The Journal of Negro Education, 91 (1), 112-124

Black Students in Undergraduate Engineering Programs: A Qualitative Systematic Review

Karis E. Boyd-Sinkler **Duke University**
Teirra K. Holloman **Virginia Tech**
Crystal M. Pee **Virginia Tech**
Walter C. Lee **Virginia Tech**
Jeremi S. London **Virginia Tech**

Motivated by the desire to disrupt marginalization, the purpose of this qualitative systematic literature review is to identify salient aspects of the Black student experience in undergraduate engineering programs. The authors identified and analyzed 19 germane research articles. For each article, they extracted various components of the study to identify key findings that illuminate the lived experiences of Black students and offer recommendations for improving student support efforts. Major themes were related to student persistence and performance, the impact of racial and gender identity, and supportive social networks.

Keywords**:** *engineering, systematic literature review, undergraduate students, STEM*

INTRODUCTION

The science, technology, engineering, and mathematics (STEM) fields are broadly seen as prestigious and vital to the growth and stability of the U.S. economy (Noonan, 2017). STEM fields are often attributed to higher salaries and lower rates of unemployment (Noonan, 2017). Combined, these realities have correlated with a growing interest in STEM degrees, particularly in engineering. From 2009 to 2018, according to the American Society of Engineering Education (ASEE; in Gibbons, 2009 and Roy, 2019), the number of bachelor's degrees awarded in engineering increased by approximately 83%, rising from 74,387 to 136,223. During this same period, the number of engineering bachelor's degrees awarded to students from underrepresented ethnic/racial groups has also increased. However, the proportion of engineering bachelor's degrees awarded to these groups have decreased, lowering their representation despite the broader growth in the field.

There have been significant efforts in recent years to increase the numerical diversity and representation of underrepresented ethnic/racial groups in engineering (e.g., Handelsman & Smith, 2016; Nelson & Reid, 2016). This study is particularly interested in Black Americans because this demographic group has seen a notable percentage decrease in the attainment of bachelor's degrees in engineering since 2009. Despite the consistent effort to broaden participation, the percentage of engineering bachelor's degrees awarded to Black Americans has decreased from 4.6% in 2009 to 4.1% in 2017 (Gibbons, 2009; Roy, 2019). Lord and colleagues (2019) suggested that Black students who start in an engineering discipline have the lowest graduation rate and highest attrition rate among their Asian, White, and Hispanic counterparts. This study aims to advance understanding of why this might be the case.

Chang and associates (2014) posited that the effect of race on STEM performance is primarily associated with inadequate STEM preparation and accessibility to resources compared to other ethnic/racial groups. Some students are underprepared for college-level mathematics and science courses and subsequently have a harder transition to college, decreasing levels of academic self-efficacy (Chang et al., 2014; Russell & Atwater, 2005). While a lack of family support can lead to decreased levels of intrinsic motivation and a desire to persist (Russell & Atwater, 2005), the campus racial climate has also been shown to impact students' experiences and retention rates (Titus, 2004). Underrepresented student engagement with other peers in STEM, joining STEM-related

organizations, and participation in undergraduate research have been shown to positively impact persistence (Espinosa, 2011).

While statistics are crucial for identifying trends in the recruitment and retention of Black students, quantitative data can be limiting as it relates to understanding *how* students experience the engineering education process. Statistics do not capture the meaning-making process or how students interpret a variety of situations (e.g., Hatch, 2002). Understanding the lived experiences of Black students in undergraduate engineering programs is critical because first-hand experiences can illuminate critical aspects of engineering education that would otherwise remain hidden (e.g., Ong et al., 2020). We aim to address this need. More specifically, the purpose of this qualitative systematic literature review is to identify salient aspects of the Black student experience in undergraduate engineering programs. The study highlights opportunities for future inquiries on this topic and potential avenues for supporting Black engineering students.

METHODOLOGY

To understand the experiences of Black students in undergraduate engineering programs, a systematic literature review (SLR) was conducted as a part of a larger project focused on Black Americans in engineering and computer science. According to Borrego, Foster, and Froyd (2014), SLRs prove to be a useful tool when needing to summarize, critically evaluate, or reconcile conflicting evidence that informs policy and practice. SLRs can also be used to identify gaps in the literature and describe the current state of knowledge. Herein, we aim to summarize and describe the current state of knowledge.

Two resources guided the design of this SLR: Petticrew and Roberts (2006) provided insights on how researchers from a variety of disciplines conduct SLRs, while Borrego and associates (2014) supplemented this work by providing needed context for the engineering education community to use this methodology. Together these works inform the five major steps implemented for this study including:

1. Formulate guiding research questions and corresponding inclusion criteria
2. Find and catalogue sources
3. Critique and appraise the quality of selected literature
4. Address bias, validity, and reliability concerns
5. Synthesize insights

These steps are outlined next, including the process of collecting, identifying, and synthesizing articles for this study.

Formulating Guiding Research Questions and Inclusion Criteria

Petticrew and Roberts (2006) stress the importance of developing appropriate research questions because they give insight to all future design decisions, including the types of studies included in the review. Because the purpose of this SLR was to identify salient aspects of the Black student experience in undergraduate engineering programs, the following questions were developed:

- What themes are most salient in qualitative studies of Black students in undergraduate engineering programs?
- What recommendations have been proposed to improve these experiences?
- What future research has been suggested to better understand these experiences?

