colleges in intergenerational mobility. The Equality of Opportunity Project. http://www.equality-of-opportunity.org/assets/documents/coll_mrc_paper.pdf

Coleman, J. S., Campbell, E.Q., Hobson, C.J., McPartland, J., Mood, A.M., Weinfeld, F.D., York, R.L. (1966). Equality of educational opportunity. U.S. Dept. of Health, Education, and Welfare. http://hdl.handle.net/2027/umn.319510000865241

College Board Report (2018).

Creswell, J., & Creswell, D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th edition). Sage Publications.

Cross, W. E., Parham, T. A. & Helms, J. E. (1991). The stages of Black identity development: Nigrescence models. In Reginald L. Jones (Ed.). *Black psychology* (3rd ed.; *p. 319-338).* Berkley, CA: Cobb and Henry.

Currie, J. (2009). Health disparities and gaps in school readiness. *The Future of Children, 15*(1), 117–138.

Diemer, M. A., & Li, C.-H. (2012). Longitudinal roles of precollege contexts in low-income youths' postsecondary persistence. *Developmental Psychology*, *48*(6), 1686–1693. https://doi.org/10.1037/a0025347

Doolen, T. L., & Long, M. (2015). Identification of retention levers using a survey of engineering freshman attitudes at Oregon State University, *European Journal of Engineering Education*, *32*(6), 721–734. https://doi.org/10.1080/03043790701520784

Engineering Fields Questionnaire (2005) [Unpublished questionnaire]. R.W. Lent, personal communication, October 25, 2020.

Field of degree: Minorities. (2019, March 8). Retrieved August 14, 2020, from https://ncses.nsf.gov/pubs/nsf19304/digest/field-of-degree-minorities

Felder Thompson, P. (2005). African American doctoral degree completers and the factors that influence their success in the ivy league (Order No. 3197745). ProQuest Dissertations & Theses Global. (305457961). http://ezproxy.msu.edu/login?url=https://search-proquest-com.proxy2.cl.msu.edu/docview/305457961?accountid=12598

Ford-Edwards, J. (2002). Towards a theoretical model of minority student success: Successful black students and their perspectives on the variables that promote and retard their retention (Order No. 3046032). ProQuest Dissertations & Theses Global. (304801976). Retrieved from http://ezproxy.msu.edu/login?url=https://search-proquest-com.proxy2.cl.msu.edu/docview/304801976?accountid=12598

Forrest-Bank, S. S., & Cuellar, M. J. (2018). The Mediating Effects of Ethnic Identity on the Relationships between Racial Microaggression and Psychological Well-Being. *Social Work Research, 42*(1), 44–56. https://doi.org/10.1093/swr/svx023

Fries-Britt, S. L., Younger, T. K., & Hall, W. D. (2010). Lessons from high-achieving students of color in physics. *New Directions for Institutional Research*, 148, 75–83. https://doi.org/10.1002/ir.363

Fries-Britt, S. S. (2017). It takes more than academic preparation: A nuanced look at Black male success in STEM. *Journal of African American Males in Education, 8*(1), 6–22.

Goldrick-Rab, S., Kelchen, R., Harris, D. N., & Benson, J. (2016). Reducing income inequality in educational attainment: Experimental evidence on the impact of financial aid on college completion. *American Journal of Sociology, 121*(6), 1762–1817. https://doi.org/10.1086/685442

Hall, S. P., & Carter, R. T. (2006). The Relationship Between Racial Identity, Ethnic Identity, and Perceptions of Racial Discrimination in an Afro-Caribbean Descent Sample. Journal of Black Psychology, 32(2), 155–175. https://doi.org/10.1177/0095798406287071

Harper, S. R. (2010). An anti-deficit achievement framework for research on students of color in STEM. In S. R. Harper & C. B. Newman (Eds.), *Students of color in STEM: Engineering a new research agenda*. New Directions for Institutional Research (pp. 63–74). Jossey-Bass.

Harper, S. R. (2012). Black male student success in higher education: A report from the national Black male college achievement study. Philadelphia: University of Pennsylvania, Center for the Study of Race and Equity in Education.

Henley, L., & Roberts, P. (2016). Perceived barriers to higher education in STEM among disadvantaged rural students: A case Study. *Inquiry, 20*(1), 19–38.

Jencks, C., & Phillips, M. (Eds.). (1998). *The Black–White test score gap*. Brookings Institution Press.

Johnston, M.P., Pizzolato, J.E., & Kanny, M.A. (2015). Examining the Significance of "Race" in College Students' Identity Within a "Postracial" Era. *Journal of College Student Development 56*(3), 227-242. doi:10.1353/csd.2015.0023.

Kim, Y. K., Rennick, L. A., & Franco, M. A. (2014). Latino college students at highly selective institutions: A comparison of their college experiences and outcomes to other racial/ethnic groups. *Journal of Hispanic Higher Education, 13*(4), 245–268. https://doi.org/10.1177/1538192714532815

Kuh, G. D., Kinzie, J., Buckley, J. A., Bridges, B. K., & Hayek, J. C. (2006). What matters to student success: A review of the literature spearheading a dialog on student success.

Final report for the National Postsecondary Education Cooperative and National Center for Education Statistics, *18(July)*, 156. https://doi.org/10.1111/ijs.12356

Lam, P. C., Doverspike, D., & Mawasha, R. P. (1999). Predicting success in a minority engineering program. *Journal of Engineering Education*, *88*(3), 265–370. https://doi.org/10.1002/j.2168-9830.1999.tb00445.x

Lam, P., & Srivatsan, T. (2005). A ten year assessment of the pre-engineering program for under-represented, low income and/or first generation college students at the University of Akron. *Journal of STEM Education*, *6*(3), 14–20. https://doi.org/10.1109/FIE.2004.1408599

Lam, P. C., Srivatsan, T., Doverspike, D., Vesalo, J., & Mawasha, P. R. (2005). A ten year assessment of the pre-engineering program for under-represented, low income and/or first generation college students at the University of Akron. *Journal of STEM Education*, *6*(3/4), 14–19.

Landis, R. B. (1988). The case for minority engineering programs. *Engineering Education*, *78*(8), 756-61.

Leonard, S. E., Pearcy, B. M., Shehab, R. L., & Walden, S. E. (2013). Minority student informed retention strategies. Proceedings - Frontiers in Education Conference, FIE, 567–573. https://doi.org/10.1109/FIE.2013.6684887

Li, Q., Swaminathan, H. & Tang, J. (2009). Development of a classification system for engineering student characteristics affecting college enrollment and retention. *Journal of Engineering Education*, *98*(4), 361–376.

Lent, R. W., Brown, S. D., Brenner, B., Batra Chopra, S., Davis, T., Talleyrand, R., & Suthakaran, V. (2001). The Role of Contextual Supports and Barriers in the Choice of Math/Science Educational Options: A Test of Social Cognitive Hypotheses. *Journal of Counseling Psychology*, *48*(4), 474–483. https://doi.org/10.1037/0022-0167.48.4.474

Lent, R. W., Brown, S. D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of Contextual Supports and Barriers to Choice Behavior in Engineering Majors: Test of Alternative Social Cognitive Models. Journal of Counseling Psychology, 50(4), 458–465. https://doi.org/10.1037/0022-0167.50.4.458

Lent, R. W., Brown, S. D., Sheu, H.-B., Schmidt, J., Brenner, B. R., Gloster, C. S., Wilkins, G., Schmidt, L. C., Lyons, H., & Treistman, D. (2005). Social Cognitive Predictors of Academic Interests and Goals in Engineering: Utility for Women and Students at Historically Black Universities. *Journal of Counseling Psychology*, *52*(1), 84–92. https://doi.org/10.1037/0022-0167.52.1.84

Lent, R. W. & Brown, S. D. (2006). On Conceptualizing and Assessing Social Cognitive Constructs in Career Research: A Measurement Guide. *Journal of Career Assessment*,

14(1), 12–35. DOI: 10.1177/1069072705281364

Lent, R. W., Sheu, H., Gloster, C. S., & Wilkins, G. (2010). Longitudinal test of the social cognitive model of choice in engineering students at historically Black universities. Journal of Vocational Behavior, 76(3), 387–394. https://doi.org/10.1016/j.jvb.2009.09.002

Flores, L. Y., Atilano, R., Suh, H. N., & Navarro, R. L. (2020). A Latent Growth Modeling Analysis of the Effects of Perceived Supports, Perceived Barriers, and Coping Efficacy on Latina/o Engineering Students' Life Satisfaction. *Journal of Career Development*, *47*(1), 29–43. https://doi.org/10.1177/0894845319826251

Maton, K. I., Hrabowski Iii, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. *Journal of Research in Science and Teaching, 37*(7), 629–654.

Maton, K. I., Beason, T. S., Godsay, S., Mariano, M. R., Bailey, T. S. C., Sun, S., & Hrabowski, F. A. (2016). Outcomes and processes in the Meyerhoff scholars program: STEM PhD completion, sense of community, perceived program benefit, science identity, and research self-efficacy. *CBE Life Sciences Education, 15*(3), 1–11. https://doi.org/10.1187/cbe.16-01-0062

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2012). Leaving engineering: A multi-year single institution study. *Journal of Engineering Education, 101*(1), 6–27.

Massey, D. S., & Denton, N. A. (1998). *American apartheid: Segregation and the making of the underclass.* Harvard University Press.

May, G. & Chubin, D. (2003). A retrospective on undergraduate engineering success for underrepresented minority students. *Journal of Engineering Education*, *92*(1), 27–39. https://doi.org/10.1002/j.2168-9830.2003.tb00735.x

McClain, S., Beasley, S. T., Jones, B., Awosogba, O., Jackson, S., & Cokley, K. (2016). An Examination of the Impact of Racial and Ethnic Identity, Impostor Feelings, and Minority Status Stress on the Mental Health of Black College Students. *Journal of Multicultural Counseling and Development*, *44*(2), 101–117. https://doi.org/10.1002/jmcd.12040

McGee, E. O., & 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. https://doi.org/10.3102/0002831211423972

Mejia, J. A., Revelo, R. A., Villanueva, I., & Mejia, J. (2018). Critical theoretical frameworks in engineering education: An anti-deficit and liberative approach. *Education Sciences*, *8*(4), 158. https://doi.org/10.3390/educsci8040158

Anonymous personal communication, July 22, 2020.

Meyers, K., & Mertz, B. (2011). A large scale analysis of first-year engineering student essays on engineering interests. Proceedings of the 2011 ASEE Annual Conference & Exposition, 574, 1–16.

Min, Y., Zhang, G., Long, R., Anderson, T., & Ohland, M. (2011). Nonparametric survival analysis of the loss rate of undergraduate engineering students. *Journal of Engineering Education, 100*(2), 349–373. http://onlinelibrary.wiley.com/doi/10.1002/j.2168-9830.2011.tb00017.x/abstract

Myers, L. C. (2008). Student success in an urban community college: Applying the expertise model of student success (Order No. 3337138). ProQuest Dissertations & Theses Global. (288082472). http://ezproxy.msu.edu/login?url=https://search-proquest-com.proxy2.cl.msu.edu/docview/288082472?accountid=12598

National Assessment of Educational Progress [NAEP]. (2015). Reading and mathematics score Trends. *Condition of Education*. U.S. Department of Education, Institute of Education Sciences. https://nces.ed.gov/programs/coe/indicator_cnj.asp

National Assessment of Educational Progress [NAEP]. (2019). Glossary. https://nces.ed.gov/nationsreportcard/glossary.aspx#achievement_levels

National Center for Education Statistics. (2005). The nation's report card: NAEP 2004 Trends in Academic Progress Three Decades of Student Performance in Reading and Mathematics https://nces.ed.gov/nationsreportcard/pdf/main2005/2005464.pdf

National Center for Education Statistics. (2018). Fast Facts: SAT scores. https://nces.ed.gov/fastfacts/display.asp?id=171

National Center for Healthy Housing. (n.d.). Issue brief: Childhood lead exposure and educational outcomes. https://nchh.org/resource-library/Childhood_Lead_Exposure.pdf

National Science Foundation, National Center for Science and Engineering Statistics. (2019). Women, minorities, and persons with disabilities in science and engineering. https://ncses.nsf.gov/pubs/nsf19304/digest/glossary-and-key-to-acronyms

Newman, C. B. (2016). Minority engineering programs at a crossroads: An empirical multiple case study of two historically white public research universities. Journal for Multicultural Education, 10(2), 217–233. https://doi.org/10.1108/JME-01-2016-0016

Ohland, M. W., & Zhang, G. (2002). A study of the impact of minority engineering programs at the FAMU-FSU college of engineering. *Journal of Engineering Education, 91*(4), 435–440. https://doi.org/10.1002/j.2168-9830.2002.tb00729.x

Ohland, M. W., Brawner, C. E., Camacho, M. M., Layton, R. A., Long, R. A., Lord, S. M., &

Washburn, M. H. (2011). Race, gender, and measures of success in engineering education. *Journal of Engineering Education, 100*(2), 225–252. https://doi.org/10.1002/j.2168-9830.2011.tb00012.x

Okada, T., Stoller, D. S., & Weinfeld, F. D. (1968). Dynamic of achievement: A study of differential growth of achievement over time. National Center for Educational Statistics, Technical Report 53. https://files.eric.ed.gov/fulltext/ED020527.pdf

Orfield, G. (2003). Housing segregation produces unequal schools. In P.L. Carter & K.G. Welner (Eds.). *Closing the Opportunity Gap: What America Must Do to Give Every Child an Even Chance.* Oxford University Press.

Anonymous Institutional Research, 2020. Anonymous Institution.

Padilla, R. V. (1991). Assessing heuristic knowledge to enhance college students' success (G. D. Keller, J.R. Deneen & R. J. Magallan, Eds.). State University Press.

Padilla, R. V. (1994). The unfolding matrix: A technique for qualitative data acquisition and analysis. In R. G. Burgess (Ed.), *Studies in qualitative methodology* (pp. 273–285). JAI Press.

Padilla, R. V, Treviño, J. G., Gonzalez, K., & Treviño, J. (1997). Developing local models of minority student success in college. *Journal of College Student Development, 38*(2), 125–135.

Padilla, R. V. (1999). College student retention: Focus on success. *Journal of College Student Retention: Research, Theory & Practice, 1*(2), 131–145. https://doi.org/10.2190/6w96-528b-n1kp-h17n

Park, J. J., Kim, Y. K., Salazar, C., & Eagan, M. K. (2022). Racial discrimination and student–faculty interaction in STEM: Probing the mechanisms influencing inequality. *Journal of Diversity in Higher Education, 15*(2), 218–229. https://doi.org/10.1037/dhe0000224

Perna, L. W., & Thomas, S. L. (2006). A framework for reducing the college success gap and promoting success for all. National Symposium on Postsecondary Student Success: Spearheading a Dialog on Student Success. http://repository.upenn.edu/gse_pubs/328

Phinney, J. S. (1992). The multiethnic identity measure: A new scale for use with diverse groups. Journal of Adolescent Research, 7, 156-176.

Phinney, J. S. (2006). Ethnic Identity Exploration in Emerging Adulthood. In J. J. Arnett, & J. L. Tanner (Eds.), Emerging adults in America: Coming of age in the 21st century; Emerging adults in America: Coming of age in the 21st century. (pp. 117-134, Chapter xxii, 340 Pages). American Psychological Association, American Psychological Association. https://doi.org/10.1037/11381-005

Pieterse, A. L., Carter, R. T., Evans, S. A., & Walter, R. A. (2010). An Exploratory Examination of the Associations Among Racial and Ethnic Discrimination, Racial Climate, and Trauma-Related Symptoms in a College Student Population. *Journal of Counseling Psychology*, *57*(3), 255–263. https://doi.org/10.1037/a0020040

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Reisel, J. R., Jablonski, M., Hosseini, H., & Munson, E. (2012) Assessment of factors impacting success for incoming college engineering students in a summer bridge program, International *Journal of Mathematical Education in Science and Technology, 43*(4), 421–433. https://doi.org/10.1080/0020739X.2011.618560

Reynolds, A.L., Sneva, J.N., & Beehler, G.P. (2010). The Influence of Racism-Related Stress on the Academic Motivation of Black and Latino/a Students. *Journal of College Student Development 51*(2), 135-149. doi:10.1353/csd.0.0120

Robinson, H. L. (2016). Understanding African American male persistence in the urban university: The student expertise model (Order No. 10157563). ProQuest Dissertations & Theses Global. (1823621558). http://ezproxy.msu.edu/login?url=https://search-proquest-com.proxy2.cl.msu.edu/docview/1823621558?accountid=12598

Roderick, M., Coca, V., & Nagaoka, J. (2011). Potholes on the road to college: High school effects in shaping urban students' participation in college application, four-year college enrollment, and college match. *Sociology of Education, 84*(3), 178–211. https://doi.org/10.1177/0038040711411280

Roksa, J., & Potter, D. (2011). Parenting and academic achievement: Intergenerational transmission of educational advantage. *Sociology of Education, 84*(4), 299–321. http://doi.org/10.1177/0038040711417013

Saldaña, J. (2016). The coding manual for qualitative researchers (3E. ed.). SAGE.

