International Journal of Engineering Education Vol. 37, No. 2, pp. 497–511, 2021
Printed in Great Britain

0949-149X/91 $3.00+0.00

Underrepresented and Overlooked: Insights from a Systematic Literature Review about Black Graduate Students in Engineering and Computer Science*

TEIRRA K. HOLLOMAN
Virginia Polytechnic Institute and State University, 345 Goodwin Hall (MC 0218), 635 Prices Fork Rd, Blacksburg, VA 24060, USA. E-mail: teirrah@vt.edu

JEREMI LONDON
Virginia Polytechnic Institute and State University, 363 Goodwin Hall (MC 0218), 635 Prices Fork Rd, Blacksburg, VA 24060, USA. E-mail: jslondon@vt.edu

WALTER C. LEE
Virginia Polytechnic Institute and State University, 373 Goodwin Hall (MC 0218), 635 Prices Fork Rd, Blacksburg, VA 24060, USA. E-mail: walterl@vt.edu

CRYSTAL M. PEE
Virginia Polytechnic Institute and State University, 345 Goodwin Hall (MC 0218), 635 Prices Fork Rd, Blacksburg, VA 24060, USA. E-mail: crystalmpee@vt.edu

CHANEÉ HAWKINS ASH
Foresight Strategy Solutions, California, USA 9459. E-mail: chanee@foresightstrategysolutions.com

BEVLEE WATFORD
212 Hancock Hall (0275), 490 Old Turner St., Blacksburg, VA 24061, USA. E-mail: deuce@vt.edu

Engineers and computer scientists with advanced degrees play a critical role in addressing complex societal challenges while serving as role models for undergraduate students pursuing degrees in these areas. However, the results of a literature map, conducted as a part of a larger study, suggest that we tend to focus on undergraduate education when discussing how to diversify the talent pool. This paper presents the findings from a systematic literature review on the barriers to graduate-level participation in engineering as experienced by African Americans, one of the most underrepresented groups. Twenty-two articles resulted from the search, 11 passing the quality check. The analysis focused on synthesizing themes surrounding how researchers study the problem, barriers to participation, and recommendations for addressing them. Results highlight that investigators tend to focus on three topic areas: (1) Student Identity, (2) Recruitment and Persistence, and (3) Students' Perceptions of Graduate School. This synthesis presents the current state of the literature on broadening participation of African American engineering graduate students and highlights opportunities for future inquiries.

Keywords: African American; graduate students; engineering; computer science

1. Introduction

Since the 1970s, national reports have called for increased diversity and inclusion in science, technology, engineering, and mathematics (STEM) education and the workforce [1, 2]. These calls have resulted in a breadth of activities performed by researchers, practitioners, and policymakers committed to addressing this issue [3–5]. Fig. 1 reveals the trends in participation in engineering and computer science for two groups that are of national significance in this conversation: African Americans and Hispanic populations. Despite progress in representation for some groups over the last four decades (e.g., women, Latinx) [6], the numbers remain stagnant – and sometimes decline – for others. This declining trend is alarming and is the impetus for our focus on African Americans in this study.

In light of these trends, the authors of this study initiated a study entitled "Pushing Students Away: Developing a Research Agenda for Broadening Participation of African Americans in Engineering and Computer Science". In it, we argue that producing a diverse engineering and computer science workforce is unlikely if the country continues to lose underrepresented racial minorities at critical segments along the education-to-workforce pathway. In order to address this issue, it is imperative that we: (1) critically examine what is causing the disconnect between research and practice as it relates to broadening participation, (2) figure out

* Accepted 15 October 2020.