When searching for literature, the inclusion criteria utilized were publication date range, database selection, and search string selection. This study is part of a larger project, and more detail about these processes can be found in a previously published article about the overall process of conducting an SLR (Phillips et al., 2017). Documenting the inclusion criteria of this study aids other researchers who may seek to replicate the same process (Borrego et al., 2014). Additionally, this continued transparency adds to the quality of the study (Tracy, 2010).

Finding and Cataloguing Sources

The process of identifying databases and search strings was aided by a librarian, researchers from the team's professional network, and keywords associated with "Diversity" from the Engineering Education Research Taxonomy (Finelli, Borrego, & Rasoulifar, 2015). Given the variety of sources where information is stored, it was essential to the SLR that professionals, who could help us identify related work, be consulted. With assistance from professionals, the authors identified 1,180 articles. Following the removal of 100 duplicate publications, 1,080 article abstracts were evaluated against three hierarchical inclusion criteria: (a) Is the article written in English and about education or the STEM workforce in the United States? (b) Is the article focused on engineering/computer science in any context *or* STEM in a K–12 context? And (c) Is the article focused on issues or the experiences of Black Americans or on some aspect of the wide variety of topics associated with broadening participation? A total of 470 articles met the criteria, spanning across the K–12 education-to-workforce pathway. Additional details about the 470 articles are included in a systematic mapping review that has been published elsewhere (London et al., 2020). This article focuses on a subset of articles related to undergraduate education.

Critique and Appraise Quality of Literature

Of the 470 articles that met the inclusion criteria of the larger project, 255 focused on undergraduate education. Because SLRs are only as good as the literature reviewed, these 255 documents underwent an additional quality check. The following five questions were used to appraise all documents in this SLR:

1. Is the problem/purpose/aim of the study clearly stated?
2. Is the sampling strategy apparent and appropriate?
3. Does the sample represent our target population?
4. Is information about data collection procedures apparent and appropriate?
5. Is information about the approach to analyzing data apparent and appropriate for addressing the stated purpose?

Following this final step of appraisal, 163 of the 255 documents remained. Of these articles, 17 more were removed because they focused on assessment as opposed to research, which would be included in a separate SLR (Holloman et al., 2021). Due to the focus on this analysis on qualitative studies, the remaining 146 articles were further filtered to remove those that included participants who were not Black or used quantitative, mixed, or inconclusive methods. Scoping down to focus on qualitative works was a strategic choice made by the researchers to make conducting this SLR more focused. This process resulted in a total of 19 articles focused on undergraduate education using qualitative methods. These articles were published from 2003–2016. Most were published in journals, followed by dissertations, conferences, and then book chapters.

Authors used theories ranging from social cognitive career theory (Calhoun, 2014; Reid, 2010) to various tenets of critical race theory (Charleston & Charleston, 2014; Hayes, 2014; Hendricks, 2014). Methodologies included grounded theory, case studies, and phenomenologies (Calhoun, 2014; Cross & Paretti, 2015; Hayes, 2014; Hendricks, 2014; Holmes, 2014; McGee, 2010,2013; Moore III et al., 2003, 2004; Newman, 2011; Parker, 2014; Reid, 2010; Smith & Paretti, 2015).

Address Bias, Validity, and Reliability Concerns

Borrego and colleagues (2014) stated that, "the quality of a systematic review is determined primarily by consistency and transparency in selecting and reporting procedures for every step of the review" (p. 63). Thus, various precautionary measures were taken in this study to address bias, validity, and reliability concerns (Mullen & Ramírez, 2006). Search techniques were utilized that could reveal literature outside of the typical journal publications, as suggested by Higgins and Green (2008). Authors' names, affiliations, and journal names were masked during the quality appraisal to mitigate bias. During the process of identifying keywords and databases, a librarian was consulted.

Additionally, the criteria for inclusion and quality appraisal were discussed and applied by multiple coders to help establish reliability. Although the precautions were employed, some of the limitations of conducting an SLR remain (Cook, Mulrow, & Haynes, 1997).

Synthesize Insights

Synthesis for systematic reviews involves exploring the results of the literature search to derive the most valuable part of the systematic review: what do we know and what gaps remain regarding the topic (Borrego et al., 2014). To begin the synthesis process for the study, articles were grouped into three clusters based on the genders represented in the data (i.e., Black women only, Black men only, Black women and men). Part of the reason for doing this is that gender has been shown to impact the engineering experience as well (Lichtenstein et al., 2014). Among the 19 articles, six were about Black women, seven about Black men, and six about both Black women and men. Next, the findings, recommendations, and future work suggestions were extracted from each article. Identified commonalities across the findings, recommendations, and future work were extracted and synthesized from each of the three clusters. Two researchers (Boyd-Sinkler and Holloman) were involved in this iterative process of constant comparison analysis (Glaser & Strauss, 1999) where each piece of extracted data were organized into initial categories based on common themes. The researchers then compared the extracted data across all three clusters and reviewed this information with additional members of the research team. These categories were then re-analyzed and combined to form three major themes across the extracted data from all 19 articles. The three themes that emerged were based on the most consistent factors across all articles that impact Black undergraduate engineering student experiences.