Scottham, K. M., Cooke, D. Y., Sellers, R. M., & Ford, K. (2010). Integrating process with content in understanding African American racial identity development. Self and Identity, 9(1), 19–40. https://doi.org/10.1080/15298860802505384

Seaton, E. K., Yip, T., Morgan-Lopez, A., & Sellers, R. M. (2012). Racial Discrimination and Racial Socialization as Predictors of African American Adolescents' Racial Identity Development Using Latent Transition Analysis. Developmental Psychology, 48(2), 448–458. https://doi.org/10.1037/a0025328

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

Sheppard, S., Gilmartin, S., Chen, H. L., Donaldson, K., Lichtenstein, G., Eris, Ö., Lande, M., &

Toye, G. (2010). *Exploring the Engineering Student Experience: Findings from the Academic Pathways of People Learning Engineering Survey* (APPLES) (TR-10-01). Center for the Advancement of Engineering Education. http://depts.washington.edu/celtweb/caee/APPLES_report.html

Solorzano, D., Ceja, M., & Yosso, T. (2000). Critical Race Theory, Racial Microaggressions, and Campus Racial Climate: The Experiences of African American College Students. *The Journal of Negro Education*, *69*(1/2), 60–73. http://www.jstor.org/stable/2696265

Sparkman, L. A., Maulding, W. S. & Roberts, J. G. (2012). Non-cognitive predictors of student success in college. *College Student Journal, 46*(3), 642–652. https://www.ingentaconnect.com/content/prin/csj/2012/00000046/00000003/art00018

Stebleton, M. J., & Soria, K. M. (2012). Breaking down barriers: Academic obstacles of first-generation students at research universities. *Learning Assistance Review, 17*(2), 7–19.

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist, 52*(6), 613–629. https://doi.org/10.1037/0003-066X.52.6.613

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*(5), 797–811. https://doi.org/10.1037//0022-3514.69.5.797

Strayhorn, T. L. (2011). Bridging the pipeline: Increasing underrepresented students' preparation for college through a summer bridge program. *American Behavioral Scientist, 55*(2), 142–159. https://doi.org/10.1177/0002764210381871

Strayhorn, T. L., Long III, L. L., Kitchen, J. A., Williams, M. S., & Stentz, M. (June, 2013). *Academic and social barriers to black and latino male collegians' success in engineering and related STEM fields* [Paper ID #8199]. 120th American Society for Engineering Education Annual Conference, Atlanta, GA, United States.

Tomasko, B. D. L., Ridgway, J. S., Waller, R. J., & Olesik, S. V. (2016). Association of summer bridge program outcomes with STEM retention of targeted demographic groups. *Journal of College Science Teaching, 45*(4), 90–99. https://my.nsta.org/resource/?id=10.2505/4/jcst16_045_04_90

True-Funk, A., Poleacovschi, C., Jones-Johnson, G., Feinstein, S., Smith, K., & Luster-Teasley, S. (2021). Intersectional Engineers: Diversity of Gender and Race Microaggressions and Their Effects in Engineering Education. Journal of Management in Engineering, 37(3). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000889

Ushomirsky, N., & Williams, D. (2015). Funding gaps 2015: Too many states still spend less on educating students who need the most. The Education Trust. https://edtrust.org/wp-

content/uploads/2014/09/FundingGaps2015_TheEducationTrust1.pdf

Van Aken, E. M., Watford, B., & Medina-Borja, A. (1999). The use of focus groups for minority engineering program assessment. *Journal of Engineering Education*, *88*(3), 333–343. https://www.scopus.com/inward/record.uri?eid=2-s2.0-19544367439&partnerID=40&md5=b6e118983862039b3d74d08573bb1523

Wade, N. L. (2019). Measuring, manipulating, and predicting student success: A 10-year assessment of Carnegie R1 doctoral universities between 2004 and 2013. *Journal of College Student Retention: Research, Theory and Practice, 21*(1), 119–141. https://doi.org/10.1177/1521025119831456

Wei, M., Ku, T., & Liao, K. Y. (2011). Minority stress and college persistence attitudes among African American, Asian American, and Latino students: Perception of university environment as a mediator. *Cultural Diversity and Ethnic Minority Psychology, 17*(2), 195-203. https://doi.org/10.1037/a0023359

White, J. L., Altschuld, J. W., & Lee, Y. (2006). Persistence of interest in science, technology, engineering, and mathematics: A minority retention study. *Journal of Women and Minorities in Science and Engineering*, *12*(1), 47–64.

Wickham, H. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, 2016.

Wirth, R. M., & Padilla, R. V. (2008). College Student Success: A Qualitative Modeling Approach. Community College Journal of Research and Practice, 32(9), 688–711. https://doi.org/10.1080/10668920701380942

Yip, T., Seaton, E. K., & Sellers, R. M. (2006). African American Racial Identity Across the Lifespan: Identity Status, Identity Content, and Depressive Symptoms. *Child Development*, *77*(5), 1504–1517. https://doi.org/10.1111/j.1467-8624.2006.00950.x

York, T. T., Gibson, C., & Rankin, S. (2015). Defining and measuring academic success. *Practical Assessment, Research & Evaluation, 20*(5), 1–20. http://pareonline.net/getvn.asp?v=20%26n=5

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth, Race Ethnicity and Education, 8(1), 69-91, DOI:10.1080/1361332052000341006

Zhang, G., Anderson, T. J., Ohland, M. W., & Thorndike, B. R. (2004). Identifying factors influencing engineering student graduation: A longitudinal and cross-institutional study. *Journal of Engineering Education*, *93*(4), 313–320.

APPENDIX A: PAST RESEARCH, CRITIQUE POINTS, AND IMPLICATIONS

Table 24

Past Research, Critique Points, and Implications

Examples from Past Research *engineering or STEM focused	**Critique Points**	**How this study addresses these critique points**	**Implications** What impact will the proposed research have?
Coleman et al. (1966): focused on reporting "deficiencies in achievement" (p.21) and the "degree of education disadvantage" (p. 218) of racial/ethnic groups **Okada, Stoller, Weinfeld (1968):** reported "pronounced lower rate of achievement" (p.31) and/or "lag-years" for Blacks **Borrego, Padilla, Zhang, Ohland, & Anderson (2005)*:** results focused on semester, GPA, and major when students leave engineering **Lam, Srivatsan, Doverspike, Vesalo & Mawasha (2005):** Discussed bridge program used diagnostic testing for high school students to determine their deficiencies in mathematics (p.14) **Min, Zhang, Long, Anderson and Ohland (2011)*:** defined students in terms of failure (left engineering) and non-failure (stayed in engineering) (p. 354) **Reisel, Jablonski, Hosseini & Munson (2011):** discussed bridge program used to address deficiencies in lower-level math skills	**Critique Point 1:** *The implicit or explicit use of deficit approaches promotes stereotypes and misconceptions about the achievement of Black students*	Anti-deficit and expertise frameworks guide the creation of asset-based research questions; and The expertise model of successful students provides a framework to elicit the heuristic knowledge Black students use to facilitate asset-based pathways in engineering.	Will provide an example of how critical perspectives should be incorporated into engineering education research; Will directly challenge the use of deficit perspectives in engineering education research that maintain the status quo of engineering as a White, male-dominated field; and Will counter the socially constructed deficiencies in Black student achievement in engineering.

Table 24 (cont'd)

Coleman et al. (1966): survey neglected the variability between students within the same school (p.23), which was 4x as larger than between schools; each racial/ethnic group was examined separately **Okada, Stoller, Weinfeld (1968):** each racial/ethnic group was examined separately **Boyd (1980):** disaggregated black student data based on demographics (p.24); **Seymour & Hewitt (1997)*:** disaggregated data by race **Borrego, Padilla, Zhang, Ohland, & Anderson (2005)*:** -Native Amer. Black or African Amer., and Hispanic students were aggregated as a single group - minorities **Ohland, Brawner, Camacho, Layton, Long, Lord & Wasburn (2011)*:** disaggregated racial/ethnic groups; defined "systematic majority measurement bias" within engineering(p. 244) **Min, Zhang, Long, Anderson and Ohland (2011)*:** African Americans, Hispanics, Native Americans, Alaskan Natives, and Native Pacific Islanders) were aggregated as a single group - minorities **Sheppard, Gilmartin, Chen, Lichtenstein, Eris & Lande (2010)*:** aggregated URMs as a single group – minorities	**Critique Point 2:** *Research methods that combine URM data within samples heavily populated with white students leads to the invisibility of Black students in engineering*	The following research methods will be used to illuminate the experiences and achievement of Black students: 1) *Target Population:* white participants as well as Hispanic and Native American participants will be excluded from the target population to intentionally focus on Black students; and 2) *Analysis:* will highlight important similarities, differences, and relationships within and between Black engineering students	Will eliminate the dominant influence the majority white population in engineering has on results; and Will increase accuracy in reporting variability of success pathways among Black students in engineering that is often missing in engineering research

Table 24 (cont'd)

Maton, Hrabowski, and Schmitt (2000)*: Measures of URM success included retention, STEM GPA, overall GPA, and graduation rates **Lam, Srivatsan, Doverspike, Vesalo & Mawasha (2005)*:** Measures of URM success included retention, GPA at graduation, and graduation **Kim, Rennick, and Franco (2014):** all racial/ethnic groups reported significant gains in cognitive skills but their college GPA showed a negative change (i.e., decrease) **York, Gibson & Rankin, 2015):** the most commonly assessed aspect of academic success is GPA; grades and GPA are not always accurate measures of learning or growth in cognitive capabilities **Maton, Pollard, McDougall Weise, and Hrabowski (2016)*:** Measures of URM success included retention, STEM GPA, overall GPA, and graduation rates	**Critique point 3:** *Using graduation rate and GPA as the basis for defining URM student success ignores the harmful limitations of these assessments*	By defining "successful" Black students not only as being able to achieve the required GPA to be retained in engineering, but as also being able to navigate unique challenges on their path to graduation; and Examine the specific barriers, knowledge, and actions of Black students in engineering to understand how they navigated their path to graduation	Will expand on Padilla's (1991, 1994) work presenting a way to understand Black students success that is inclusive of their lived experiences as racial and ethnic minorities in engineering; and Will provide insight into the specific challenges Black students face in engineering, provide a framework for understanding their experiences, and highlight the qualities Black students possess to achieve success in engineering; and Will provide an institution-specific expertise model of successful Black students in engineering that can be used to 1) critically evaluate initiatives and resources targeted at improving Black student success in engineering and 2) provide Black, first year engineering students the campus-specific knowledge of other Black students to increase their persistence within the engineering pipeline

APPENDIX B: SUMMARY OF PARTICIPANTS

Table 25

Summary of Participants

Participant	**Student Type** Continuing Engineering Student (CEG) or Former Engineering Student (FEG)	**Gender Identity**	**Classification / Semester Enrolled in Fall 2020**
AW1	CEG	Male	Junior / 5th Semester
AA2	CEG	Male	Junior / 5th Semester
LN5	CEG	Male	Sophomore / 3rd Semester
TN7	CEG	Female	Senior / 7th Semester
IM8	CEG	Male	Junior / 5th Semester
AE9	CEG	Male	Sophomore / 3rd Semester
OE10	CEG	Female	Senior / 7th Semester
LA12	CEG	Female	Sophomore / 3rd Semester
VM14	CEG	Female	Sophomore / 3rd Semester
SC15	CEG	Female	Sophomore / 3rd Semester
AW16	CEG	Female	Senior / 7th Semester
LO3	FEG	Female	Sophomore / 3rd Semester
CO4	FEG	Female	Junior / 5th Semester
LA6	FEG	Female	Junior / 5th Semester
SH11	FEG	Female	Junior / 5th Semester
MG13	FEG	Female	Junior / 5th Semester

APPENDIX C: ALIGNMENT OF MEASURES WITH RESEARCH QUESTIONS

Table 26

The Alignment of Measures with the Research Questions

Research Question (RQ)	**Definition of Terms**	**Student Experience Items (76 items)** Likert Scale Strongly disagree - Disagree - Neither agree or disagree - Agree - Strongly agree - Not experienced
RQ1: What barriers do Black engineering students experience?	**Barrier:** an obstacle Black students have experienced while enrolled at the site institution that had the potential to or hindered their progress toward graduating with an engineering degree.	**Academic Barriers** 1. Communication problems with professors or teaching assistants 2. A lack of faculty that looked like me in engineering 3. Limited tutoring assistance for engineering classes when I felt I needed such help 4. Difficulty finding study groups for my engineering classes 5. Difficulty working in teams/group work in my engineering classes 6. A lack of support from professors or my academic advisor 7. Difficulty finding ways to study effectively for engineering courses due to competing demands for my time **Social Barriers** 1. Feeling that, socially, the environment in engineering classes was not very welcoming 2. Not having a sense of belonging in engineering 3. Feeling excluded from engineering clubs/organizations 4. A lack of other engineering students that looked like me 5. Difficulty accessing an engineering "mentor" who could offer me advice and encouragement 6. Not feeling well-liked by engineering classmates or professors 7. Difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities 8. Feeling that I don't fit in socially with other students in engineering **Personal Barriers** 1. Receiving negative comments or discouragement about my engineering major from family members 2. The lack of pre-college preparation for STEM coursework in college 3. Financial pressures related to completing a degree in engineering 4. Feeling pressure from parents or other important people to change my major to some other field 5. Difficulty engaging in my engineering classes 6. Worrying that an engineering career path would require too much time or schooling 7. Difficulty accessing a "role model" in engineering (i.e. someone I can look up to and learn from by observing). 8. Receiving negative comments or discouragement about my engineering major from my friends **Psychological Barriers** 1. Experiencing negative perceptions or stereotypes of students of color in engineering 2. Experiencing racial discrimination in engineering 3. Feelings of alienation and invisibility in engineering 4. Experiencing gender discrimination in engineering 5. Feelings of being an "imposter" in engineering **Personal Perspective related to Barriers** 1. The barriers I identified are different than the ones experienced by other engineering students. 2. The barriers in engineering I identified are unique to Black engineering students. 3. The barriers in engineering I identified are unique to me. 4. There were barriers in engineering I experienced at Anonymous Institution that made me consider leaving engineering.

Table 26 (cont'd)

RQ2: What heuristic knowledge do Black engineering students need to overcome barriers experienced ?	**Heuristic Knowledge:** information Black students acquired through first-hand experience, observation, or through others that aids their ability to overcome barriers faced in college.	**Academic Knowledge** 1. Know how to advocate for myself in instructional/classroom environments 2. Know how to communicate with engineering faculty 3. Know about academic support resources for assistance in engineering classes (e.g. tutoring, review sessions, professors office hours, etc.) 4. Know that I can get helpful assistance from my academic advisor in engineering 5. Know how to deal with group dynamics for team/group work in engineering classes **Social Knowledge** 1. Know how to navigate the social environment in engineering 2. Know how to find ~~mentors~~ a "mentor" who could offer advice and encouragement 3. Know how to manage feelings of not belonging in engineering 4. Know the culture in engineering clubs/organizations helped me overcome barriers in engineering. 5. Know how to find engineering students that look like me 6. Know that my friends encouraged me to pursue an engineering major **Personal Knowledge** 1. Know what engineers do on a daily basis 2. Know that important people in my life (e.g. teachers) support my decision to pursue engineering 3. Know how to solve financial aid problems - who to contact and when 4. Know that close friends or relatives are proud of me for making the decision to pursue engineering 5. Know how to increase my engagement in my engineering classes 6. Know that my family members support my decision to pursue engineering **Psychological Knowledge** 1. Know how to manage feelings of alienation and invisibility 2. Know how to manage the negative perceptions or stereotypes of students of color 3. Know about the mental health support resources on campus 4. Know how to address race discrimination 5. Know how to address gender discrimination **Personal Perspective related to Knowledge** 1. The knowledge I needed to overcome barriers in engineering is different from the ones experienced by other engineering students. 2. The knowledge I needed to overcome barriers in engineering is unique to Black engineering students. 3. The knowledge I needed to overcome barriers in engineering is unique to me. 4. I considered leaving engineering because I did NOT have the knowledge I needed to overcome barriers in engineering at Anonymous Institution.