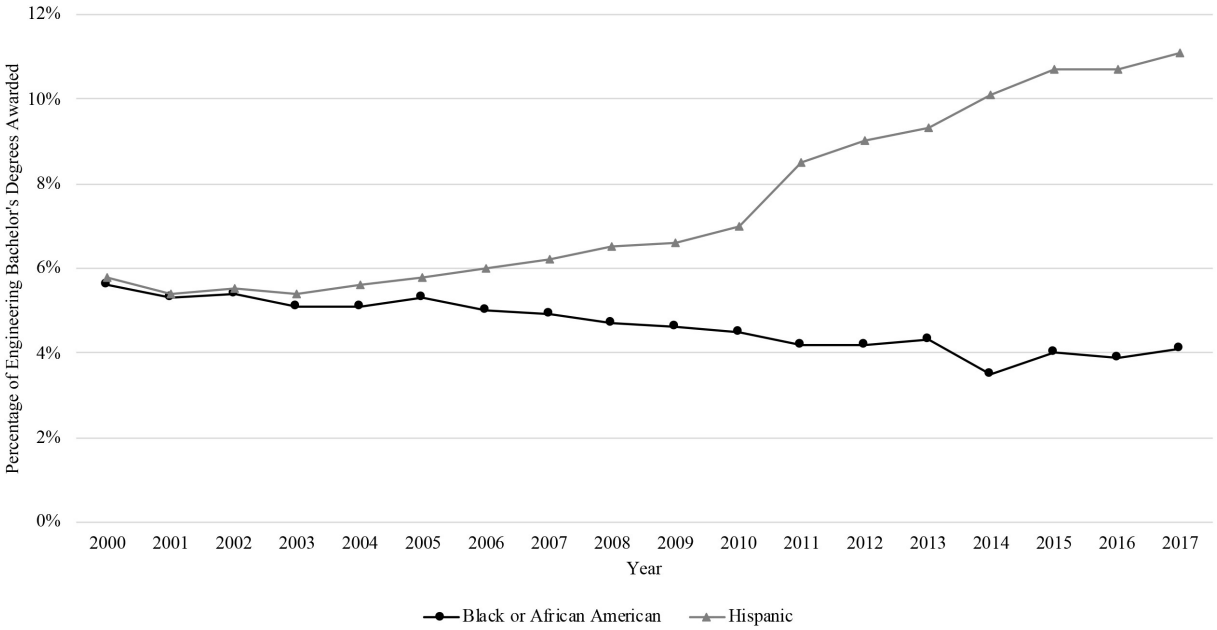

Fig. 1. Percentage of bachelor's degrees awarded to African Americans and Hispanics of all degrees awarded in engineering. Graph produced based on the Yoder report [6].

what is *pushing students away*, and (3) develop a holistic agenda for moving forward.

These aims are being accomplished using a three-phase study. While details of the complete summary of the project can be found online [7], the current study is a part of the first phase. Phase I of this study consists of producing a systematic mapping of existing scholarship and a series of systematic literature reviews associated with barriers to participation along the four segments of the education-to-workforce pathway: K-12 education, undergraduate education, graduate education, and the workforce. In short, a systematic literature map documents trends in the most salient features of existing studies on a particular topic; it is most useful when scoping an unknown research area and identifying gaps from which to commission future research [8]. Two of the most salient findings of the literature map were: (1) most of the existing scholarship, focused on broadening participation of African Americans in engineering and computer science, is focused on undergraduate and K-12 students; and (2) there is relatively little scholarship focused on graduate education students [9].

This lack of attention to graduate education and students is disheartening for a variety of reasons. The knowledge, skills, and attributes that students gain in graduate school allow them to "compete in the global economy, as well as solve problems of national and global scope" [10, p. 1]. In fact, it is not uncommon for the Bureau of Labor Statistics to produce reports citing what proportion of jobs will require a master's or doctoral degree; that number tends to hover around 20% [11]. Lastly, engineers and computer scientists with advanced degrees serve as role models for other minoritized students pursuing degrees in these areas [12, 13]. Thus, addressing issues of broadening participation at the graduate level has implications for broadening participation at every other level of education and society.

This study is motivated by the need to explore insights from existing scholarship as part of developing a strategy to move forward. Broadening participation in engineering and computer science (CS) education and the workforce requires focus at every level, including graduate education. However, we argue that there is a need to first make sense of what we already know about this problem as part of the effort to determine areas for future investigation and action. Thus, the purpose of this study is to present the results of a systematic literature review of scholarship focused specifically on barriers to participation in graduate engineering and CS education, particularly for African Americans, and highlight opportunities for future inquiries on this topic.

2. Methodology

The contributions of any scholarly work must be situated within an existing body of knowledge. Although literature reviews are well established and utilized in engineering education, systematic literature reviews (SLR) are not used as often [14]. Other disciplines have found a use for SLRs to

summarize, critically evaluate, and reconcile conflicting evidence to inform policy and practice [14]. SLRs can vary in purpose from describing the current state of knowledge, to evaluating theory, to identifying gaps in the literature [15].

Two main sources guided the five major steps we used to conduct this systematic literature review – one resource that spells out details of the process for researchers in a variety of disciplines conducting SLRs [15], and one that operationalizes SLR methodology for the engineering education community [14]. The five major steps of this SLR include:

1. Formulate Guiding Research Questions and Corresponding Inclusion Criteria.
2. Find and Catalogue Sources.
3. Critique and Appraise the Quality of Selected Literature.
4. Synthesize Insights.
5. Address Bias, Validity, and Reliability Concerns.

These steps will serve as a framework for how the rest of this section is organized. The first three and final steps are related to methods of data collection and analysis, while the fourth step relates to the results of the SLR.

2.1 Formulate Guiding Research Questions and Inclusion Criteria

The questions guiding this study are:

1. *What is the current state of scholarship on barriers to participating in graduate engineering and/or computer science education faced by African Americans?*
2. *What themes exist regarding research questions, theoretical frameworks, methodological choices, participant demographics, and recommendations in the current scholarship?*

The literature found during the systematic mapping [9] was used to address these question. As a result, the inclusion criteria used during the mapping review and by extension the SLR are as follows: (1) publication date range, (2) database selection, and (3) search string selection. Historical events associated with efforts to broaden the participation of African Americans in engineering and computer science were used to inform the date range (e.g., the formation of minority engineering programs and the National Society of Black Engineers). The other two criteria will be discussed in the next section.