RESULTS AND DISCUSSION

The three significant patterns that emerged from the research studies focused on the (a) identity saliency, (b) persistence, and (c) support resources of Black undergraduate engineering students. An overview of each of the three related themes is presented, followed by a more detailed discussion of related patterns.

Theme 1

Race and gender are often assumed to impact the experiences of Black undergraduate students. While this premise was supported by most of the articles, it was not always the students' perception, particularly for Black men. Identity salience refers to the degree a student acknowledged their race and/or gender identity impacted their experience (Stryker, 1968). Many of the research studies where students acknowledged their race and/or gender were about Black men (Hendricks, 2014; Moore III et al., 2003; Yohannes-Reda 2011). In addition, a constant thread throughout those papers discussed a "prove-them-wrong" mentality or the need to combat the threat of being stereotyped. Parker (2014) concluded that Black women emphasized that their race was more prevalent than their gender in STEM spaces. Although there was only one study in which students stated there was no saliency for race or gender (Calhoun, 2014), there were multiple studies in which students stated that identity salience fluctuated.

Studies Indicating that Identity is Salient. Of the studies that explicitly discussed how race and/or gender influenced student experiences, the majority of the studies centered around Black men (Hendricks, 2014; Moore III et al., 2003; Yohannes-Reda 2011). For example, Moore III and colleagues (2003) emphasized that Black men in engineering programs tend to exhibit 'prove-them-wrong' syndrome. Prove-them-wrong is a psychological concept that arises from feelings of Black inferiority based on societal treatment (Howard & Hammond, 1985). For students in the study, their desire to work harder to disprove stereotypes can be viewed as a coping mechanism to actively attack adversity in terms of their academic performance. Black men appear to have faced this dualistic nature more often than Black women; a possible explanation for this pattern could be due to things like cool-posing, a phenomenon often experienced by Black men in education (Harris, Palmer, & Struve, 2011).

Cool-posing is when Black men embody certain traits, from ways of speaking to how they dress, to emphasize Black masculine norms (Majors, 2001). Since Black men face their own unique set of challenges (e.g., decreased college access and degree attainment), it could be suggested that cool-posing helps Black men view their identity as salient.

Regarding Black women, Holmes (2014) looked at the perceptions of 11 women in their STEM classroom experiences. Of the ten themes they found, two focused on race and gender empowerment. For gender empowerment, students addressed not being intimidated by the men in the classroom and pushing through and proving to men that they can be successful in STEM. Race empowerment pertained to not letting skin color be a barrier to something that one wishes to overcome. Both themes follow the prove-them-wrong syndrome that was seen in Moore III and colleagues (2003).

Parker (2014) looked at the undergraduate STEM experiences of 10 African American female students. Of the five factors that affected their experiences, race and gender emerged as one of the themes. For the female students in the study, those that attended a predominantly White institution (PWI) had a heightened sense of their race when compared to those that attended historically Black colleges and universities (HBCUs). Those at HBCUs described fewer negative experiences due to their race than those at PWIs. However, the students at HBCUs perceived levels of isolation due to their gender or STEM rigor, whereas those at PWIs felt excluded due to their minority race status. Students at PWIs felt their academic ability was questioned more because of their race than about their gender and this was evident in their interactions with STEM faculty and peers (Parker, 2014). Specifically, regarding gender, students at PWIs and HBCUs discussed the lack of opportunities due to physical workload demands imposed by a job (Parker, 2014).

Studies Indicating that Identity is Non-Salient. Through the SLR, we found one study where students did not acknowledge that their race or gender identities impacted their experiences. Calhoun (2014) conducted a study of African American male first-year STEM students. None of the students noticed their "uniqueness due to race and gender in their classes" (p. 113). However, the students adopted the mentality that because there are already a smaller number of underrepresented students in STEM, they may find themselves to be the only African American male present in their classes.

Studies Indicating that Identity Saliency Fluctuates. There were a few studies where students described that their racial and gender identities were both salient and non-salient. Yohannes-Reda's (2011) study on understanding the academic success of Black men in STEM discusses this dualistic nature of identity saliency. Of the five emergent themes from the study, one theme entitled Uniqueness and Underrepresentation describes the identity saliency dynamic. For Black men at a PWI, they describe how being one of the few Black men in their classes produced positive and negative emotions for them. Some students discussed how regardless of their race, they put in the effort to get to where they are currently and how their stereotypes had pros and cons. Positively, the students could be viewed as a rarity in their field and obtain certain job positions or qualify to access programs that help address shortcomings in their background. However, negatively, a student would feel as though they are academically behind. Similarly, Black men in Cross & Paretti's (2015) study did not perceive that their race impacted their experience working on a team. However, they did discuss how they felt stereotyped in the larger academic system by their academic department and the university.