Table 26 (cont'd)

RQ 3: What specific actions do academically Black engineering students take to overcome barriers experienced?	**Actions:** what Black students do, a behavior they engage in, to overcome a barrier or obstacle faced in college.	**Academic Actions** 1. Researched engineering majors to find the best fit 2. Set realistic academic expectations regarding the demands of my academic workload 3. Found academic support resources on campus (e.g. tutoring, professors office hours, etc.) 4. Got assistance from an academic advisor 5. Developed relationships with engineering faculty 6. Learned from other engineering students about the "good" engineering faculty **Social Actions** 1. Joined engineering focused student clubs or organizations 2. Established connections with other engineering students through social media platforms (i.e. TikTok, Instagram, GroupMe, etc.) 3. Learned how to manage feelings of not belonging 4. Built friendships/relationships with engineering students that did not look like me 5. Joined non-engineering focused student clubs or organizations 6. Built friendships/relationships with engineering students that looked like me **Personal Actions** 1. Developed time management skills 2. Developed study skills 3. Told family and friends when I needed to prioritize school 4. Made a strategic plan for my four (4) years at Anonymous Institution 5. Made my education a priority 6. I contacted or followed up with the Office of Financial Aid **Psychological Actions** 1. Found a "mentor" who could offer advice and encouragement 2. Used mental health resources on campus 3. Learned how to manage feelings of alienation and invisibility 4. Leaned on friends and family for emotional support 5. Gained confidence in my engineering abilities 6. Learned how to manage negative perceptions or stereotypes of students of color **Personal Perspective related to Action** 1. The actions I took are different than the ones experienced by my peers. 2. The actions I took are unique to Black engineering students. 3. The actions I took are unique to me. 4. I considered leaving engineering because I did NOT take the actions I needed to overcome barriers in engineering at Anonymous Institution.

APPENDIX D: MSU CONSENT FORM FOR HUMAN SUBJECTS

(Displayed the beginning of the Qualtrics form)

You are being asked to participate in a research study. The purpose of the study is to *understand undergraduate students' experiences while in engineering*. You will be asked to *complete demographic questions followed by student experience items*. Your participation is voluntary. You have the right to say no. You may change your mind at any time and withdraw. You may choose not to answer specific questions or to stop participating at any time. You can withdraw at any time. You must be 18 or older to participate. You will receive a $20 gift card for your participation. If you have any questions please contact *Michelle Smith Ware,* at *smithwar@msu.edu* or *504-914-5210*. By clicking on the button below, you indicate your voluntary agreement to participate in this online survey. (https://hrpp.msu.edu/templates/consent.html)

APPENDIX E: RECRUITMENT EMAIL

Dear (Student's First Name),

You are receiving this email to inform you of an opportunity to participate in a research study approved through the Institutional Review Boards at the Anonymous Institution and Michigan State University.

The purpose of the study is to understand undergraduate students' experiences while in engineering (either currently or previously as an engineering major). You will receive a $20 gift card for your participation in completing the initial online survey where you will be asked to complete demographic questions followed by student experience items. Following your completion of the online survey, you may be selected to participate in a one-hour follow-up interview. If selected to participate in a one-hour follow-up interview, you will receive another $20 gift card for your participation in the interview phase.

Eligibility criteria:

- Must be 18 or older to participate;
- Must be currently pursuing a major in the College of Engineering at the Anonymous Institution OR previously pursued a major in the College of Engineering at the Anonymous Institution, but changed to non-engineering major during or after your 2nd semester at Anonymous Institution; and
- Must identify as "Black" or "African-American"

If you fit the eligibility criteria and are interested in participating in this research study, please email Michelle Smith Ware, at smithwar@msu.edu.

APPENDIX F: CONSENT FORM FOR FOLLOW-UP ZOOM INTERVIEW

You are being asked to participate in a research study. The purpose of the study is to understand undergraduate students' experiences while in engineering. You will be asked to answer some questions. It should take no more than 60 minutes. Your participation is voluntary. If you not want to answer any of the questions, please let me know. You can also ask me to stop at any time. You must be 18 or older to participate. You will receive a $20 gift card for your participation. Is it okay if I record our interview? If you have any questions after the interview, please contact Michelle Smith Ware, at smithwar@msu.edu or 504-914-5210. You indicate that you voluntarily agree to participate in this research study by proceeding with the interview.

APPENDIX G: ENGINEERING EXPERIENCES ONLINE SURVEY

Start of Block: Online Survey Consent Form

Q1 Below is a reminder of the consent form you signed previously indicating that you read and answered "Yes" to participate in this online survey.

CONSENT FORM FOR THE ENGINEERING PATHWAYS ONLINE SURVEY

You are being asked to participate in a research study. The purpose of the study is to *understand undergraduate students' experiences while in engineering*. You will be asked to *complete demographic questions followed by student experience questions*. It should take no more than ***30*** minutes to complete. Your participation is voluntary. You have the right to say no. You may change your mind at any time and withdraw. You may choose not to answer specific questions or to stop participating at any time. You can withdraw at any time. You must be 18 or older to participate. You will receive a $20 Amazon gift card for your participation. If you have any questions please contact *Michelle Smith Ware*, at *smithwar@msu.edu* or *504-914-5210*. **Please click the arrow (-->) button to move to the online survey.**

Start of Block: Demographic Questions

Q2 Last Name (Optional)

Q3 First Name (Optional)

Q4 Email (Required)

(NOTE: Email collected only for notifications related to this study (i.e., to send $20 e-gift card, to contact for follow-up interview, to conduct post-study debriefing if requested, to dissemination of study results if requested)

Q5 Gender Identity

- o Male (1)
- o Female (2)
- o Non Binary (identify as neither male nor female) (3)

Q6 Ethnic Identity (click all that apply)

- ▢ American Indian or Alaska Native (1)
- ▢ Asian or Asian American (2)
- ▢ Black or African American (3)
- ▢ Hispanic or Latino (4)
- ▢ Native Hawaiian or Pacific Islander (5)
- ▢ White or European (6)

Q7 Will you be the first in your family to complete a 4-year college degree?

- ▢ Yes (1)
- ▢ No (2)
- ▢ Not sure (3)

Q8 Has anyone in your family pursued or completed a degree in engineering?

- o Yes (1)
- o No (2)
- o Not sure (3)

Q9 Current Primary College

- ▢ School of Architecture (1)
- ▢ College of Arts & Letters (2)
- ▢ College of Business (3)
- ▢ College of Engineering (4)
- ▢ College of Science (5)
- ▢ Dual Degree Program (6)

Q10 Current Primary Major (if in a Dual Degree Program, list both majors)

_____

Q11 Classification / Semester Enrolled

- o Sophomore / 3rd semester enrolled (1)
- o Junior / 5th semester enrolled (2)
- o Senior / 7th semester enrolled (3)
- o 5th Year Senior / 10th semester enrolled (4)

Start of Block: Student Experience Questions

DQ1 **Part I (GOAL ORIENTATION)**

Instructions: Using the scale below, indicate your level of agreement with each of the following statements.

Q12 How much do you agree or disagree with the following statements:

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)
I am majoring in an engineering-related field (1)	o	o	o	o	o

I plan to remain enrolled in my current major over the next semester (2)	o	o	o	o	o
I think that earning a bachelor's degree is a realistic goal for me (3)	o	o	o	o	o
I am fully committed to getting my college degree from the Anonymous Institution (4)	o	o	o	o	o

DQ2 **Part II (SELF-EFFICACY - ENGINEERING MILESTONES)**

Instructions: The following is a list of steps along the way to completing an engineering degree. Reflecting on your most recent term as an engineering student, please indicate how confident you were in your ability to complete each of these steps. Use the 0-9 scale below to indicate your degree of confidence.

Q13 How confident were you in your ability to:

	Not Confident at All					Some Confidence				Complete Confidence
	0	1	2	3	4	5	5	6	7	8	9
Complete all of the “basic science”(i.e., math, physics, chemistry) requirements for your engineering major with grades of B or better ()											

Excel in your engineering major over the next semester ()	
Excel in your engineering major over the next **two** semesters ()	
Complete the upper level required courses in your engineering major with an overall grade point average of B or better ()	

DQ3 Part III (Ability to cope with engineering barriers)

Instructions: We are interested in knowing how well you believe you could cope with each of the following barriers, or problems, related to the engineering major that you are **currently or previously** pursued. Please indicate your confidence in your ability to cope with, or solve, each of the following problem situations while in engineering. Use the 0 - 9 scale below to indicate your degree of confidence.

Q14 How confident were you that you could:

	No Confidence at All				Some Confidence					Complete Confidence
	0	1	2	3	4	5	5	6	7	8	9
Cope with a lack of support from professors or your advisor ()											
Complete a degree in engineering despite financial pressures ()											
Continue in engineering even if you did not feel well-liked by your classmates or professors ()											
Find ways to overcome communication problems with professors or teaching assistants in engineering courses ()											

Balance the pressures of studying for engineering courses with the desire to have free time for fun and other activities ()	
Continue on in engineering even if you felt that, socially, the environment in these classes was not very welcoming to you ()	
Find ways to study effectively for engineering courses despite having competing demands for your time ()	

DQ4 **Part IV - A (BARRIERS)**

Instructions: The barriers listed below have been suggested as having the potential to or hindered students' progress toward graduating with an engineering degree. Please indicate your level of agreement with the statements below by selecting the corresponding response.

Based on your personal experiences (experienced directly by you), how much do you agree each of these barriers have hindered your progress toward a degree in engineering?

Q15a My progress in engineering was hindered due to:

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)	Did Not Experience (0)
Communication problems with professors or teaching assistants (1)	o	o	o	o	o	o
A lack of faculty that looked like me in engineering (2)	o	o	o	o	o	o
Limited tutoring assistance for engineering classes when I felt I needed such help (3)	o	o	o	o	o	o

Difficulty finding study groups for my engineering classes (4)	o	o	o	o	o	o
Difficulty working in teams/group work in my engineering classes (5)	o	o	o	o	o	o
A lack of support from professors or my academic advisor (6)	o	o	o	o	o	o
Difficulty finding ways to study effectively for engineering courses despite having due to competing demands for my time (7)	o	o	o	o	o	o
Feeling that, socially, the environment in engineering classes was not very welcoming (8)	o	o	o	o	o	o
Not having a sense of belonging in engineering (9)	o	o	o	o	o	o
Difficulty accessing an engineering “mentor” who could offer me advice and encouragement (10)	o	o	o	o	o	o

Feeling excluded from engineering clubs/organizations (11)	o	o	o	o	o	o
A lack of other engineering students that looked like me (12)	o	o	o	o	o	o
Not feeling well-liked by engineering classmates or professors (13)	o	o	o	o	o	o
Difficulty balancing the pressures of studying for engineering courses with the desire to have free time for fun and other activities (14)	o	o	o	o	o	o

Q15b My progress in engineering was hindered due to:

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)	Did Not Experience (0)
Feeling that I don't fit in socially with other students in engineering (15)	o	o	o	o	o	o

Receiving negative comments or discouragement about my engineering major from family members (16)	o	o	o	o	o	o
The lack of pre-college preparation for STEM coursework in college (17)	o	o	o	o	o	o
Financial pressures related to completing a degree in engineering (18)	o	o	o	o	o	o
Feeling pressure from parents or other important people to change my major to some other field (19)	o	o	o	o	o	o
Difficulty engaging in my engineering classes (20)	o	o	o	o	o	o
Worrying that an engineering career path would require too much time or schooling (21)	o	o	o	o	o	o

Difficulty accessing a "role model" in engineering (i.e., someone I can look up to and learn from by observing) (22)	o	o	o	o	o	o
Receiving negative comments or discouragement about my engineering major from my friends (23)	o	o	o	o	o	o
Experiencing negative perceptions or stereotypes of students of color in engineering (24)	o	o	o	o	o	o
Experiencing racial discrimination in engineering (25)	o	o	o	o	o	o
Feelings of alienation and invisibility in engineering (26)	o	o	o	o	o	o
Experiencing gender discrimination in engineering (27)	o	o	o	o	o	o

Feelings of being an "imposter" in engineering (28)	o	o	o	o	o	o

Q16 **Part IV - B**

Instructions: Please indicate your level of agreement with the statements below by selecting the corresponding response.

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)
The barriers I experienced in engineering were different than the ones experienced by other engineering students. (6)	o	o	o	o	o
The barriers I experienced in engineering were unique to Black engineering students. (7)	o	o	o	o	o
The barriers I experienced in engineering were unique to me. (10)	o	o	o	o	o

There were barriers I experienced in engineering at Anonymous Institution that made me consider leaving engineering. (11)	o	o	o	o	o

DQ5 **Part V - A (KNOWLEDGE)**

Instructions: The knowledge listed below has been suggested to be information that helped students overcome barriers they faced in engineering. Please indicate your level of agreement with the statements below by selecting the corresponding response.

Based on your personal experiences (experienced directly by you), how much do you agree having the knowledge listed below helped you overcome barriers you faced in engineering?

Q17a **To overcome barriers I faced in engineering, I needed to:**

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)	Did Not Know This (0)
Know how to advocate for myself in instructional/classroom environments (1)	o	o	o	o	o	o
Know how to communicate with engineering faculty (2)	o	o	o	o	o	o
Know about academic support resources for assistance in engineering classes (e.g., tutoring, review sessions, professors office hours, etc.) (3)	o	o	o	o	o	o

Know that I can get helpful assistance from my academic advisor in engineering (4)	o	o	o	o	o	o
Know how to deal with group dynamics for team/group work in engineering classes (5)	o	o	o	o	o	o
Know how to navigate the social environment in engineering (6)	o	o	o	o	o	o
Know how to find a “mentor” who could offer advice and encouragement (7)	o	o	o	o	o	o
Know how to manage feelings of not belonging in engineering (8)	o	o	o	o	o	o
Know the culture in engineering clubs/organizations (9)	o	o	o	o	o	o
Know how to find engineering students that look like me (10)	o	o	o	o	o	o
Know that my friends encouraged me to pursue an engineering major (11)	o	o	o	o	o	o

Q17b **To overcome barriers I faced in engineering, I needed to:**

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)	Did Not Know This (0)

Know what engineers do on a daily basis (12)	o	o	o	o	o	o
Know that important people in my life (e.g., teachers) support my decision to pursue engineering (13)	o	o	o	o	o	o
Know how to solve financial aid problems - who to contact and when (14)	o	o	o	o	o	o
Know that close friends or relatives are proud of me for making the decision to pursue engineering (15)	o	o	o	o	o	o
Know how to increase my engagement in my engineering classes (16)	o	o	o	o	o	o

Know that my family members support my decision to pursue engineering (17)	o	o	o	o	o	o
Know how to manage feelings of alienation and invisibility (18)	o	o	o	o	o	o
Know how to manage the negative perceptions or stereotypes of students of color (19)	o	o	o	o	o	o
Know about the mental health support resources on campus (20)	o	o	o	o	o	o
Know how to address race discrimination (21)	o	o	o	o	o	o
Know how to address gender discrimination (22)	o	o	o	o	o	o

Q18 **Part V - B**

Instructions: Please indicate your level of agreement with the statements below by selecting the corresponding response.

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)
The knowledge I needed to overcome barriers in engineering was different from the ones experienced by other engineering students. (4)	o	o	o	o	o
The knowledge I needed to overcome barriers in engineering was unique to Black engineering students. (5)	o	o	o	o	o
The knowledge I needed to overcome barriers in engineering was unique to me. (6)	o	o	o	o	o

I considered leaving engineering because I did not have the knowledge I needed to overcome barriers in engineering at Anonymous Institution. (7)	o	o	o	o	o

DQ6 **Part VI - A (ACTIONS)**

Instructions: The actions listed below have been suggested to be behaviors that helped students overcome barriers they faced in engineering. Please indicate your level of agreement with the statements below by selecting the corresponding response.

Based on your personal experiences (experienced directly by you), how much do you agree taking the actions listed below helped you overcome barriers faced in engineering?