2.2 Find and Catalogue Sources

A librarian's expertise was useful for identifying databases, performing the database searches, and limiting publication bias. Search strings were validated using sentinel articles. In short, sentinel articles are used during preliminary checks to determine whether the search results are yielding the types of articles of interest. Table 1 presents the final list of databases, search strings, and notes that may be useful for replicating the search. We recognize that the terms Black and African American are not one and the same however, they are often used interchangeably in the literature. Thus, our search strings include both as does our language when reporting results in future sections. Further details on this mapping review can be found in another publication [9]. The data associated with this SLR was collected in January 2017.

Following the removal of duplicate publications, 1,080 articles were screened based on three hierarchical eligibility criteria: (1) Is the article written

Table 1. Databases and search strings used to locate articles

Database Name	Search String	Note
Education Source and PsycINFO (EBSCOhost interface)	((bias OR discrimination OR multicultural* OR inclusiv* OR racism OR prejudice) OR (motivation OR attainment OR achievement OR aspiration OR persist* OR retention)) AND ((AB african w2 american OR SU african w2 american OR TI african w2 american) OR (AB black OR SU black OR TI black) OR (AB people N2 color* OR SU people N2 color* OR TI people N2 color*)) AND ((AB STEM OR SU STEM OR TI STEM) OR (AB engineer* OR SU engineer* OR TI engineer) OR (AB "computer science" OR SU "computer science" OR TI "computer science"))	Search all fields for words used to include or exclude people Search Abstract, Title, Subject headings for terms used for African American Search Abstract, Title, Subject headings for STEM, engineering, and computer science
Compendex and INSPEC (Ei Village interface)	< ((motivation OR attainment OR achievement OR aspiration OR persist* OR retention) WN All fields) > OR < ((bias or discrimination or multicultural* or inclusiv* or racism or prejudice) WN All fields) > AND < ((((african ONEAR/2 american) WN KY) OR ((black) WN KY)) OR ((people NEAR/2 color) WN KY)) > AND < ((STEM OR engineer* OR "computer science") WN KY) >	Quick search, Autostemming off, Search all fields Search Subject/Title/Abstract, Autostemming off Search Subject/Title/Abstract, Autostemming off

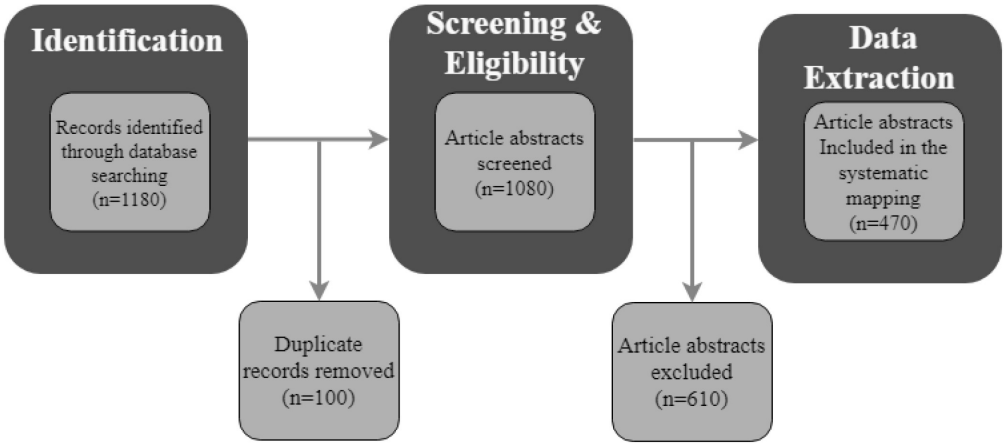

Fig. 2. PRISMA Flowchart for Systematic Map.

in English and about education or the STEM workforce in the United States? (2) Is the article focused on engineering or computer science in any context, or STEM disciplines in a K-12 context? (3) Is the article focused on issues or the experiences of Black or African Americans, or on some aspect of the wide variety of topics associated with broadening participation? (One of our previously-published articles includes reflections on the "messiness" of executing these initial, value-laden steps of an SLR, using this project as an example [16].)

Three coders analyzed each article, meeting when needed to discuss articles that required an additional opinion. In total, 470 out of 1180 (40%) articles met the three eligibility criteria. Table 2 presents these findings and highlights the initial search for literature as it relates to graduate students resulting in a total of 22 out of 470 documents. The complete result of the literature map can be found elsewhere [9]. Fig. 2 depicts the PRISMA flowchart associated with this systematic mapping and Table 2 denotes the number of articles associated with it.

2.3 Critique and Appraise the Quality of Literature

Following the documentation of the literature map results, the 22 documents associated with graduate education went through a quality check. In general, SLRs require researchers to conduct quality checks to ensure that critical aspects of a research study are present. Although all of the articles that met the eligibility criteria were included in the systematic mapping, four final questions determined whether a study passed the quality check and would be included in this SLR. Each question required a yes or no response. The questions were as follows:

1. Is the problem/purpose/aim of the study clearly stated; and if so, is it focused on graduate education and/or graduate students?
2. Is the sampling strategy apparent and appropriate? Does the sample represent the target population?
3. Is information about data collection procedures apparent and appropriate?
4. Is information about the approach to analyzing data apparent and appropriate for addressing the study's purpose?