Another study, McGee (2013), involved the duality of identity salience, comparing the perceptions of a Black man and a Black woman in STEM. McGee (2013) provides a unique narrative study that looks at the identity saliency of two mathematically high-achieving students with two different perspectives. The woman in the study, Tiffany, describes how her experiences of racial isolation and discrimination impacted her confidence and academic journey so much that she ultimately left the university and transferred to another institution. Tiffany's knowledge of her Black cultural capital was co-constructed with the dominant cultural capital. However, Cory, the man in the study, only adapted the dominant cultural capital because it aligned with his identity as a "colorless man." Cory diminished all experiences with racism. One could hypothesize that he may have done this to protect his racial and academic identities.

Theme 2

Persistence and performance for Black American undergraduates proved to be impacted by both their internal beliefs and goals, and their engagement with others, such as peers, faculty, and family. Overall, students talked about factors that contribute to their persistence and performance in STEM. Particularly, they discussed personal interactions that impacted their experiences, factors that motivated them to persist, and personal characteristics and beliefs that impacted their ability to push forward and perform (Bonous-Hammarth, 2000; Charleston & Charleston, 2014; Cross & Paretti, 2015; Hendricks, 2014; Holmes, 2014; Hughes et al., 2011; Martin-Dunlop & Johnson, 2014; Moore III et al., 2003, 2004; Newman, 2011; Parker, 2014; Yohannes-Reda, 2011). There were several important personal interactions, particularly those related to professors and peers. Many of the motivators to major and persist in STEM were due to the involvement of faculty and the prove-them-wrong syndrome exhibited by students. Some of the personal beliefs and characteristics of the students were a sense of confidence, doubt, and assured self-worth.

Increasing Persistence through Personal Interactions. Charleston and Charleston (2014) stated that for African Americans, a plethora of people including parents, professors, advisors, and teachers encouraged and supported students in their educational and occupational successes. More specifically, the study found and dove deeper into major sub-themes related to peer and community modeling, family cultivation, and multi-faceted mentorship. Peer modeling consisted of social groups and peers who helped foster the positive socialization of Black students in the field of computing science and subsequently encouraged students to matriculate through their undergraduate studies. Community modeling involves community dynamics including peers who were in more advanced stages of their academic degree who frequently persuaded students to switch their major to computing. As the students progressed in their studies, familial cultivation, or the role of the family when it came to moral, educational, and financial support for students also increased. Multi-faceted mentors primarily in the form of faculty and graduate students helped socialize students to the field of computing and encourage undergraduate students to persist.

Meaningful interactions are more likely to increase persistence, especially for Black men at PWIs who regularly interact with African American and non-African American faculty, staff, and peers (Moore III et al., 2004). Cross and Paretti (2015) discussed the significance of personal interactions for Black men on multiracial teams. Personal interactions helped establish trust among team members and encouraged voluntary social interactions which "fostered stronger peer-support groups" (p. 7). Additionally, personal interactions allowed Black men to self-disclose information to their teammates which helped develop positive personal interactions and cross-race friendships.

For studies that focused on Black women, researchers concluded that developing meaningful relationships was vital for success (Holmes, 2014; Martin-Dunlop & Johnson, 2014). Strong relationships with parents and teachers help motivate and encourage students during their STEM journey (Holmes, 2014). Interactions with professors can positively impact students and a supportive network outside of the classroom can counter any negative classroom experiences (Martin-Dunlop & Johnson, 2014). Positive relationships with STEM professors helped expose Black females to the realities of the "real-world" after college and assisted in advising them (Martin-Dunlop & Johnson, 2014).

Motivation to Major and Persist in STEM. Another major area found in a student's lived experience was the motivation to major and persist in engineering. For Black men, some areas of motivation are internal while others are motivated by the job outlook and financial aspects of being a STEM graduate (Yohannes-Reda, 2011). For studies that involved Black men and women, having positive social influences, community building, and a sense of belonging helped expose and drive students to matriculate in STEM (Charleston & Charleston, 2014). In addition to having goals such as graduating and those related to earning an income, additional goals such as acquiring a future career or job also motivated students to persist (Hughes et al., 2011). Faculty that are interested in the success of their students also play a role and encourage the persistence and motivation of Black undergraduate students (Newman, 2011).

Personal Characteristics and Beliefs that Impact Retention in STEM. For Black men, one's cultural background helped them maintain and affirm assured self-worth (Hendricks, 2014). Black men's belief in self often showed up as being used to overcome stereotype threat and to work harder to prove those stereotypes wrong (Moore III et al., 2003). Several of the personal attributes of Black men such as being focused, self-motivated, and determined by their own internal drive impacted their lived experiences as well (Yohannes-Reda, 2011). For Black women, feelings of self-confidence and doubt highly impacted their experiences when facing a challenge (Parker, 2014).

Several of the women in the study experienced situations where they had to assert themselves and not be easily intimidated. When it came to doubt, some women were unsure of their academic ability to succeed in a STEM major, especially after receiving failing grades during their first year of college.

Theme 3

Family and programmatic efforts appear to be two major support resources for Black American undergraduates. In addition to family and programmatic efforts as forms of support, other studies mentioned support through peers (Charleston & Charleston, 2014; Stitt, 2016; Yohannes-Reda, 2011), faculty and staff (Charleston & Charleston, 2014; Martin-Dunlop & Johnson, 2014; Newman, 2011; Stitt, 2016), finances (Charleston & Charleston, 2014), the influence of spirituality (Martin-Dunlop & Johnson, 2014; Parker, 2014), and structures with culturally-relevant pedagogy (Parker, 2014).