Q19a **To overcome barriers I faced in engineering, I :**

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)	Did Not Do This (0)
Researched engineering majors to find the best fit (1)	o	o	o	o	o	o
Set realistic academic expectations regarding the demands of my engineering workload (2)	o	o	o	o	o	o
Found academic support resources on campus (e.g., tutoring, professors office hours, etc.) (3)	o	o	o	o	o	o
Got assistance from an academic advisor (4)	o	o	o	o	o	o

Developed relationships with engineering faculty (5)	o	o	o	o	o	o
Learned from other engineering students about the “good” engineering faculty (6)	o	o	o	o	o	o
Joined engineering focused student clubs or organizations (7)	o	o	o	o	o	o
Established connections with other engineering students through social media platforms (i.e., TikTok, Instagram, GroupMe, etc.) (8)	o	o	o	o	o	o
Learned how to manage feelings of not belonging (9)	o	o	o	o	o	o
Built friendships/relationships with engineering students that <u>did not</u> look like me (10)	o	o	o	o	o	o
Joined non-engineering focused student clubs or organizations (11)	o	o	o	o	o	o
Built friendships/relationships with engineering students that looked like me (12)	o	o	o	o	o	o

Q19b **To overcome barriers I faced in engineering, I :**

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)	Did Not Do This (0)
Developed time management skills (13)	o	o	o	o	o	o
Developed study skills (14)	o	o	o	o	o	o
Told family and friends when I needed to prioritize school (15)	o	o	o	o	o	o
Made a strategic plan for my four (4) years at Anonymous Institution (16)	o	o	o	o	o	o
Made my education a priority (17)	o	o	o	o	o	o
I contacted or followed up with the Office of Financial Aid (18)	o	o	o	o	o	o
Found a “mentor” who could offer advice and encouragement (19)	o	o	o	o	o	o
Used mental health resources on campus (20)	o	o	o	o	o	o

Learned how to manage feelings of alienation and invisibility (21)	o	o	o	o	o	o
Leaned on friends and family for emotional support (22)	o	o	o	o	o	o
Gained confidence in my engineering abilities (23)	o	o	o	o	o	o
Learned how to manage negative perceptions or stereotypes of students of color (24)	o	o	o	o	o	o

Q20 **Part VI - B**

Instructions: Please indicate your level of agreement with the statements below by selecting the corresponding response.

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)
The actions I took were different than the ones experienced by my peers. (4)	o	o	o	o	o

The actions I took were unique to Black engineering students. (5)	o	o	o	o	o
The actions I took were unique to me. (6)	o	o	o	o	o
I considered leaving engineering because I did not take the actions I needed to overcome barriers in engineering at Anonymous Institution. (7)	o	o	o	o	o

Q21 **Part VII (Outcome Expectations)**

Instructions: Using the scale below, please indicate the extent to which you agree or disagree with each of the following statements.

I believed graduating with a degree in engineering would allow me to:

	Strongly Disagree (1)	Disagree (2)	Unsure (3)	Agree (4)	Strongly Agree (5)
... receive a good job offer (1)	o	o	o	o	o
... earn an attractive salary (6)	o	o	o	o	o
... get respect from other people (7)	o	o	o	o	o

... do work that I would find satisfying (8)	o	o	o	o	o
... increase my sense of self-worth (9)	o	o	o	o	o
... have a career that is valued by my family (10)	o	o	o	o	o
... do work that can “make a difference” in people’s lives (11)	o	o	o	o	o
... go into a field with high employment demand (12)	o	o	o	o	o
... do exciting work (13)	o	o	o	o	o
... have the right type and amount of contact with other people (i.e., “right” for me) (14)	o	o	o	o	o

Q22 **Part VIII (Interests)**

Instructions: Please indicate your degree of interest in doing each of the following activities. Use the responses below to show how much interest you have in each activity.

How much interest do you have in...

	Very Low Interest (1)	Low Interest (2)	Medium Interest (3)	High Interest (4)	Very High Interest (5)
Solving practical math problems (1)	o	o	o	o	o
Reading articles or books about technical issues (4)	o	o	o	o	o
Solving computer software problems (5)	o	o	o	o	o
Working on a project involving engineering-related principles (6)	o	o	o	o	o
Solving complicated technical problems (7)	o	o	o	o	o
Learning new computer applications (8)	o	o	o	o	o
Working on a project involving scientific concepts (9)	o	o	o	o	o

Start of Block: Post-Survey Confirmation Questions

PQ0 **Post-Survey Confirmations**

Please respond (i.e., Yes or No) to the post-survey statements indicating your consent or request for follow-up by the primary investigator.

PQ1 I would like my name and/or email address to be used to **receive my $20 Amazon e-gift card for completing the online survey**.

o Yes (1)

o No (2)

PQ2 I would like to be **contacted by the researcher if selected for a follow-up 60-minute Zoom interview** (for an additional $20 Amazon e-gift card).

o Yes (1)

o No (2)

PQ3 I would like to **request post-study debriefing** (an in-depth summary of the purpose of the current study sent via email).

o Yes (1)

o No (2)

PQ4 I would like to **request a copy of the study results** at the conclusion of the study.

o Yes (1)

o No (2)

APPENDIX H: DATA CLEAN-UP PROCEDURE IN SPSS*

* Guided by MSU Center for Statistical Training and Consulting (CSTAT)

Data Clean-up in SPSS:

V1: The ResponseID was kept and the subject identifier was added
V2 - V10: Unnecessary Qualtric format data was removed (i.e., response set, name, external data reference, email, IPaddress, status, start date, end date, and finished)
DQ1 - 6: Instructions were deleted

Qualtrics format data Location Latitude, Location Longitude and Location Accuracy were deleted

Q5 - Q10_Coded = **Nominal** (a naming scale, where variables are simply "named" or labeled, with no specific order.

Q11 - Q22_9 = **Ordinal** (scale has all its variables in a specific order, beyond just naming them)
Q12 - Q22: Labels were simplified to better fit on SPSS outputs

Q1: deleted instructions
Q2: deleted last name
Q3: deleted first name
Q4: deleted email address
Q6: ethnicity was "check all that apply"

- Q6_1 = American Indian or Alaska Native was used to add all SPSS ethnic identities label values
- Q6_3 (Black or African-American) label value = 3 was added to the Q6_1 column
- All participants were Black or African-American = 3, except 1 Multi-Ethnic = 7
    - Multi-Ethnic = 7 was added as a label value in SPSS (not on original survey) to account for the 1 participant that marked two ethnicities
- Q6_2 - Q6_6 were deleted

Q7: first generation (3 response options)

- Q7_1 = Yes was used to add all SPSS label values
- Q7_2 = No (2) and Q7_7 = Not Sure (3) were added to the Q7_1 column
- Q7_2 and Q7_7 columns were then deleted

Q9: current primary college

- Q9_4 = College of Engineering was used to add all SPSS label values since most students were current engineering students
- Responses to Q9_1, Q9_2, Q9_5 and Q9_6 were added to Q9_4, then these columns were deleted

Q10: current primary major was maintained

- Q10_Coded was added to identify 1=Engineer and 2=Former Engineer, then data was added based on these label values

Q11: classification was maintained
Q13 and Q14: changed to have no decimal

APPENDIX I: SEMI-STRUCTURED ZOOM INTERVIEW SCHEDULE

Directions: All text to be read aloud by the researcher is included in a text box.

Introduction and Consent
This interview will be recorded. Before I begin recording you can change the name in your Zoom window if you would like to in order to remain anonymous by name. I will begin the recording now. **START RECORDING** Thank you for your help with this research study. The purpose of the study is to understand undergraduate students' experiences while in engineering. This study is focused on students that currently pursue engineering or previously pursued engineering that also identify as Black or African-American. You participated in phase one of the study when you completed the Engineering Experiences survey. This interview is phase two of the same study and should take **no more than 60 minutes**. All the data collected will be kept confidential. Be assured that no one except the researchers will view these recordings. The recordings will be securely stored at the conclusion of this interview. Identities will be coded with numbers, and pseudonyms will be used for all analysis, presentations, and publications. No identifiers will be stored with the collection of research data. Your participation in this study is completely voluntary. You have the freedom to not respond to certain questions that you do not feel comfortable answering. Please indicate that you voluntarily agree to participate in this interview by saying "Yes, I volunteer to participate in this interview." If you do not want to participate in this interview, please indicate this by saying, "No, I do not volunteer to participate in this interview." **YES** - You indicated that you do want to participate in this interview. I will proceed with the interview now. **NO** - You indicated that you do not want to participate in this interview. I will stop this interview and the recording now.

The participants need to consent before beginning the next section.

Directions for Dialogue
I am going to ask you sets of questions that I would like you to talk about. Please be aware that there are no right or wrong answers. I am interested in your perspectives and experiences as a Black or African-American, undergraduate student while in engineering - either previously or currently.

Section 1: Background Experiences related to Racial Identity
I would like to begin by understanding more about your pre-college experiences, how you define your racial identity, and how both have informed your perspectives and experiences.

Personal Background

1. **Tell me where you call home?**
2. **How would you describe the community where you grew up (including family, friends, etc.)**
    a. Was your high school in this community?
    b. Do you feel that your high school prepared you to pursue an engineering major at the Anonymous Institution?
        i. How? In what ways?
        ii. If not, why not? What do you feel was missing?
    c. Can you describe the experiences you had with engineering-related activities during high school?
        i. Do you feel these experiences prepared you to pursue an engineering major at the University?
            1. How? In what ways?
            2. If not, why not? What do you feel was missing?

Racial Identity

3. **How do you define your racial identity?**
4. **Do you feel your racial identity influenced your experiencing while in engineering?**
    a. **EG -** How **has** your racial identity influenced your experiences in engineering? Can you give me some concrete examples?
    b. **Former EG -** How **did** your racial identity influence your experiences while in engineering? Can you give me some concrete examples?

Section 2: Goal Orientation
Interview Questions: focused on the current goal orientations of both groups related to completing their degrees

1. **What are your academic goals?**
    a. Who helped shape or influence these goals?
        i. Yourself (internal)
        ii. Family (close external) - **Did your family shape these goals?**
        iii. Friends (external)
        iv. Mentor or someone important in your life (external)
    b. What motivates you to achieve these goals?
    c. How will you know when you have achieved these goals?

Section 3: Self-Efficacy early in Engineering
Interview Questions: focused on students' early confidence or lack of confidence in engineering

1. **Coming into the University, were you confident in your decision to pursue engineering as a major?**
2. **How confident were you in pursuing engineering as a major?**
    a. Complete Confidence *(possible questions to this type of response)*
        i. Please describe the <u>academic experiences</u> that influenced your confidence in pursuing engineering?
        ii. Please describe any <u>personal experiences</u> (such as with family, friends, etc.) that influenced your confidence in pursuing engineering?
        iii. Were there any situations where this confidence was **increased or boosted**?
        iv. Were there any situations where this confidence was **decreased or lessened?**

    b. Some Confidence *(possible questions to this type of response)*
        i. Please describe the <u>academic experiences</u> that influenced your confidence in pursuing engineering?
        ii. Please describe any <u>personal experiences</u> (such as with family, friends, etc.) that influenced your confidence in pursuing engineering?
        iii. Were there any situations where this confidence was **increased or boosted**?

iv. Were there any situations where this confidence was **decreased or lessened?**

c. No Confidence at All *(possible questions to this type of response)*

i. Please describe the <u>academic experiences</u> that influenced your confidence in pursuing engineering?
ii. Please describe any <u>personal experiences</u> (such as with family, friends, etc.) that influenced your confidence in pursuing engineering?
iii. Were there any situations where this confidence was **increased or boosted**?
iv. Were there any situations where this confidence was **decreased or lessened?**

Section 4a: Barriers (or Obstacles) Experienced in Engineering **Section 4b: Barriers - Personal Perspectives**
Interview Questions (4a): focused on students describing their personal experiences with the barriers below based on the groups indicating a high or low magnitude of agreement these barriers hindered their progress toward a degree in engineering. ***Interview Questions (4b):*** focused on students describing their personal perspectives related to the magnitude these barriers impacted themselves and others

1. **EG -** What barriers or obstacles <u>have you experienced</u> in engineering that you feel hindered your progress in engineering?
2. **Former EG** - What barriers or obstacles <u>did you experience</u> in engineering that you feel hindered your progress in engineering?
3. Do you feel the barriers you experienced were <u>unique to Black engineering students</u>?
    a. **YES** - In what ways? Please explain.
    b. **NO** - Why do you think they are not unique?
2. How did the barriers you experienced while in engineering influence your decision to **<u>stay</u>** in engineering?

Section 5a: Knowledge **Section 5b: Knowledge - Personal Perspective**
Interview Questions (5a): focused on students describing the impact of having and not having this knowledge while in engineering ***Interview Questions (5b):*** focused on students describing their personal perspectives related to how their knowledge informed themselves and others

1. **Do you think you needed specific knowledge or information to overcome the barriers you discussed?**
    a. What specific knowledge do you think is needed to overcome the barriers you described?
    b. **How did you gain** the knowledge you felt was needed in engineering?
    c. How did you know **when to use the knowledge** you gained while in engineering?
    d. If you didn't have this knowledge, then what?
2. Do you feel the knowledge you had was unique to Black engineering students?
    a. YES - In what ways? Please explain.
    b. NO - Why do you think it was not unique
2. How did the knowledge you had related to engineering influence your decision to **stay** in engineering?

Section 6a: Actions **Section 6b: Actions - Personal Perspectives**
Interview Questions (6a): focused on students describing the impact of taking or not taking these actions while in engineering ***Interview Questions (6b):*** focused on students describing their personal perspectives related to how the actions they took or did not take compare to other engineering students

1. **Do you think you needed to take certain actions to overcome the barriers you experienced?**
    a. What specific action did you take to overcome the barriers you described?
    b. How did you know **when to take these actions**?
    c. If you didn't take these actions, then what?
2. **Do you feel the actions you took were unique to Black engineering students?**
    a. YES - In what ways? Please explain.
    b. NO - Why do you think it was not unique?
3. How did the actions you took related to engineering influence your decision to **stay** in engineering?

Section 7 - Outcome Expectations
Interview Questions: focused on students beliefs about the outcomes of performing particular behaviors related to pursuing an engineering major

1. **What beliefs or expectations did you have about what an engineering degree could do for you?**

a. **What did you find to be <u>true</u> about these expectations?**
    i. How did confirming your expectations influence your motivation to pursue engineering?
b. **What did you find to be <u>false</u> about these expectations?**
    i. When did you realize your expectations of engineering did not match with what you were experiencing?
    ii. What did you do?

2. What surprised you the most about pursuing a degree in engineering?

Conclusion/Wrap-up
We are coming to the end of the interview. Before we finish the interview and stop recording, 1. **Is there advice you would like to share with incoming Black students that may be considering a major in engineering at the Anonymous Institution?** 2. Is there anything else you would like to share with me that I did not ask during this interview? 3. Do you have any questions for me before I end the interview? If you have any questions after the interview, please contact me, *Michelle Smith Ware*, at *smithwar@msu.edu* or on my cell at *504-914-5210.* After I get off Zoom with you and secure this recording, I will use the email you provided when you took the online survey to send your $20 Amazon Gift Card. Thank you again for participating in this study! **STOP RECORDING**

APPENDIX J: ADDITIONAL RESULTS FOR BARRIER ITEMS

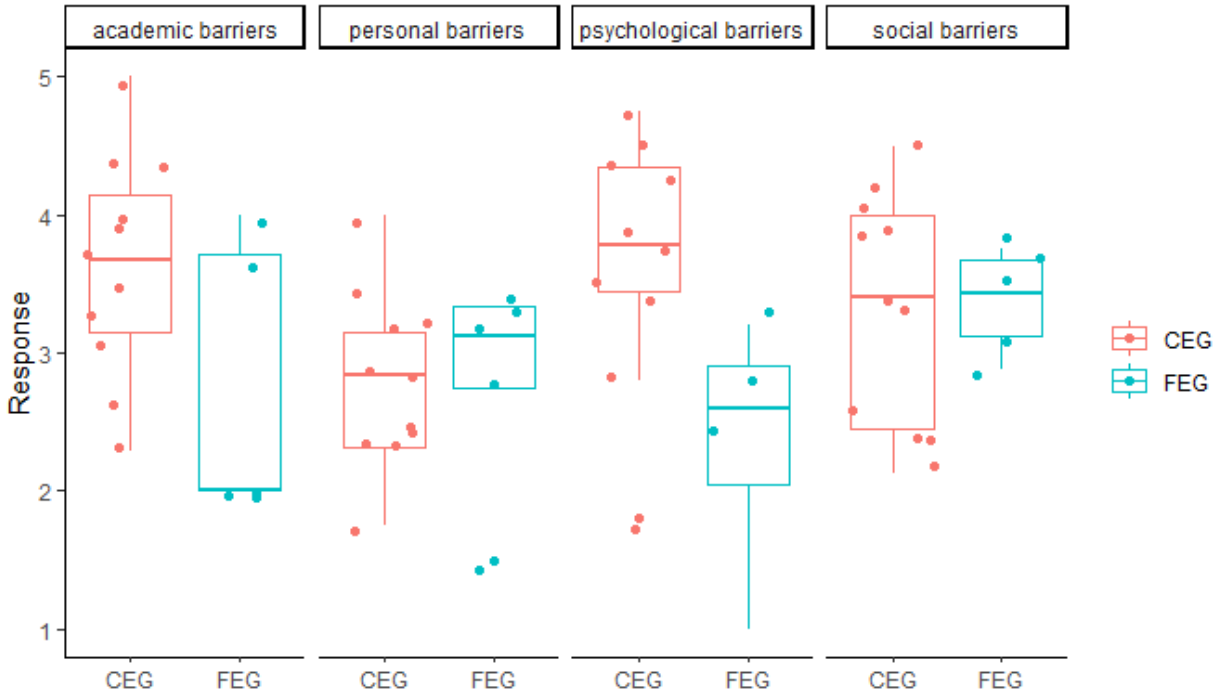

Figure 3: Boxplot of barrier subscale items.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