Ultimately, 12 of the 22 articles associated with graduate education passed the quality check. Upon closer review of each document, it was discovered that one document was a duplicate recording of a

Table 2. Systematic mapping of literature on broadening participation of African Americans in engineering and computer science

Segment	Engineering	CS	STEM	Subtotal
ED: K-12	7	12	69	88
ED: Community College	2	0	5	7
ED: Undergraduate	132	17	106	255
ED: Graduate	5	1	16	22
Workforce: Academia	11	0	9	20
Workforce: Non-Academic	8	1	3	12
Across Segments	18	5	28	51
Other	3	4	8	15
Grand Total	**186**	**40**	**244**	**470**

dissertation thesis in the form of a conference paper. Because of this, the conference paper was removed from the review and the dissertation was retained because it contained more information about the study.

2.4 Address Bias, Validity, and Reliability Concerns

Existing research outlines a variety of steps to take in order to address bias, validity, and reliability concerns while conducting an SLR [17]. This section describes how those guidelines were implemented in this work. In order to minimize bias traditionally stemming from authors electing to report only certain outcomes and/or studies with only positive results, search techniques that consider grey literature (and not just journal publications, for example) were employed [18]. As mentioned, a librarian was involved in the process of identifying keywords and databases to mitigate the impact of researcher bias. Accordingly, primary studies were masked for author names, affiliations, and journal names during the quality appraisal phase to avoid selection bias. Furthermore, this article and other SLRs associated with this project include a thorough explanation of the methodology used to identify and collect data; this has been explained above to showcase consistency and transparency. Additionally, multiple coders were used to apply and discuss criteria for inclusion/exclusion and quality assessment to help establish reliability and further minimize our own bias. Collectively, these efforts were designed to address concerns that may stem from questions about bias, validity, and reliability.

Despite these efforts, this study still has limitations. According to Cook, Mulrow, and Haynes [19] the limitations of a systematic literature review stem from: (1) the quality and quantity of the selected studies, and (2) the quality of the systematic review procedures. In this study, we were interested in literature focused on the intersection of Black graduate students and graduate students in engineering and computer science. With this in mind, literature solely about Black graduate students, in general, and about graduate students in engineering, in general, did not pass our inclusion criteria and as a result, were excluded. We acknowledge that this choice will lead to the possibility that this SLR is not comprehensive of all literature related to this population. This is a limitation of our interest in scholarship specifically focused on the intersection of these topics. Additionally, we excluded assessment-focused papers from this review. As a result, this review is more focused on research than interventions. (Another publication is in development that focuses solely on relevant interventions and assessments.) Furthermore, the fact that this topic has not been consistently studied over time (since 1975) led to small quantities of articles and by extension, more opportunities for research than insights from the existing scholarship. Lastly, because the literature in this review was collected in January 2017, the length of typical publication cycles may have led to the exclusion of more recent articles like "Into the Storm: Ecological and Sociological Impediments to Black Males' Persistence in Engineering Graduate Programs" by Burt, Williams, and Smith [20].

As stated in the aforementioned purpose – and consistent with the goals of a systematic literature review [14, 15] – we sought to not only present the current state of knowledge on the topic but also highlight opportunities for future inquiries on scholarship focused on barriers to participation in graduate engineering and CS education, particularly for African Americans. Given this scope of the study and the need to identify articles at the intersection of a set of topics – graduate education AND African Americans AND engineering OR computer science – we acknowledge that there may be other literature that is peripherally relevant because of its focus on either of the topics. However, without an emphasis on all three topics simultaneously, we consider this work beyond the scope of this SLR. Said differently, the analogy of a Venn diagram provides useful language to explain which articles were included or excluded. Articles at the "intersection of the set" of topics were included in the SLR while articles that made up the "symmetric difference of the set" did not meet the eligibility criteria.

3. Data Analysis

There were four main steps in this data analysis. As part of step one, we extracted data from each article and organized it by columns in a Microsoft Excel spreadsheet. Specifically, the following components were extracted: purpose, methods, theoretical framework, sample size, location (e.g., HBCU, PWI, HSI), participant demographics (e.g., sex, discipline, classification), major barriers, recommendations, future research, and limitations as stated by the author were collected for each article.

As part of the second step, we searched for commonalities across the purpose statements of each article. For example, Bancroft, Benson, and Johnson [21] were interested in the students' perceptions of the McNair Scholars' program as well as their graduate degree program culture based on their race and gender. Similarly, Squires [22] sought to understand the lived experiences of African American women in STEM doctoral programs

by exploring how 10 African American women described their lived experiences during STEM doctoral degree completion. While all of the articles investigated African American student experiences in the graduate school context, these articles specifically wanted to understand students' perceptions of these environments, thus resulting in one of our themes: Perceptions of Graduate School. Additionally, we noticed that two articles Chatman [23] and Tran [24] focused on the identity of the student in the purpose of their studies. Chatman wanted to better understand who is likely to go to graduate school and begin to build profiles for those who do and don't. Tran [24] explored the conflict that exists between students' science identity and other core identities that shape how they view themselves. These articles resulted in another theme: Student Identity. Lastly, the remaining seven articles dove into what factors impacted student pursuit and persistence in STEM graduate degree programs which resulted in our final theme: Recruitment and Persistence. The three themes that emerged across the purposes of the articles: (1) *recruitment and persistence*, (2) *student identity*, and (3) *perceptions of graduate school*, will provide structure for presenting the remaining results of this SLR.