Family as a Major Support Resource. Family was mentioned in several of the papers as a form of support (Calhoun, 2014; Charleston & Charleston, 2014; Hendricks, 2014; Martin-Dunlop & Johnson, 2014; McGee, 2013; Parker, 2014; Yohannes-Reda, 2011). In addition to providing a sense of encouragement for students and sometimes assisting during financial difficulties (Parker, 2014), family also support a students' belief in their ability to persist and continue to pursue a STEM major (Calhoun, 2014; Charleston & Charleston, 2014; Hendricks, 2014; Martin-Dunlop & Johnson, 2014; Yohannes-Reda, 2011). Charleston and Charleston (2014) go further to say that family members, whether they had previously majored or not in STEM, encouraged and supported students as they matriculated and ultimately obtained educational occupational success. In addition, families can provide emotional and physical support to help stimulate positive mathematics socialization and identities (McGee, 2013). The family is especially important for African American families as they encouraged students to be successful in their major (Parker, 2014).

Programmatic Efforts as a Major Support Resource. Yohannes-Reda (2011) suggested that programmatic efforts, such as mentoring and other programs, provide guidance for students and empowers them to succeed. Smith & Paretti (2015) also discuss how a mentoring program can assist African American women. The authors allude that formal mentorship programs while still beneficial can limit the depth of conversations between mentors and mentees, those conversations being focused on academic and career advice. Formal mentorships Martin-Dunlop and Johnson (2014) suggested that programmatic efforts can also stem from professional organizations, religious communities, and STEM departmental staff while Reid (2010) highlighted the value of participating in undergraduate research. Undergraduate research can increase a student's self-knowledge and confidence while also increasing the clarity surrounding career interests and possibilities (Reid, 2010). Given the experiences faced by Black students in STEM, students tend to utilize a variety of support mechanisms.

IMPLICATIONS FOR RESEARCH AND PRACTICE

While conducting the SLR, we used the recommendations and future research areas mentioned in the 19 articles to create implications that are centered around research and practice.

Implications for Research

Three main areas were identified for future research designs: (a) using a theoretical framework to construct research studies, (b) expanding the use of methodological approaches, and (c) including understudied research populations/intersections. We also identified topics for future research, such as

structured interventions, usage of pedagogical approaches, and studies that examine the experiences within the Black community.

Explicitly include a theoretical framework. In conducting this literature review, we found that most studies that included a theoretical framework did not explicitly connect the theory to inform and guide their research study. This produced an area of concern for the validity of several studies. It is important to acknowledge that not all research studies need to have an expansive literature framework as a research study can be exploratory. However, as indicated by the studies that included a theoretical framework, a framework can provide a lens to view and examine the findings of the research study. For example, social cognitive career theory (SSCT) could be used to help examine the intersection of efficacy, student expectations, teaching pedagogy, STEM persistence, and attrition rates of Black students (Calhoun, 2014).

Expand methodological approaches. The expansion of methodological choices can be useful in developing innovative ways to advance understanding. Using various methodological approaches can also be useful when studying students to make effective changes in the lived experiences of Black undergraduate engineering students. Holmes (2014) suggested the need for more longitudinal studies and studies that also link qualitative and quantitative data. For example, Hendricks (2014) recommended a longitudinal study that follows a Black male from elementary to postsecondary to look at the level of academic engagement and possibly compare the development of students from rural and urban areas. Moore III and colleagues (2004) encouraged the need for more qualitative and quantitative research that looks at the non-persisting Black men.

Understudied research populations/intersections. Future studies should examine the experiences of non-traditional Black students in undergraduate engineering education. For example, more studies should look at students who are transfers from community colleges, veterans, or adult learners. With that said, there could be more studies which purposely focus on the experiences of Black students who are in a specific academic year, such as the middle years, or Black students who have participated in extra-curricular experiences, such as a study abroad program. By focusing on understudied research populations and their intersections, future studies would provide a more holistic understanding of the experiences of Black students, and how these experiences can be supported, developed, and implemented.

Research topics. Future research studies should consider incorporating the analysis of stereotype threat into studies that focus on the perception, anxiety, or academic performance of a particular group (Calhoun, 2014). There could be more research questions that center around a specific structured intervention (Calhoun, 2014). Studies could look at the factors that drive the help-seeking of Black men (Calhoun, 2014). There could be a study that looks at a students' self-efficacy beliefs and if there is a tie to pedagogical choices used in a STEM class (Calhoun, 2014). Such an investigation could help address problems pertaining to persistence and help faculty develop professional development opportunities (Calhoun, 2014).

Hendricks (2014) suggested a study that looks at the impacts and influences of all ethnic groups to determine how they impacted a student's decision to pursue or not pursue a STEM degree. Moore III and others (2003) suggested that more research is needed to look at how unwelcoming environments perpetuate Black inferiority and trigger prove-them-wrong syndrome for Black men. Additionally, more research on the classroom environment and peer interactions and how it impacts the socio-cognitive influences Black students (Hughes et al., 2011) may be beneficial. McGee (2013) suggested that researchers should examine the meaning-making process and the individual, contextual, and social factors involved. It would also be interesting to explore the role of geography and the vast range of institution types on a student's experience (Newman, 2011). Simmons and Martin (2011) suggested looking at the influences of Black students in their engineering degree programs. Research studies could compare the experiences of Black men from rural and urban areas, or their experiences compared to those outside of the U.S. (Hendricks, 2014).