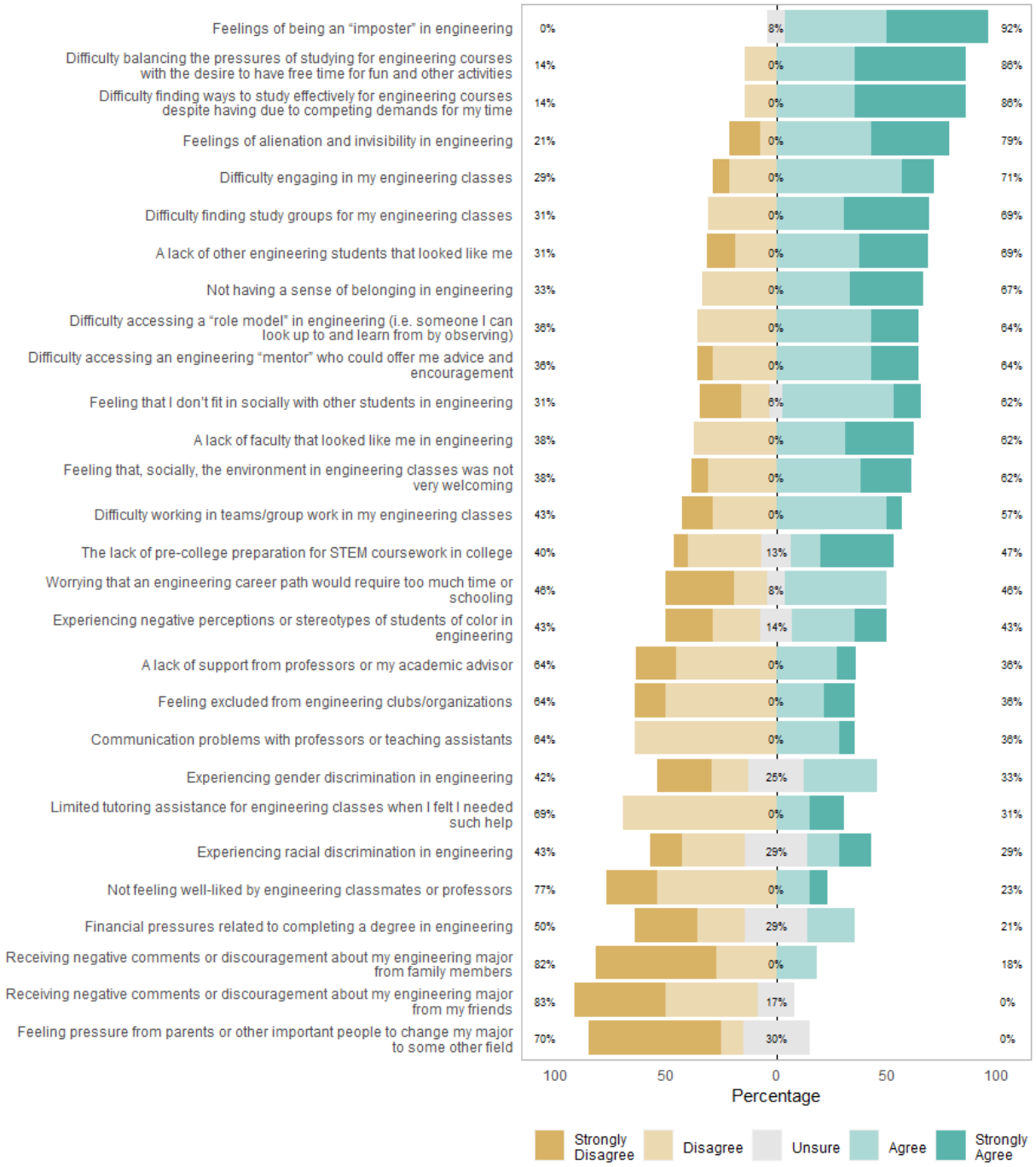

Figure 4: Barriers items ordered by percent of agreement for all participants.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

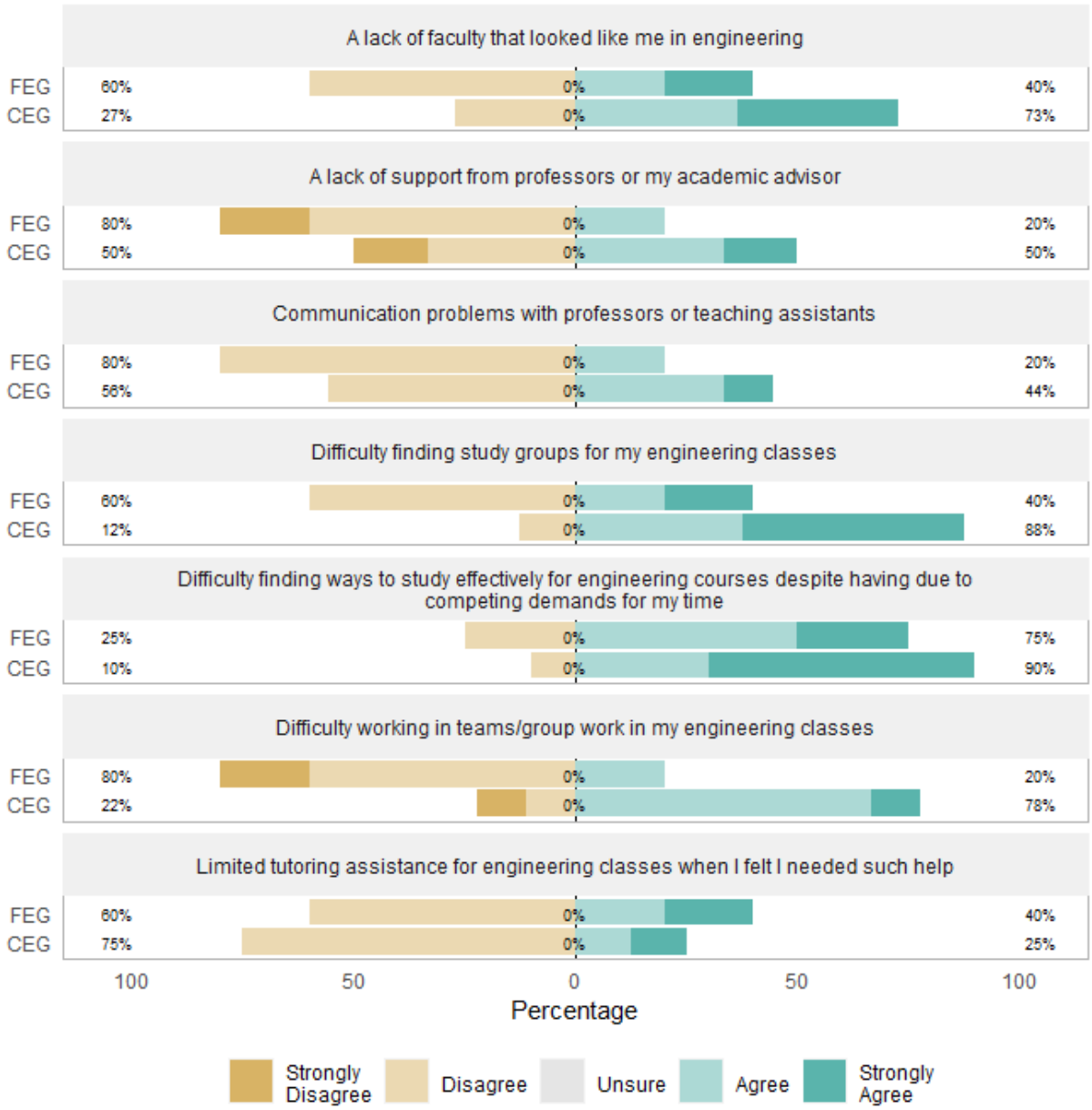

Figure 5: Academic barrier items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

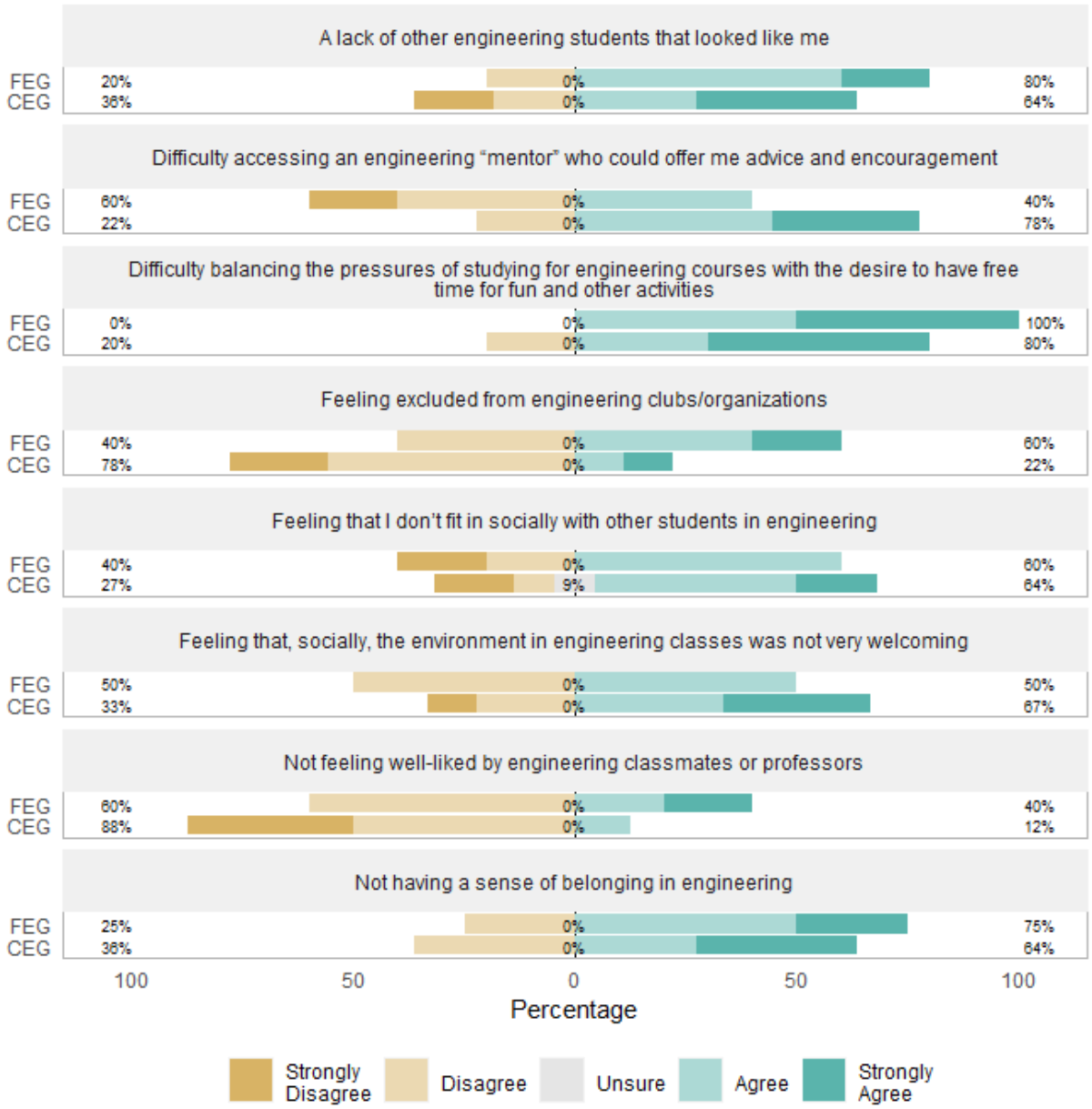

Figure 6: Social barrier items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

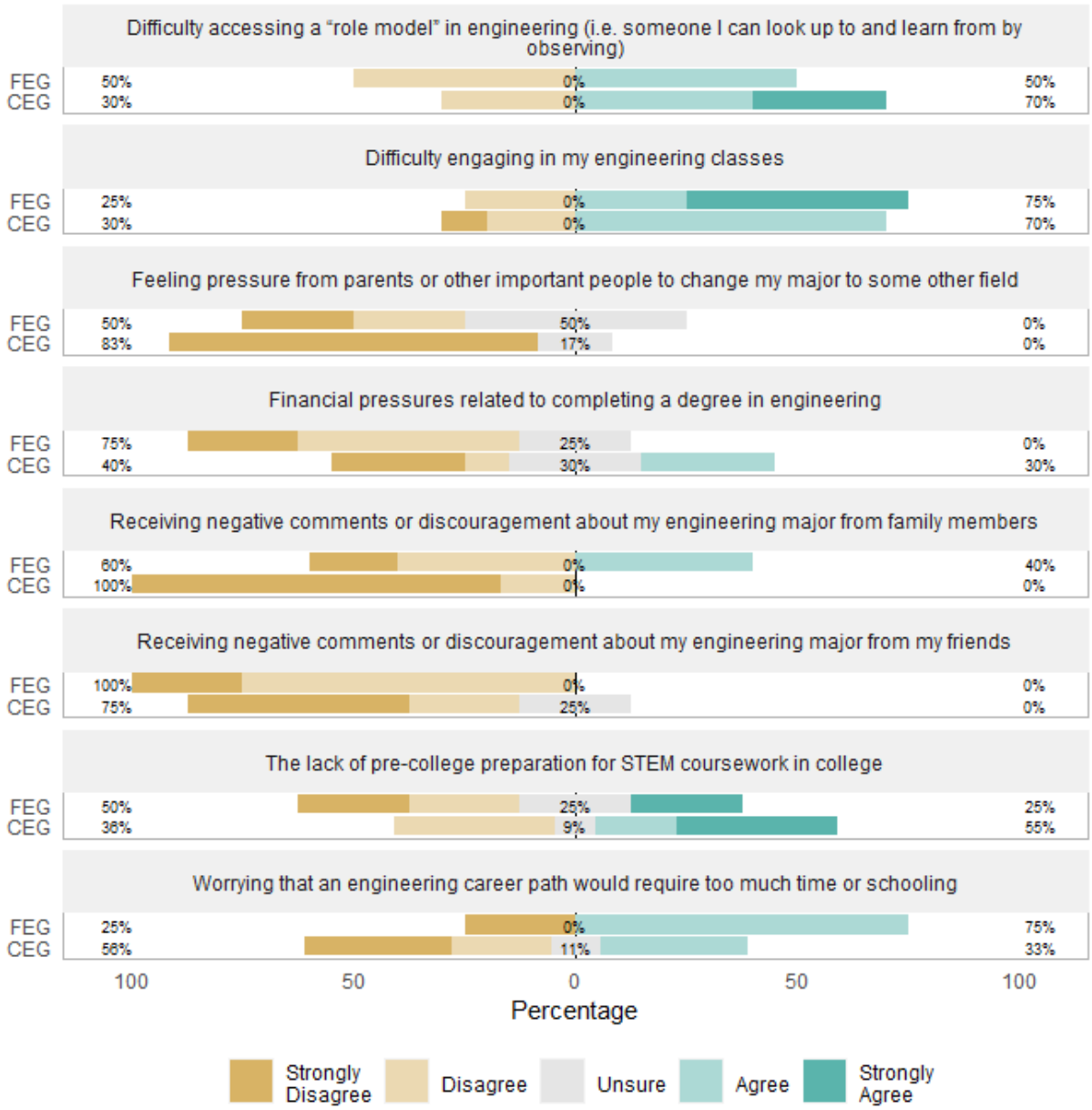

Figure 7: Personal barrier items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