The next step includes two parts and was completed for each theme. Within each of these three themes, we synthesized two types of information: (1) how researchers were framing and investigating the problem, and (2) research findings that resulted from their analysis. A variety of the extracted data was used for this step of the analysis (e.g., methods, framework, participant information, and major barriers). The salient details from the extraction are included in Tables 3, 4, and 5 in the Results. The last section of the results stemmed from the final step of the analysis. During this step, we synthesized the positive and negative factors contributing to graduate student success and the recommendations suggested in all 11 articles.

4. Systematic Literature Review Results

Three themes emerged from the analysis of the 11 documents that passed the quality check: (1) *recruitment and persistence*; (2) *student identity*; and (3) *perceptions of graduate school*. This section uses these three topics as a framework for documenting trends that answer the foci introduced in the guiding research question – trends in the research questions, theoretical frameworks, methodological choices, participant demographics, barriers to participation, and recommendations for addressing them. After each theme is discussed, a cross-topic analysis and implications of these results will be presented in the subsequent section.

4.1 Theme I: Recruitment and Persistence

The majority of the studies in this SLR, 7 of 11 [25–31], contained purpose statements about recruiting and keeping students in graduate programs. Although one study (i.e., [25]) used quantitative methods to analyze big data, the majority of these studies used qualitative approaches (e.g., interviews, focus groups) to address their research goals. One unique feature of Figueroa's [28] work was its secondary use of previously collected focus group data. Frameworks used in these articles spanned a broad range: critical perspectives [32–34], theories and models of student persistence [35, 36], socialization [37, 38], decision factor theory and models [39, 40].These studies used a variety of strategies for selecting participants, and as a result, relied on a wide range of people for insights about the recruitment and persistence of Black graduate engineering students. For example, Brazziel and Brazziel [26] chose to recruit science and engineering graduates who were capable of pursuing PhDs yet opted to pursue careers in other fields. Meanwhile, Bradford [25] and Jackson-Smith [29] recruited undergraduates. The majority of authors [27, 28, 30, 31] collected data from graduate students. These studies spanned a wide array of science and engineering disciplines and even included some students from the liberal arts, humanities, and education in their sample groups. Institution type also varied among these articles, with at least three studies including more than one type (i.e., HBCU, PWI, HSI). Among the studies that mentioned the gendered makeup of the participants, one reflected parity [31], another included more women than men [25, 28, 30], one focused on women [29], and two did not include gender demographics [26, 27]. Another point related to participants was sample size. More specifically, several authors conducting qualitative studies mentioned small sample sizes and lack of generalizability as limitations. Other authors acknowledged that the results of their study may have been influenced by self-selection bias [41]. Lastly, Bradford [25] mentions the lack of control groups and unknown student participation in interventions as a limitation in their quantitative study.

4.1.1 Emerging Insights & Recommendations

Results from these studies included positive and negative influences on student participation and persistence in graduate programs. These included factors about the institution and program that either helped or hindered students. For example, Bradford [25] notes that when institutions are designing early exposure to research opportunities for underrepresented students, the type of experience and depth of engagement matters. Crumpton-

Table 3. Extracted data from articles in Theme 1 focused on the recruitment and persistence of African American graduate students in engineering and computer science

	Why?	**What?**	**HOW?**		
Articles	**Motivation for the Study**	**Purpose of the Study**	**Methods**	**Framework**	**Participants Demographics (Program) | Disciplinary Focus | Sample Size | Sex | Education Level)**
[25]	global security, global competitiveness, growing diversity population	persistence; successful intervention program characteristics	Quant	Geometric Model of Student Persistence and Achievement	M.O.R.E. (intervention) participants | Biomedical Sciences | 227 Female; 155 Male | MS and PhD
[26]	growing diversity population; loss of students to corporate jobs	factors in forgoing PhDs; how to attract underrepresented students to PhDs	Qual	Decision Funnel	PhD capable science and engineering graduates who pursued careers in other fields | Science and Engineering | 12 | N/A | PhD
[27]	disproportionate representation, need to understand how to be supportive, global competitiveness	understanding underrepresented graduate student perspectives on supportive practices	Qual	N/A	Graduate students | STEM | 91 | N/A | Not Specified
[28]	Wide racial differences in graduate degree completion within institutions of the same type are indicative of systematic barriers that affect students and are suggestive of possible "hierarchies of power, communication, and opportunity"; cultures threaten all in STEM, not just underrepresented students	supports and challenges to persistence of underrepresented students in grad school; how power, race, and underrepresentation shape those experiences; compare across institutions	Qual	critical socialization framework within a constructivist paradigm	Graduate students | Engineering, Biological and Biomedical Sciences, Mathematics, Physics, Chemistry, Environmental Science, Ecology, Psychology | 53 | 22 Female; 31 Male | M.S. and PhD
[29]	global security, global competitiveness, competent and diverse workforce	impact of summer research on pursuing grad school	Qual	The Triple Quandary Theory	Summer research participants | Animal Science, Chemical Engineering, Computer Science, Biology, Chemistry, Civil Engineering, Environmental Science | 6 | Female | Undergraduate
[30]	global competitiveness	personal and institutional factors impeding/ promoting persistence and retention	Qual	Critical Race Theory	Graduate students | Liberal arts, Humanities, Engineering, Education | 12 | 10 Female; 2 Male | PhD
[31]	very little work taking anti-deficit approach, very little qual work on this demographic	factors that influence African Americans to pursue and complete doctoral engineering degrees	Qual	Critical Race Theory, Model of doctoral degree progress, and Longitudinal model of graduate student persistence	PhD graduates | Applied physics, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Materials Science and Engineering, Mechanical Engineering, Industrial engineering | 19 | 7 Female; 12 Male | PhD