There should be more work that analyzes the experiences of women from other races and ethnicities (Holmes, 2014). Additionally, there is a need for more research that looks at faculty and

their perspectives on pedagogical practices, teaching philosophies, and curricula (Holmes, 2014). Research from institutional perspectives can also be useful to look at specific items such as class size, faculty recruitment, and funding for resources (Holmes, 2014).

Implications for Practice

Three main areas were identified for future practice: (a) including students in university programmatic efforts, (b) emphasizing the first-year experience, (c) providing pre-college exposure, and (d) expanding the roles of university administrators.

Students involved in university programs. Black students should be involved in some type of programmatic experience or effort where a student is able to engage in a variety of interactions. The relationships should be with Black and non-Black faculty, staff, and peers in a variety of academic environments such as peer tutoring or a professional development workshop (Moore III et al., 2004). Students could be involved in a residential living space that has tailored programmatic features, such as undergraduate research or study groups (Moore III et al., 2004). Other ideas include peer mentoring, tutoring, or affinity groups with which students can connect (Parker, 2014). There should be academic and social support groups to help students with upper-level coursework (Parker, 2014) and better mentoring and advising for students (Holmes, 2014).

Emphasis on the first year. Calhoun (2014) emphasizes that a greater amount of attention be allocated toward supporting students during the first year of their undergraduate engineering experience. Students are particularly vulnerable during their first year, especially when considering the perception that several first-year courses are not designed to help students succeed. Also, students could partake in a course or study skills workshop to help acclimate underrepresented students to the academic and social culture of the institution (Moore III et al., 2004).

Pre-college influences. Parents and high school instructors can help instill and grow personal traits for students navigate through STEM culture and combat adversity in their everyday lives (Moore III et al., 2004). A major concern is making sure that students are academically prepared for the math and science course load they will face in college. Thus, it is necessary to expose middle and high school students to preparatory and exploratory courses (many offered in honors, AP, IB programs) that supplement their current instruction while also helping to expose students to college life (Calhoun, 2014). Hendricks (2014) emphasized the need to encourage a student's "naturalized and creative gratification for math and science" (p. 139) and by providing more youth-development programs aimed at helping Black males, as well as females. Such programs can help negate the academic deficiencies found in some Black males to achieve postsecondary success (Hendricks, 2014). Parents can instill resiliency and set high academic standards for their child while ensuring their student feels encouraged and supported (Moore III et al., 2004).

University employees. Professors can help construct academic environments for students to have positive engagements with their peers and others. Professors can include and explicitly tie diversity-related examples and case-studies into their curriculum (Holmes, 2014; Parker, 2014). Students can also be clustered into engineering, math, and science courses based on race and/or gender (Moore III et al., 2004). Similarly, academic officials should reconsider how faculty teach and are rewarded, since some faculty members engage in various mentoring and outreach activities with underrepresented populations (Newman, 2011). University administrators and officials should have tiered interventions for students that take advantage of organizations like the National Science Foundation (NSF, 2009, 2015; National Research Council, 2011). NSF can also help fund the professional development of faculty (Calhoun, 2014). Professors should be more aware of how they respond to incorrect answers by students and conduct reviews to identify gaps in course content (Holmes, 2014). Professors should take a more active role in organizing study groups and creating engaging ways for Black women to study and work together (Holmes, 2014). Faculty should be open to talking about issues related to race and gender and make efforts to examine their own biases (Parker, 2014).

University officials can revise admission requirements and adapt introductory STEM courses to better support the learning styles of students (Parker, 2014). A lounge or other study area could be

created for students to use (Parker, 2014). Already established bridge and transition programs should be reassessed and include semester-long interventions (Calhoun, 2014). There should be more professors who are women and women of color which can help retention and recruitment efforts (Parker, 2014). PWIs can provide additional funding for Black women who work while attending school (Parker, 2014).

CONCLUSION

This study provides detailed insight into the similarities and differences of the experiences of Black men and women in STEM and implications for the future of student support for Black students in STEM supported by current research studies. This qualitative systematic review of the experiences of Black students in undergraduate engineering programs reveals numerous areas that are both under-explored (e.g., non-traditional students) and frequently explored (e.g., persistence). Consistent areas seen for Black men are the need to maintain a sense of assured self-worth and prove-them wrong syndrome while for Black women a strong sense of personal capital and confidence to further promote a STEM identity. Looking at both genders, areas of support are a need for assistance (financial, spiritual, academic) from a variety of family, friends, and faculty. Through intentional and creative research studies, there can be a greater understanding of the experiences of Black students in STEM fields.

REFERENCES

References marked with an asterisk (*) indicate studies included in the SLR.

Bonous-Hammarth, M. (2000). Pathways to success: Affirming opportunities for science, mathematics, and engineering majors. *The Journal of Negro Education*, *69*(1/2), 92-111.