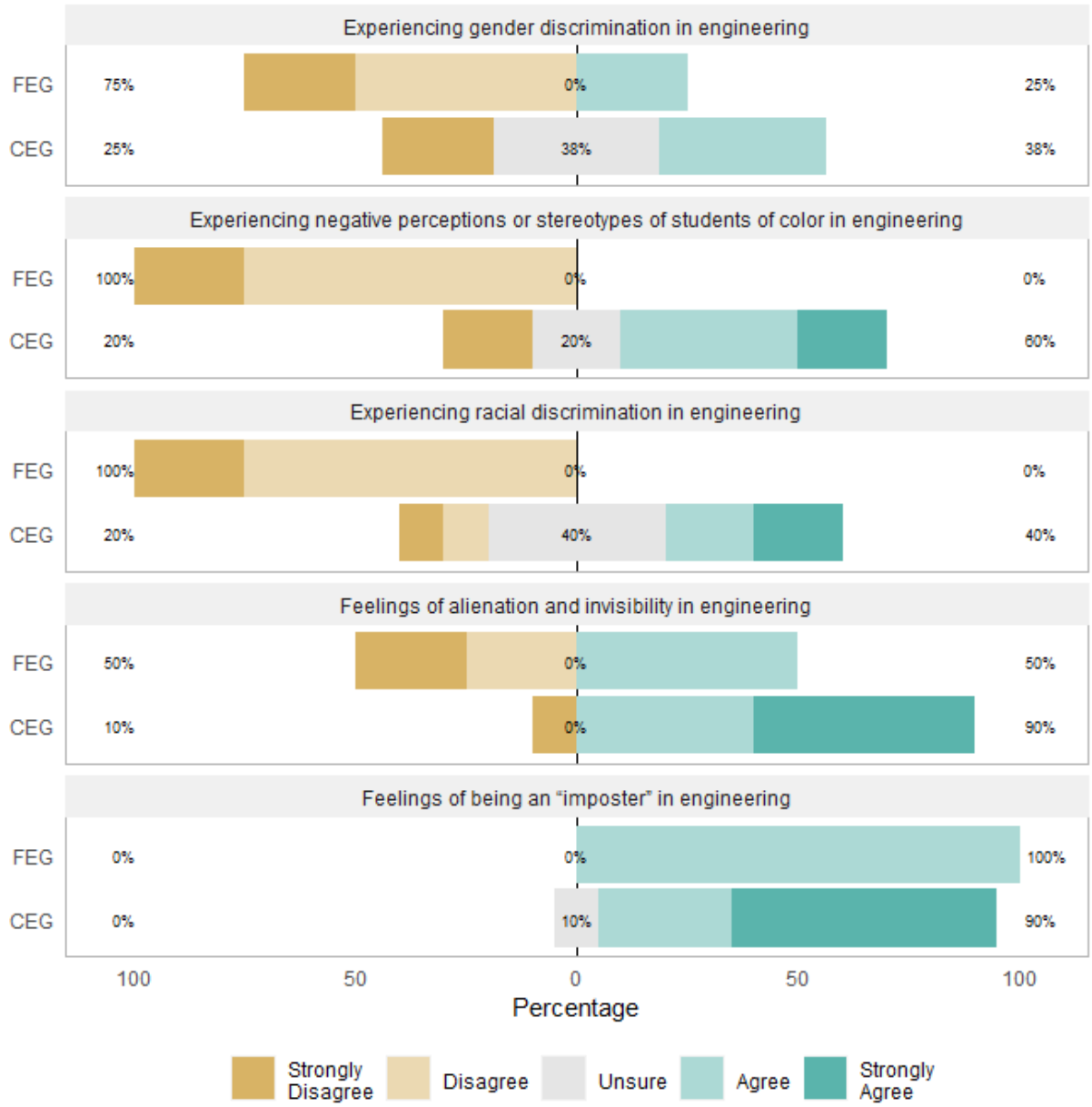

Figure 8: Psychological barrier items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

APPENDIX K: EXAMPLES OF INTERVIEW RESPONSES RELATED TO EXPERIENCING RACIAL DISCRIMINATION

Table 27

Examples of Interview Responses Related to Experiencing Racial Discrimination

Former Engineering Students		**Continuing Engineering Students**	
Yes	**No**	**Yes**	**No**
"I'm I do think I had to in terms of racial. I wouldn't, maybe I wouldn't say discrimination, but a racial awareness. I definitely had to if I needed to just get something done in a group with like where nobody else was black, I would have to say it in a very in a way that basically coddled my classmates. Because I just remember in my second group, everything I said came across as hostile. And it didn't matter what. It was like why? I'm literally just making a suggestion. So it's kind of like I had to always have, like the fake high pitch voice and end with like a question or if I like wanted them to do something, I'd have to ask a question. So that they think that you know it was their idea instead of guessing it. If I wanted to get it done, this stuff like that, that was very tedious." (MG13, female)	"I had never experienced any racial things, like that was a plus for me. No, and like racial like slurs, any anything like that personally." (SH11, female)	"I remember freshman year, you know, you know, big chemistry classes. I was sitting in the middle of row cuz you just have to grab a seat in a lot of those and nobody sat next to me. Everybody kinda filled in around me. And I mean like some empty seats and some people further down. I was like wow like they came in a row like just didn't wanna sit next to you. Like that has never happened like I've never seen that like I've heard stories from like my older relatives about stuff like that, but I had never actually experienced something like that happen to me." (AW1, male)	"I heard these things or my mom told me these are some of the things you're going to have to face. Um, I'd say yeah, growing not for my mom, but growing up just like at people knowing that I wanted to go into stem and kind of just sharing their thoughts or things that they kind of like had heard while they were in their undergrad, and then also hearing of the upperclassmen experiences, like when I was a freshman and sophomore of their experiences as students of color in engineering...I'd say it [her experience] was different and that's why I don't think that it affected me as much as I saw it, or that they explained that it affected them because it didn't happen like directly to me." (OE10, female)
"And also in like science classes and labs and stuff it was kind of like clear that certain people tend to group together. So yeah, there were times where I would only like the only person who would want to partner with me is like another black person...Yeah, it's a lot of nonverbal. Just kind of micro things that happen. Nothing is blatant really at this stage." (CO4, female)	"Yeah, um, well I think in general, for me I always feel like I've never experienced racial discrimination. Yeah. Um, and like that, that's not something that. Yeah. Like I've ever had to worry about um. So even like if I were to describe a situation where it's clear racial discrimination, I don't even feel like I would identify it as that." (LA6, female)	"When I transitioned away from Scholars Engineering it was like these people are in my major but they have had time to meet and talk. They were all white and I was not surprised because it's [anonymous university] and they are predominately white. That was not the issue, the issue was when I tried to talk and speak they would be like 'ha ha ha' then they would turn away." (IM8, male)	

APPENDIX L: ADDITIONAL RESULTS FOR HEURISTIC ITEMS

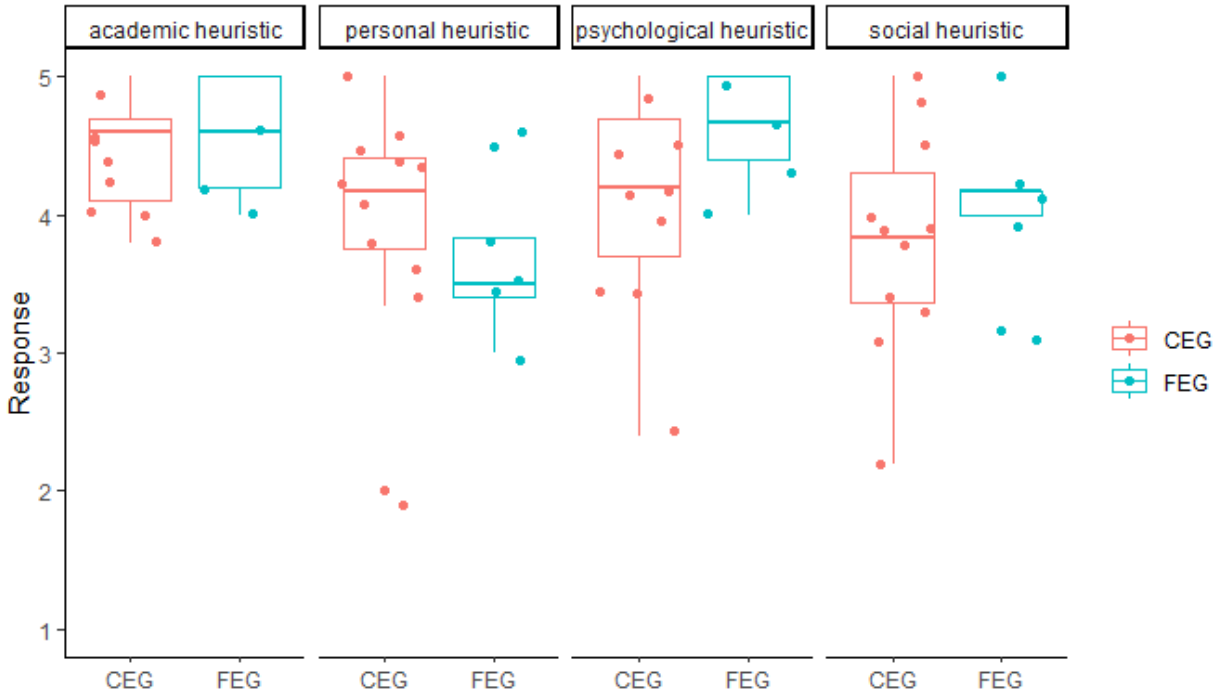

Figure 9: Boxplot of Heuristic Subscale Items.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

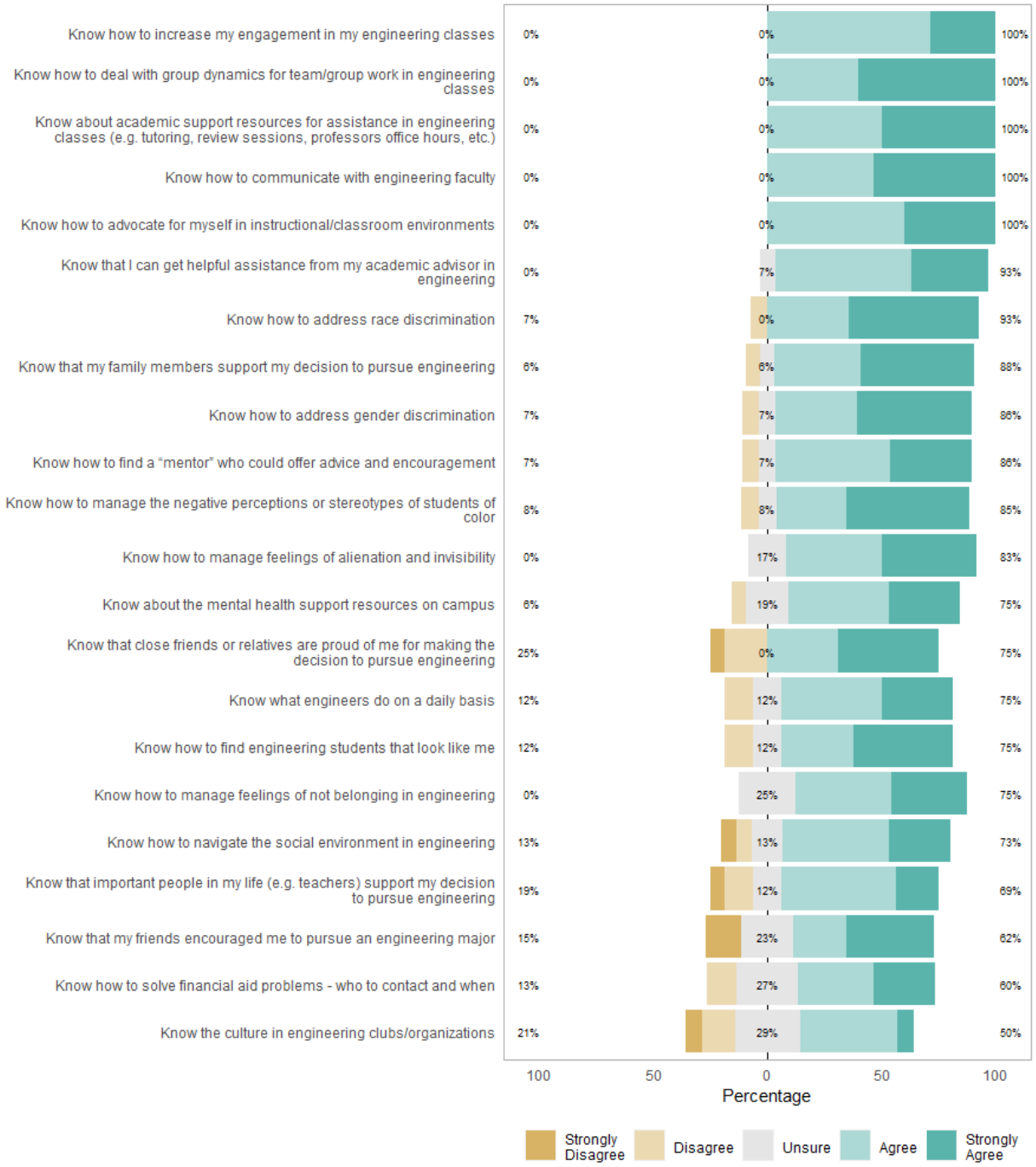

Figure 10: Heuristic items ordered by percent of agreement for all participants.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

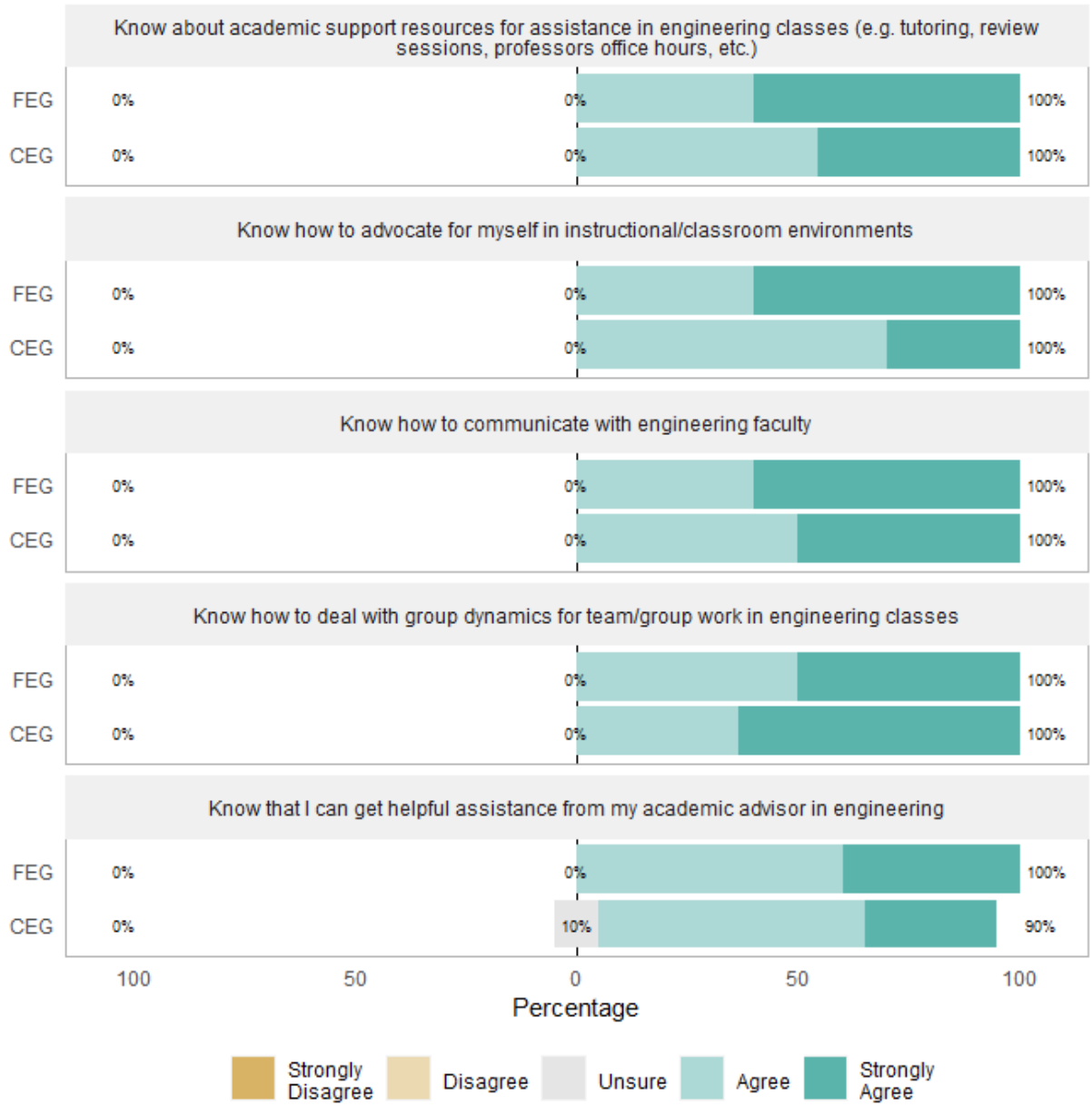

Figure 11: Academic heuristic items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