Young, Etemadi, Little & Carter [27], Little [30], and Simon [31] speak to the importance of family, peer, and faculty/advisor support in the quality of the graduate education experience, especially from others who identify as underrepresented minorities. Brazziel and Brazziel [26], Crumpton-Young, Etemadi, Little & Carter [27], and Figueroa [28] echo financial concerns and availability of institutional resources as impediments to student success. Figueroa also reveals that "intergroup and interpersonal dynamics wherein underrepresentation, power imbalances, and preferences for interaction among different student groups" can foster unwelcomed environments for underrepresented students [28, p. 297]. Little reveals the feelings of hypervisibility and invisibility to describe a Black student's presence in the academy while also noting that the "paucity of faculty of color in academia reified the 'domain of

Table 4. Extracted data from articles in Theme 2 focused on the role of identity for African American graduate students in engineering and computer science

	Why?	What?	HOW?		
Articles	**Motivation for the Study**	**Purpose of the Study**	**Methods**	**Framework**	**Participants Demographics (Program) | Disciplinary Focus | Sample Size | Sex | Education Level)**
[23]	underrepresentation at doctorate level; examine successfulness of McNair program; examine assumption that summer enrichment programs serve to ameliorate and counteract the impact of poverty on the academic achievement of economically disadvantaged and underrepresented students	describe University of Tennessee McNair participants; understand who is likely to go to graduate school; build profiles for those who do and do not	Quant	Social Learning Theory – Locus of Control	McNair (intervention) scholars who were and were not enrolled in graduate school | Physical sciences, Life sciences, Engineering, Social Sciences, Business-related Fields | 60 | 32 Female; 29 Male | Not Specified
[24]	global competitiveness	?understand and describe how graduate students in STEM disciplines experience conflict between their science identity and their social identities	Qual	The model of science identity, Model of multiple dimensions of identity, Theory of validation of culturally diverse students	Graduate students | Chemistry, Biological/ Biomedical Science, Engineering, Computer Science, Math, Physics | 73 | 33 Female; 40 Male | M.S. and PhD

Table 5. Extracted data from articles in Theme 3 focused on the perceptions that African American graduate students in engineering and computer science have about graduate school

	Why?	What?	HOW?		
Articles	**Motivation for the Study**	**Purpose of the Study**	**Methods**	**Framework**	**Participants Demographics (Program) | Disciplinary Focus | Sample Size | Sex | Education Level)**
[21]	disproportionate representation, majority-minority country in 2050, need to take a systematic view of the problem and get away from the individual	perceptions of program culture based on gender and race	Quant	Socialization	Former McNair (intervention) scholars formally or currently enrolled in graduate school | Chemistry, Life Sciences, Psychology, Physiology, Engineering, Mathematics | 14 | 10 Female; 4 Male | M.S. and PhD
[22]	social justice goals; utilize the human capital that can ensure the country's economic and global competitiveness; little literature on intersections of race and gender	understanding lived experiences of African American women in STEM doctoral programs	Qual	Critical race theory, Black feminist thought, and the science identity model	PhD graduates | Biostatistics, Biochemistry, Molecular Genetics and Microbiology, Civil Engineering, Anatomy, Cancer Biology, Chemistry, Pharmacology, Integrative Biosciences | 10 | Female | PhD

whiteness,' often reflected at the focal institution'' [30, p. 4].

These articles include a variety of recommendations for improving graduate engineering education to support recruitment and persistence. Overall, Little [30] calls for a more holistic and strategic approach requiring efforts to be made at every step of the STEM pathway from early academic messaging, to doctoral recruitment and admissions processes, to faculty perceptions and interactions. Furthermore, recommendations from these studies indicate the need to support graduate students through financial support and programming. While Brazziel and Brazziel's [26] results highlight the need for more funding to support scholarships and fellowships, Jackson-Smith [29] calls for increased funding for summer intervention programs and for training staff to accommodate the unique needs of their participants. On the other hand, Simon [31] recommends that university

administrators play an active role in making environments more suitable for student success. Meanwhile, Crumpton-Young, Etemadi, Little & Carter [27] made recommendations for departments to use motivational practices and methods as a means to improve student program completion rates. Lastly, Figueroa [28] made recommendations pertaining to intergroup relations, peer learning environments in programs with regard to structure and competitiveness, biases and discrimination from peers and faculty, and availability of institutional resources. For example, one recommendation is to improve the relationships between students and faculty, and between students and their peers. Faculty should be mindful of the power dynamics at play and be attentive to not only what they say to students, but how they communicate as well. Literature suggests prioritizing clear and effective communication between students and faculty especially as it relates to needs and expectations in order to help increase completion rates [42]. Department coordinated gatherings, study groups, and mentorship programs are suggested to help facilitate meaningful relationships among students and their peers.