Borrego, M., Foster, M. J., & Froyd, J. E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*. https://doi.org/10.1002/jee.20038

*Calhoun, W. J. (2014). *An exploratory study on initial stem classes and African American freshman males who are stem majors at a large Mid-Atlantic state university: Factors affecting self-efficacy beliefs and persistence in the STEM pipeline*. Humanities and Social Sciences. ProQuest Information & Learning.

Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal of Research in Science Teaching*, *51*(5), 555-580. https://doi.org/10.1002/tea.21146

*Charleston, L. J., & Charleston, S. A. (2014). Using culturally responsive practices to broaden participation in the educational pipeline: Addressing the unfinished business of *Brown* in the field of computing science. *The Journal of Negro Education*, *83*(3), 400-419. https://doi.org/10.7709/jnegroeducation.83.3.0400

Cook, D. J., Mulrow, C. D., & Haynes, R. B. (1997). Systematic reviews: Synthesis of best evidence for clinical decisions. *Annals of Internal Medicine, 126*(5), 376-380.

*Cross, K. J., & Paretti, M. C. (2015, June). *The impact of personal interactions on the experience of African American males on multiracial student teams*. BT-2015 122nd ASEE annual conference and exposition (Vol. 122nd ASEE). Virginia Tech, Department of Engineering Education, American Society for Engineering Education.

Espinosa, L. L. (2011). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harvard Educational Review, 81*(2), 209-240.

Finelli, C. J., Borrego, M., & Rasoulifar, G. (2015). Development of a taxonomy of keywords for engineering education research. *IEEE Transactions on Education*, *58*(4), 219-241.

Gibbons, M. T. (2009). *Engineering by the numbers.* American Society for Engineering Education. http://www. asee.org/publications/profiles/upload/2008ProfileEng. pdf

Glaser, B. G., & Strauss, A. L. (1999). T*he discovery of grounded theory: Strategies for qualitative research*. Aldine De Gruyter.

Handelsman, J., & Smith, M. (2016). *STEM for all*. The White House.
Hatch, J. A. (2002). Doing qualitative research in education settings. SUNY Press.
Harris, F., Palmer, R., & Struve, L. (2011). "Cool posing" on campus: A qualitative study of masculinities and gender expression among Black men at a private research institution. *The Journal of Negro Education*, *80*(1), 47-62. https://www.jstor.org/stable/41341105
*Hayes, R. E. I. I. I. (2014). *Understanding him in stem: Sharing the stories of African American male scholars in engineering academic programs at a predominantly White university*. Dissertation Abstracts International Section A: Humanities and Social Sciences. ProQuest Information & Learning.
*Hendricks, J. T. (2014). *"Stemulating" success factors: An investigation of the academic talents of successful Black male college graduates from STEM programs*. Humanities and Social Sciences. ProQuest Information & Learning.
Higgins, J. P. T., & Green, S. (Eds.) (2008). *Cochrane handbook for systematic reviews of interventions*. Wiley.
Holloman, T. K., Lee, W. C., London, J. S., Hawkins Ash, C. D., & Watford, B. A. (2021). The assessment cycle: Insight from a systematic literature review on broadening participation in engineering and computer science. *Journal of Engineering Education, 110*(4), 1027-1048. https://doi.org/10.1002/jee.20425
*Holmes, K. M. (2014). *The perceived undergraduate classroom experiences of African American women in science, technology, engineering, and mathematics (STEM)*. Dissertation Abstracts International Section A: Humanities and Social Sciences. ProQuest Information & Learning.
Howard, J., & Hammond R. (1985). Rumors of inferiority: The hidden obstacles to Black success. *The New Republic, 193,* 16-21.
*Hughes, Q. S., Shehab, R. L., & Walden, S. E. (2011, June). *"Success is different to different people": A qualitative study of how African American engineering students define success.* BT-118th ASEE annual conference and exposition. School of Industrial Engineering, University of Oklahoma, American Society for Engineering Education.
Lichtenstein, G., Chen, H. L., Smith, K. A., & Maldonado, T. A. (2014). Retention and persistence of women and minorities along the engineering pathway in the United States. In *Cambridge handbook of engineering education research* (pp. 311-334). Cambridge University Press. https://doi.org/10.1017/CBO9781139013451.021
London, J. S., Lee, W. C., Phillips, C., Van Epps, A. S., & Watford, B. A. (2020). A systematic mapping of scholarship on broadening participation of African American in engineering and computer science. *Journal of Women and Minorities in Science and Engineering, 26*(3). https://doi.org/10.1615/JWomenMinorScienEng.2020027889
Lord, S. M., Ohland, M. W., Layton, R. A., & Camacho, M. M. (2019). Beyond pipeline and pathways: Ecosystem metrics. *Journal of Engineering Education, 108*(1)*,* 32-56. https://doi.org/10.1002/jee.20250
Majors, R. (2001). Cool pose: Black masculinities and sports. In Whitehead, S. M., &. Barrett, F. J (Eds), *The masculinities reader*. (pp. 209-217). Blackwell.
*Martin-Dunlop, C., & Johnson, W. (2014). Intersections of African American women in STEM and lingering racial and gender bias. In Koch, J., Polnick, B., & Irby, B., (Eds.), *Girls and women in STEM: A never ending story.* (pp. 3-19). Information Age.
*McGee, E. O. (2010). *Race, identity, and resilience: Black college students negotiating success in mathematics and engineering*. *Humanities and Social Sciences*. ProQuest Information & Learning.
*McGee, E. O. (2013). Growing up Black and brilliant: Narratives of two mathematically high-achieving college students. In Leonard, J., & Martin, D. B. (Eds.), *The brilliance of Black children in mathematics: Beyond the numbers and toward new discourse* (pp. 247-272). Information Age.
*Moore III, J. L., Flowers, L. A., Guion, L. A., Zhang, Y., & Staten, D. L. (2004). Improving the experiences of non-persistent African American males in engineering programs: Implications for success. *National Association of Student Affairs Professionals Journal*, *7*(1), 105-120.