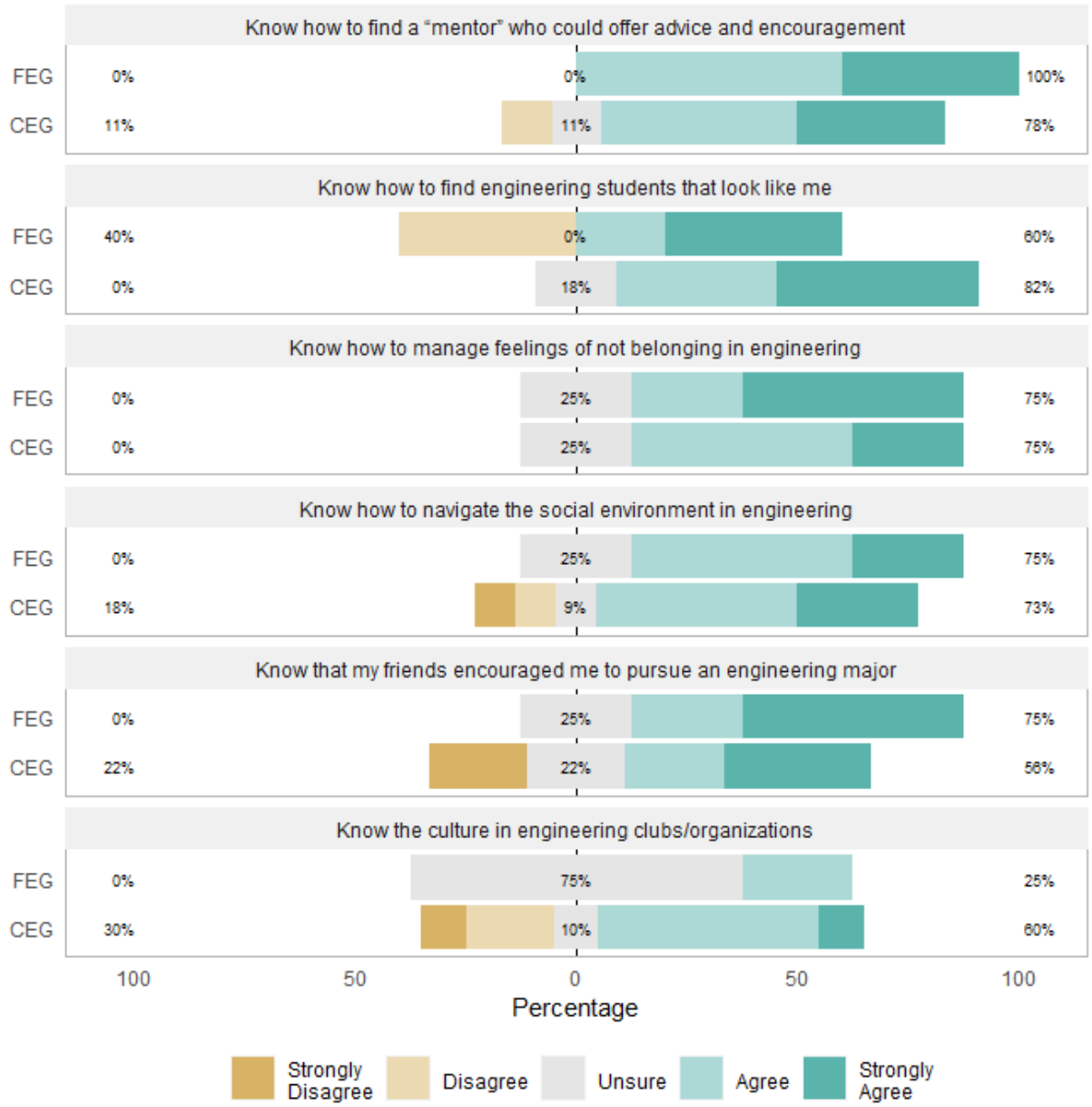

Figure 12: Social heuristic items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

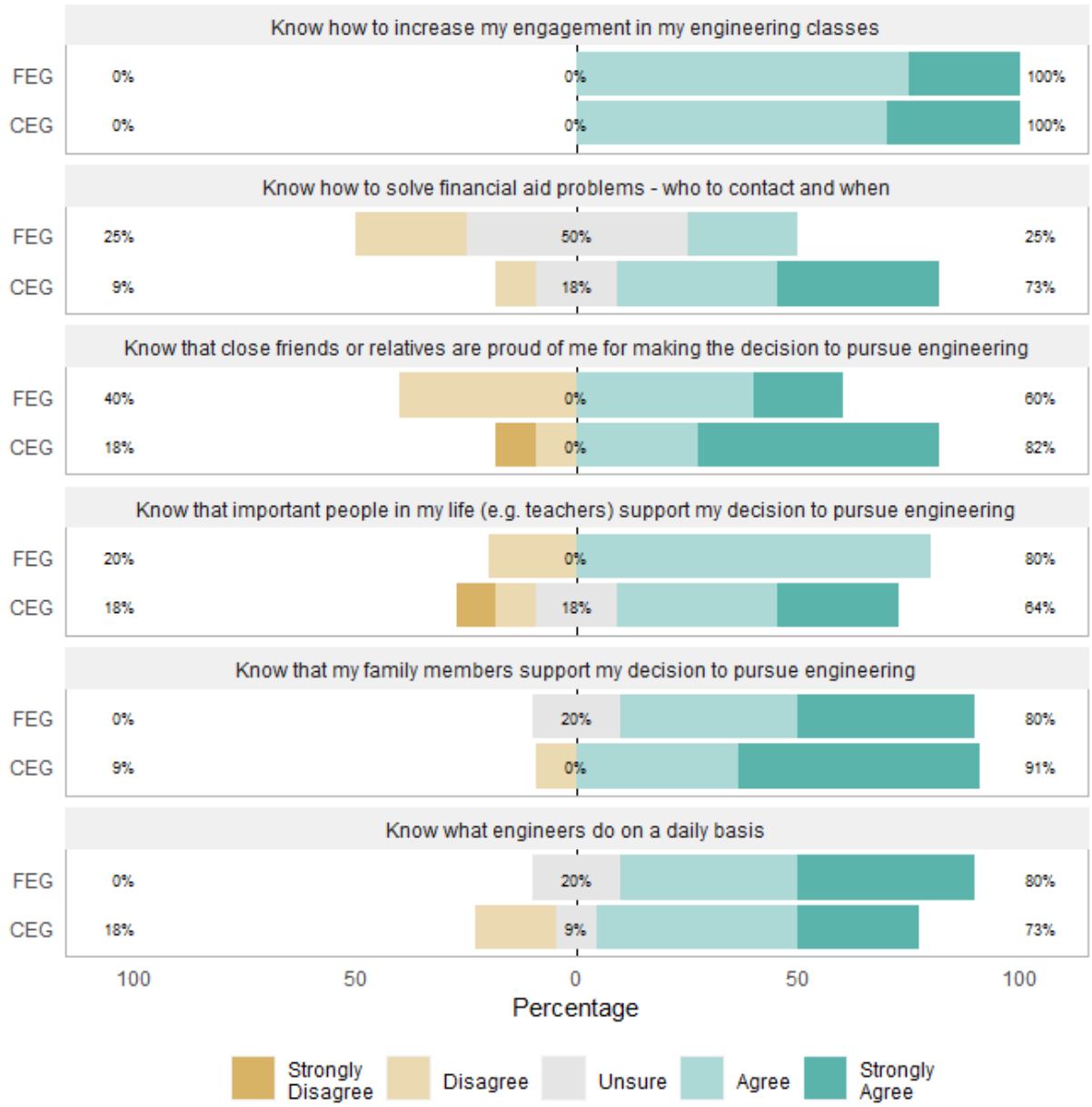

Figure 13: Personal heuristic items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

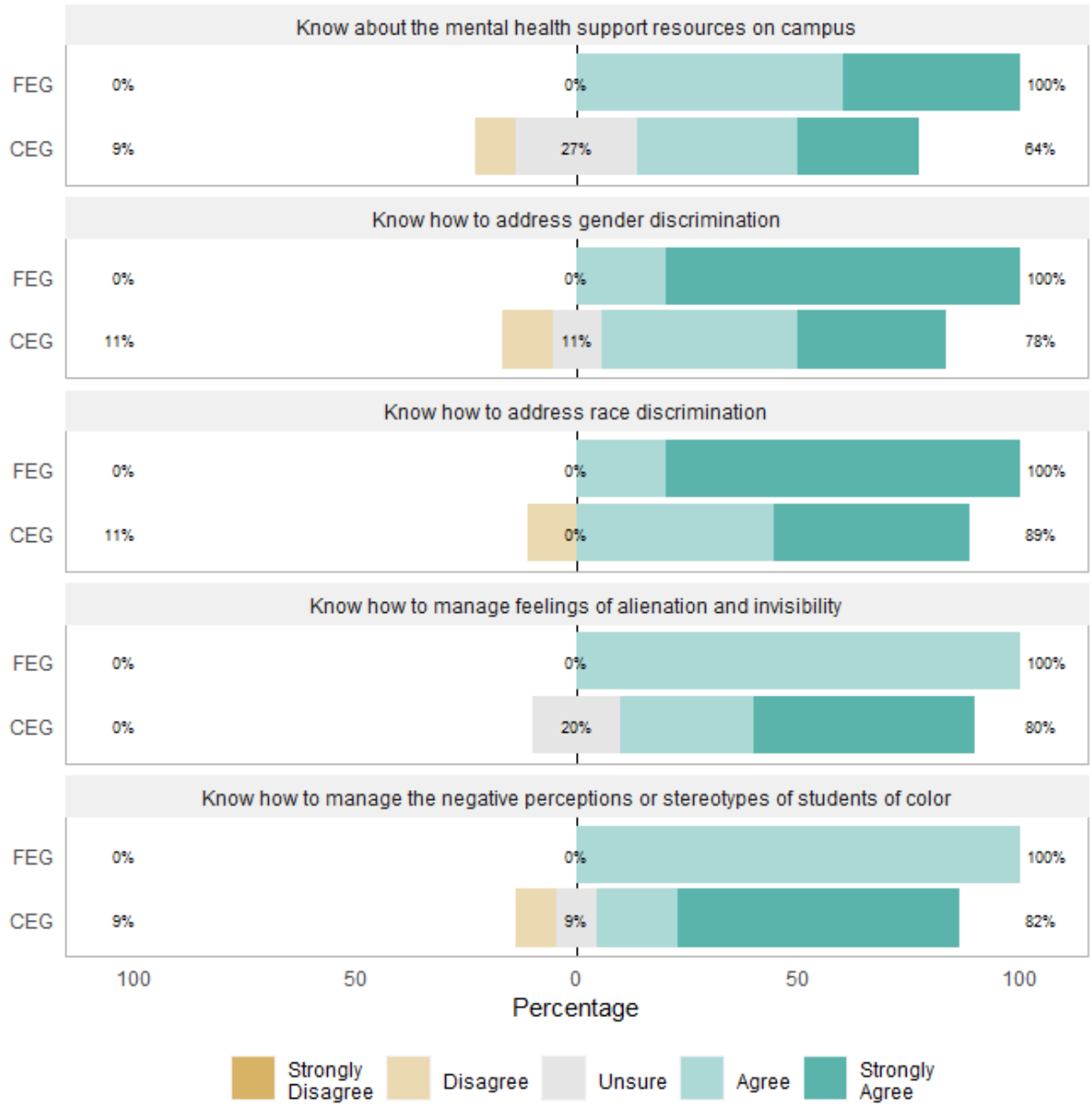

Figure 14: Psychological heuristic items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

APPENDIX M: ADDITIONAL RESULTS FOR ACTION ITEMS

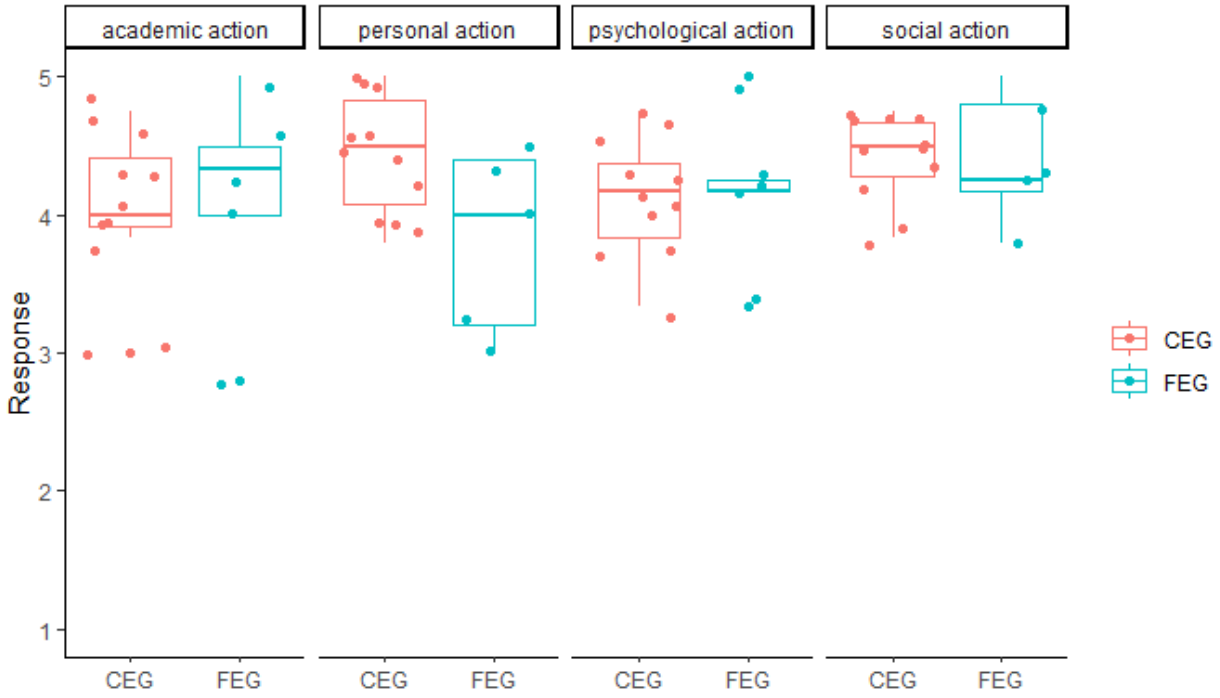

Figure 15: Boxplot of action subscale items.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

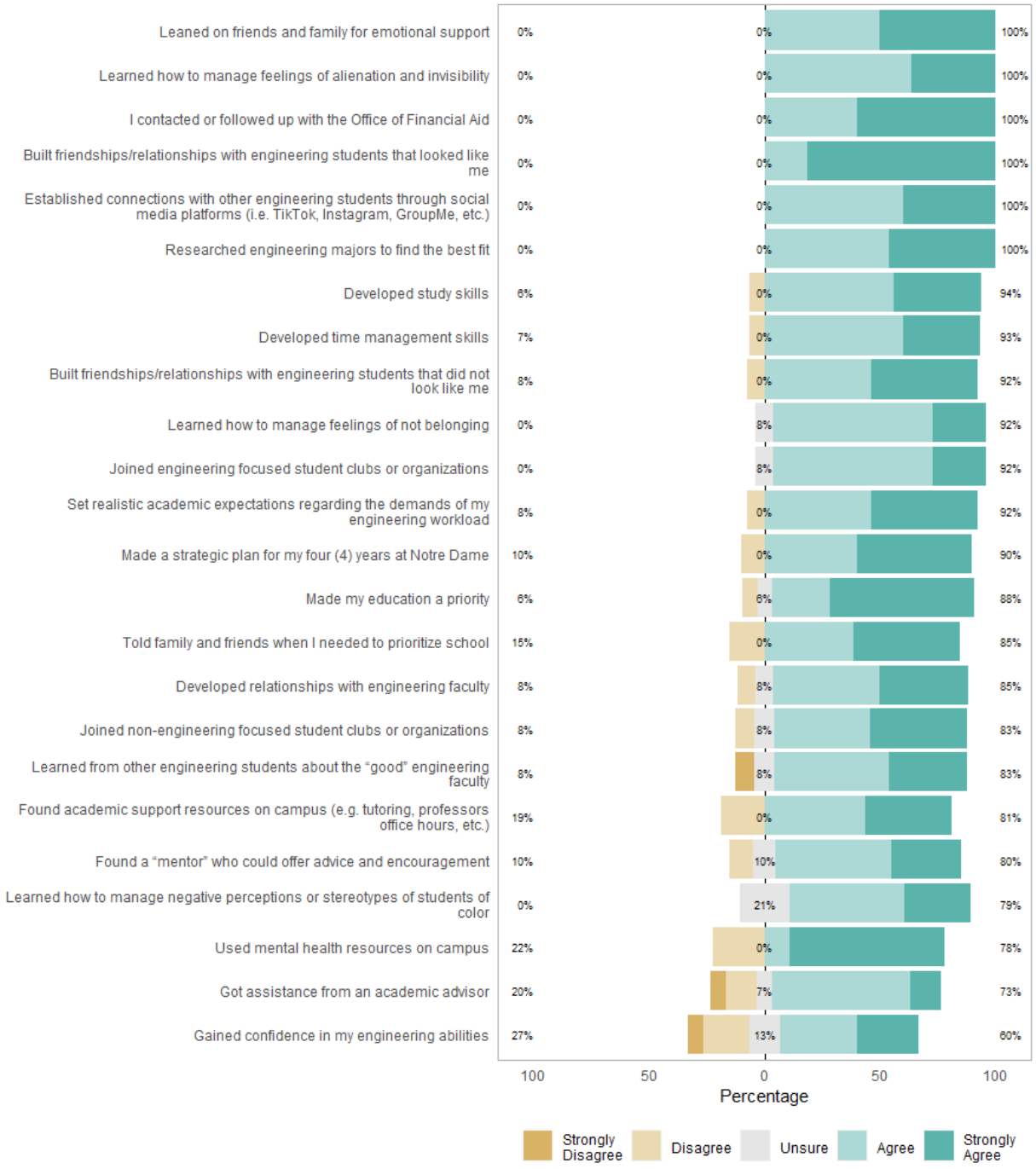

Figure 16: Action items ordered by percent of agreement for all participants.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