4.2 Theme II: Student Identity

Two of the 11 articles [23, 24] contained purposes and research questions about student identity. Chatman [23] sought to build profiles for students that indicated whether they were likely or unlikely to go to graduate school. On the other hand, Tran [24] aimed to investigate the conflict that exists between a student's science identity and other core identities, like gender and race. Chatman took a quantitative approach using secondary analysis, while Tran used focus groups as a data collection method. Chatman utilized five "seminal" studies to guide this study. Four were related to undergraduate or graduate matriculation and performance of African American students [42–45] and one was a theory regarding the relationship between levels of control and achievement [46]. Of the many choices in theoretical frameworks, Tran chose multiple theories and frameworks [47–49] that all mapped directly to student identity.

Chatman's [23] sample group consisted of undergraduate McNair Scholars (https://mcnairscholars.com) eligible for graduate school. Half of these students attended a PWI (predominantly white institution) and the remainder attended an HBCU (historically Black colleges and universities). Fifty percent of participants were women with participants spanning five various fields including engineering, life sciences, and business-related fields. Tran [24] sampled graduate students from an HBCU, three PWIs, and two HSIs (Hispanic-serving institution) with 45% of participants identifying as women. These authors highlighted various limitations of their work. Chatman notes a lack of generalizability, limited scope of analysis, the fact that data is self-reported, and the small sample size. Tran acknowledges limitations of using focus groups and secondary analysis, as well as lack of generalizability.

4.2.1 Emerging Insights & Recommendations

Results from these studies indicate possible positive influences on student participation in graduate school as well as some general results from the study. For example, Chatman [23] found that nearly 70% of the University of Tennessee Ronald McNair Program participants eligible for graduate school were enrolled in graduate school. Those who participated in the McNair Program went on to graduate school, and were significantly different from those who did not (in terms of demographic, educational, academic, and personality variables.) These findings highlight both promise for enrichment programs such as this one and a need for further study. Tran [24] notes that the dominant culture of science presents a disruption for the science identities of underrepresented minorities and women in STEM, thus students develop strategies to cope and manage this tension among identities.

These two articles provide two types of recommendations – one more localized than the other. Recommendations from Chatman [23] pertained to programmatic updates needed within the McNair Scholars at the sample institution and the program more broadly. Updates included designing the program to increase recruitment from HBCUs and use personality variables such as locus of control and behavioral preferences, as a part of the selection process. On the other hand, Tran [24] recommended practical implications, such as: offering student organizations centering on race, gender, socioeconomic status, and religion; treating students as whole persons and not as categories or numbers; adopting cultural pluralistic pedagogy and curricula; and encouraging faculty to be more supportive of students who seek to engage research for social change or participate in outreach.

4.3 Theme III: Perceptions of Graduate School

The final two articles of this SLR [21, 22] present work aiming to better understand students' perceptions of graduate school. Specifically, Squires [22] focused on understanding the lived experiences of African American women in STEM doctoral programs through interviews. Meanwhile, Bancroft, Benson, and Johnson [21] used a quantitative approach to investigate student perceptions of program culture based on the students' gender

and race by using Likert-scale surveys. Squires combined aspects of three theories: Critical Race Theory [32], Black feminist thought [50], and the science identity model [47]. Bancroft, Benson, and Johnson used a critical lens to focus on the environmental factors (such as racism, sexism, and stereotype threat) that significantly affect the student experience. They surveyed former McNair scholars, 71% of whom were female, in graduate school from various STEM disciplines at three PWIs. The majority of students (71%) were PhD students, a few (21%) were master's students, and some (7%) were unknown. Squires interviewed PhD graduates who were asked to reflect on their experience in their respective programs. Bancroft and colleagues note their small sample size and limited survey as limitations. Squires expresses limitations due to a lack of data collected from current undergraduate or graduate student experiences in STEM programs.

4.3.1 Emerging Insights & Recommendations

Results from Bancroft, Benson, and Johnson [21] included students reporting the presence of double oppression; heightened gender and race awareness; and pressure to work harder because of gender and/or race in their graduate programs. Major findings from Squires [22] included an expressed lack of African American women as options for mentors, as well as a list of seven factors attributed to the successful completion of the dissertation and doctoral degree. These factors include: (1) having a clear plan, (2) taking ownership of the writing process, (3) having an engaged advisor, (4) learning the writing style of the advisor, (5) understanding the temperament of the advisor, (6) personal will or self-motivation to finish, and (7) actively seeking support.