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

Mullen, P. D. & Ramírez, G. (2006). The promise and pitfalls of systematic reviews. *Annual Review Public Health,* 27, 81-102.

National Research Council (Ed). (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads.* The National Academies Press.

National Science Foundation. (2009). *Women, minorities, and persons with disabilities in science and engineering.* National Science Foundation.

National Science Foundation, National Center for Science and Engineering Statistics. (2015). *Women minorities, and persons with disabilities in science and engineering: 2015*. (Special report NSF 15-311). National Science Foundation, NCSES.

Nelson, M., & Reid, K. (2016). *NSBE 2025: The strategic plan to dramatically change the face of engineering by 2025.* National Society for Black Engineers.

*Newman, C. B. (2011). Engineering success: The role of faculty relationships with African American undergraduates. *Journal of Women and Minorities in Science and Engineering*, *17*(3), 193-207. https://doi.org/10.1615/JWomenMinorScienEng.2011001737

Noonan, R. (2017). *STEM jobs: 2017 update*. (ESA Issue Brief# 02-17). U.S. Department of Commerce.

*Parker, A. D. (2014). *Family matters: Familial support and science identity formation for African American female STEM majors*. *Humanities and Social Sciences*. ProQuest Information & Learning.

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide*. Blackwell.

Phillips, C. M., London, J. S., Lee, W. C., Van Epps, A. S., & Watford, B. A. (2017, October). Reflections on the messiness of initiating a systematic literature review on broadening participation in engineering and computer science. *2017 IEEE Frontiers in Education Conference* (FIE, pp. 1-8). IEEE.

*Reid, E. L. (2010). *Exploring the experiences of African American women in an undergraduate summer research program designed to address the underrepresentation of women and minorities in neuroscience: A qualitative analysis*. *Humanities and Social Sciences*. ProQuest Information & Learning.

Roy, J. (2019). Engineering by the numbers. In American Society for Engineering Education (pp. 1-40).

Russell, M. L., & Atwater, M. M. (2005). Traveling the road to success: A discourse on persistence throughout the science pipeline with African American students at a predominantly White institution. *Journal of Research in Science Teaching, 42*(6), 691-715.

*Simmons, D. R., & Martin, J. P. (2011). Implications of Black Greek letter membership on the development of the engineer of 2020. In *IEEE* (p. T4H (5 pp.). IEEE. https://doi.org/10.1109/FIE.2011.6142984

*Smith, C. S., & Paretti, M. C. (2015). Understanding the mentoring needs of African-American female engineering students: A phenomenographic preliminary analysis. In *American Society for Engineering Education* (Vol. 122nd ASEE). Department of Engineering Education, American Society for Engineering Education.

*Stitt, R. (2016). African American women in STEM fields. In Hudley, C., & Hudley, C. (Eds.), *Adolescent identity and schooling: Diverse perspectives.* (pp. 107-122). Routledge/Taylor & Francis.

Stryker, S. (1968). Identity salience and role performance: The relevance of symbolic interaction theory for family research. *Journal of Marriage and the Family. 30,* 558-564.

Titus, M. A. (2004). An examination of the influence of institutional context on student persistence at 4-year colleges and universities: A multilevel approach. *Research in Higher Education, 45*(7), 673-699.

Tracy, S. J. (2010). Qualitative quality: Eight "big-tent" criteria for excellent qualitative research. *Qualitative Inquiry*, *16*(10), 837-851.

*Yohannes-Reda, S. (2011). *Stemming the tide: Understanding the academic success of Black male college students in science, technology, engineering, and mathematics majors*. Humanities and Social Sciences. ProQuest Information & Learning.

AUTHORS

KARIS E. BOYD-SINKLER is an adjunct assistant professor and Director of Diversity, Equity, and Inclusion for the Pratt School of Engineering at Duke University. TEIRRA K. HOLLOMAN is a doctoral candidate in the Department of Engineering Education at Virginia Tech. CRYSTAL M. PEE is a doctoral candidate in the Department of Engineering Education at Virginia Tech. WALTER C. LEE is an associate professor of Engineering Education at Virginia Tech. JEREMI S. LONDON is an associate professor of Engineering Education at Virginia Tech.

All comments and queries regarding this article should be addressed to karisboyd@gmail.com