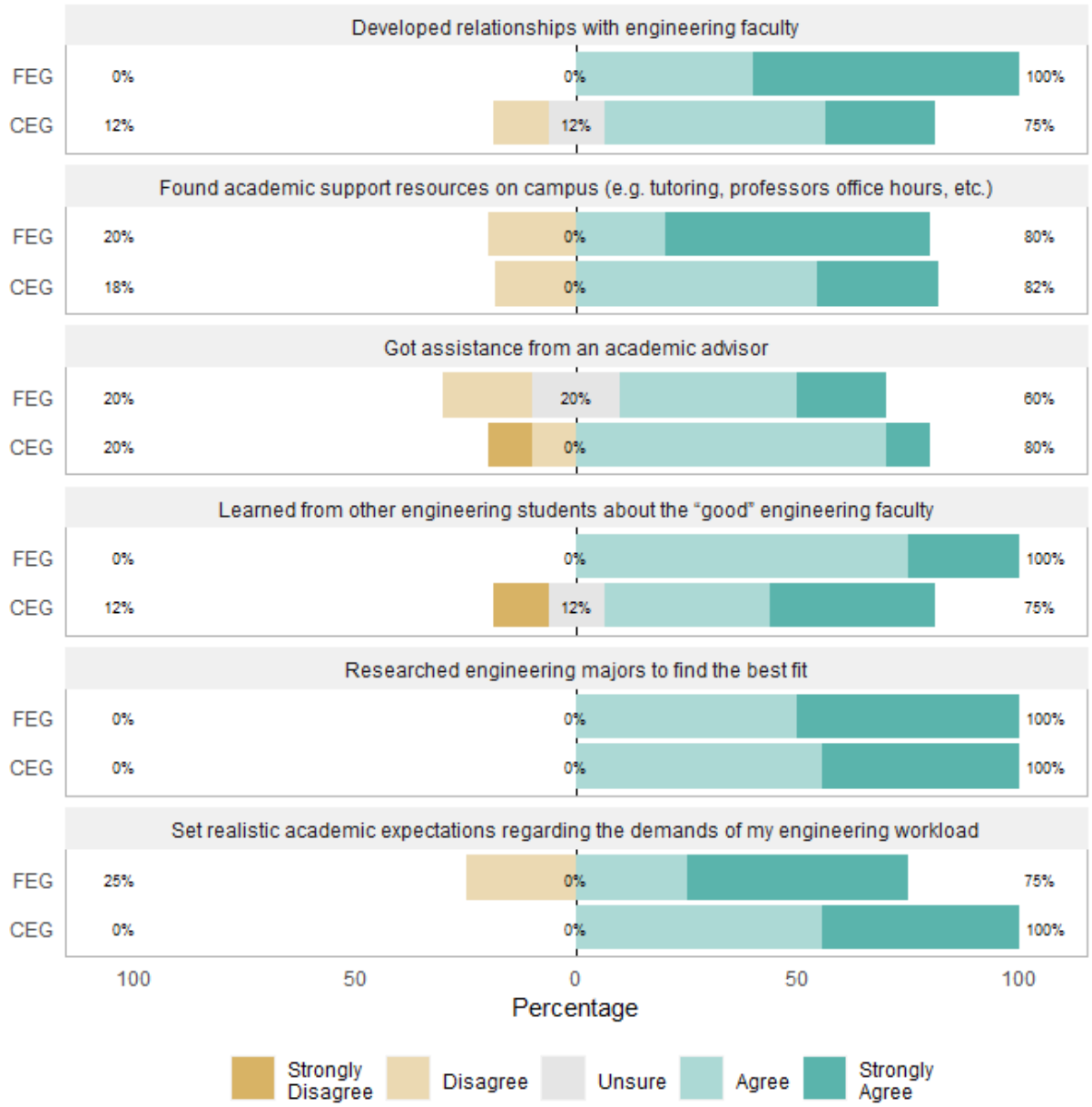

Figure 17: Academic action items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

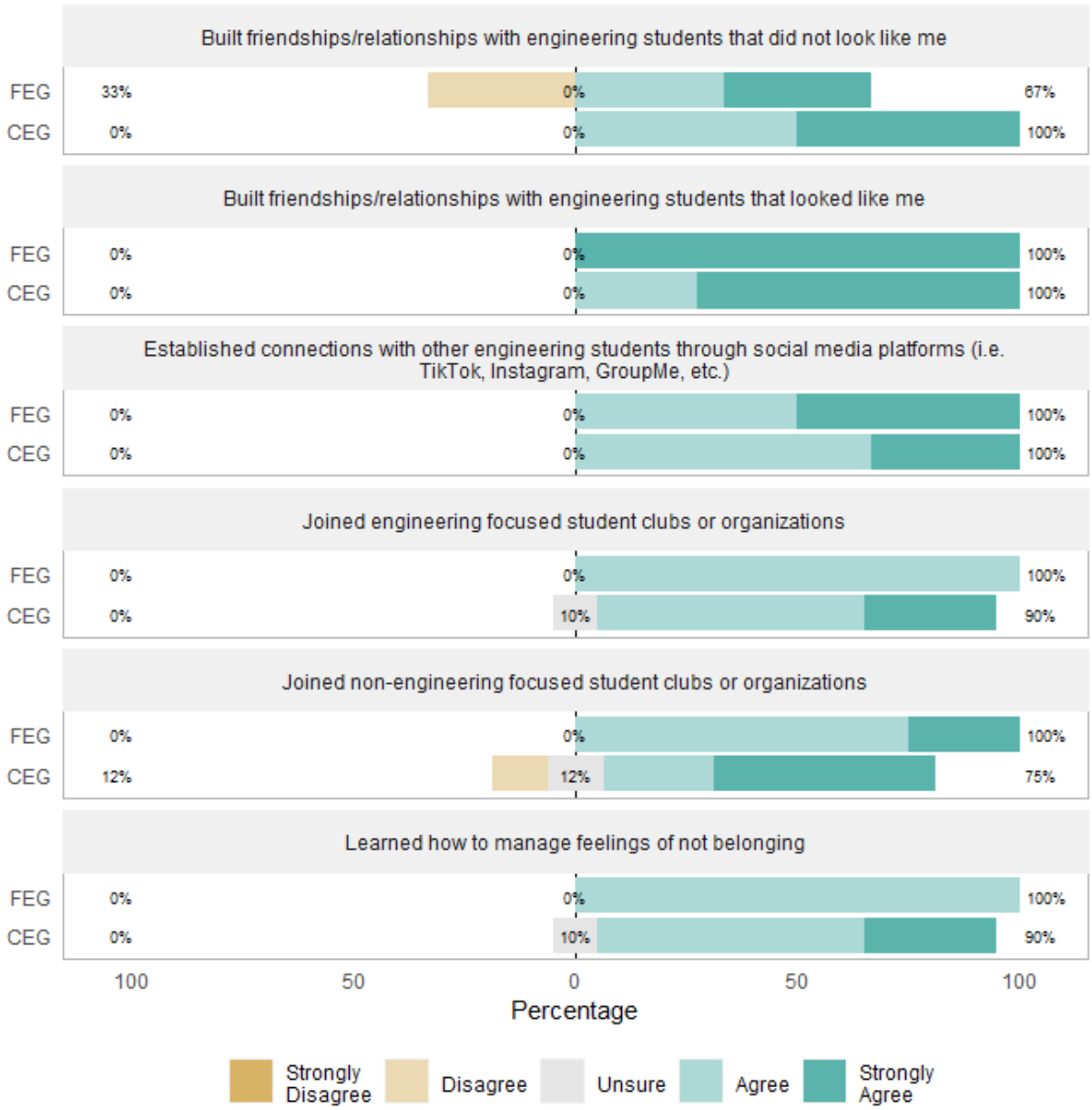

Figure 18: Social action items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

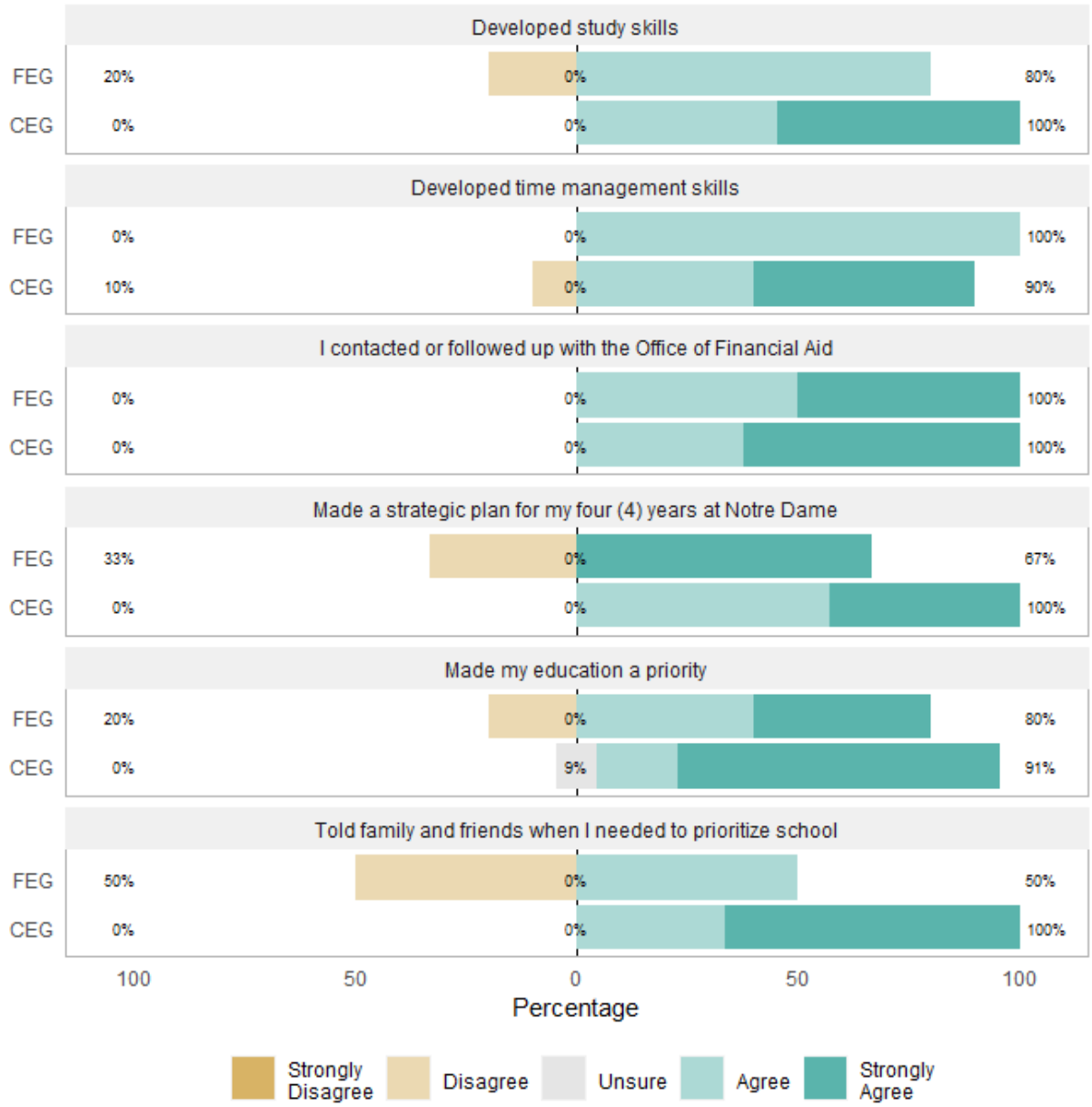

Figure 19: Personal action items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).

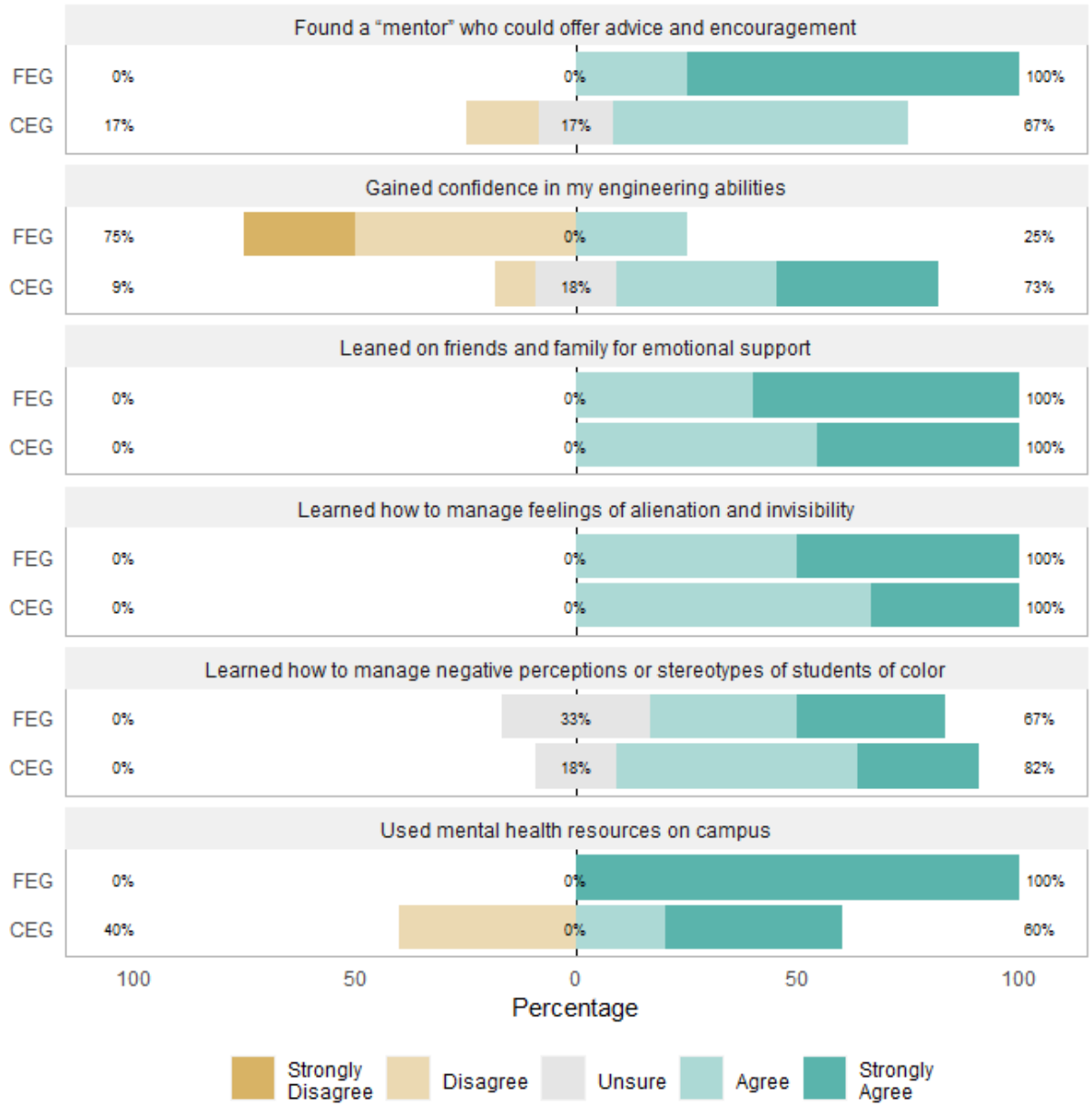

Figure 20: Psychological action items by percent of agreement for former and continuing students.

Note:
Plots were produced in R (R Core Team, 2022) using the ggplot2 (Wickham, 2016) and the likert packages (Bryer & Speerschneider, 2016).