Bancroft, Benson, and Johnson suggest that with examinations of sociocultural inequalities in graduate programs researchers can highlight gender and racial disparities, as well as, "challenge and encourage administrators and policymakers to create STEM graduate environments free of oppression" [21, p. 15]. Squires [22] concluded with calls for policymakers to fund and incentivize recommendations made by countless others to increase representation. She calls for institutions to ensure welcoming learning environments in doctoral programs for African American women. Squires recommends that future problems and solutions are centered around institutions and not the students. For example, Squires suggests that institutions can begin to "understand how [African American women] navigate doctoral degree completion in STEM disciplines by intentionally becoming culturally competent of the experiences of [African American women]" [22, p. 139] as opposed to putting the responsibility solely on the students to figure out how to cope in a non-conducive environment. African American women in STEM doctoral programs are encouraged to take it upon themselves to seek help. Lastly, summer bridge programs are suggested to help ease the transition to doctoral programs; and STEM doctoral programs are called to make just as much of an effort to accommodate underrepresented minority students as they do international students.

4.4 Synthesis Across Themes

After looking across the insights in each theme, we identified factors that both positively and negatively influenced the educational experience and outcomes of African American graduate students in engineering and computer science. Major barriers and persistence factors stemmed from three major categories. The first category was the presence of support structures. Having support in place from faculty, advisors, family, and peers were reported as positive persistence factors [22, 27, 31], and the lack thereof negatively impacted the graduate students' experience [26–28].

The second most reported factor was race and/or gender factors. For example, reports of heightened gender and/or race awareness, unwelcoming environments, and lack of representation in peers and faculty negatively impacted students' experiences [21, 27, 28, 30]. On the other hand, creating inclusive environments and having diversity among faculty and students were reported as factors supporting persistence [24, 30].

The final category was related to the availability of financial resources. Similar to the presence of support structures, the presence of financial resources was reported as a factor to promote persistence [27, 30], while the lack of finances negatively impacted student experiences [26, 27, 30].

The studies included in this SLR offer recommendations for addressing this problem. More specifically, these studies indicate attention needed within graduate programs and the institutions in which they are embedded, as well as early exposure of STEM to young children. Most recommendations focus on the environmental conditions that, if addressed, will aid African Americans in their pursuit of a doctoral degree. For example, numerous authors recommended altering organizational culture and institutional support [22, 24, 28, 30], while others also recommend that institutions utilize information regarding mentoring and culturally relevant pedagogical aspects of graduate programs [24, 26, 27]. Others also suggest that early exposure to STEM, research, and graduate school will aid in awareness and foster more aspirations to pursue graduate school earlier in life [26, 31].

5. Implications for Future Studies

This discussion includes six assertions and is organized into two major sections. The first major section discusses the implications and future directions in light of framing the problem, including ideas related to how studies are motivated, how research questions are posed, and the lack of literature on computer science. We then discuss the implications and future directions associated with studying the problem, including ideas associated with theoretical frameworks used to guide data collection and analysis, methods, and participant selection. We use a critical lens within each section to make suggestions for future work.

5.1 Implications for Framing the Problem

5.1.1 There is a need for more Expanded Motivations for Engaging in this Work

Regardless of the research topic, researchers typically motivated these studies with the argument of global competitiveness and global security, as well as a need to understand how to make graduate education work for a growing diverse population that is currently underrepresented in engineering and computer science. Most authors used a combination of various arguments to motivate a study. The majority of the documents contained the economic argument at some point in the motivation for the study to follow [21, 22, 24–26, 28–31]. The next most popular motivator was the projected minority-majority future argument [21, 25, 26]. A smaller portion of articles was motivated by a response to the decline in the number of African American doctoral degrees [23], underrepresentation being an educational concern [27], and a need for more literature that also considers those who persist in graduate studies as opposed to only considering barriers to participation [31].

How the problem is framed is important because the ways in which researchers motivate their work has implications for how they conceptualize the problem as well as what they consider success or progress. Some motivations are inherently focused on progress from the perspective of institutions and industry, whereas others are focused on progress from the perspective of people. There is a need for scholarship that has these motivations in mind and can even combine them as seen in other diversity works [51].

5.1.2 There is a need for a Wider Variety of Topics being Investigated

Upon further analysis, a huge gap in the literature emerged from the perspective of questions, methods, and theories used to investigate broadening participation efforts at the graduate level. Results showed that investigators focused their studies around the following: perceptions of programs through the lens of race and gender, factors affecting the pursuit of and persistence in graduate school, and student identities. There are a host of topics that can provide insight, such as: preparedness for future careers, career choices, advisor-student interactions, graduate education curriculum, teaching practices in graduate education, and effectively engaging in the dissertation process. These topics are all likely unique in the context of engineering and computer science and are influenced by race, and thus are important for understanding participation at the graduate level.

While the production of more scholarship is vital, we must also caution researchers on their approach to the studies they design. For example, designing studies to build profiles for students who are likely to go to graduate school and those that do not could turn out to do more harm than good, despite researchers' best intentions. For example, this kind of perspective can limit the number of students that even consider graduate school as an option and/or project a position that the student is the problem – as opposed to problems in structures that have historically/systematically excluded African Americans from accessing higher education in this country [28].

5.1.3 There is a need for more Emphasis on Graduate Students in Computing

Among our articles, we identified a lack of focus on and consideration for CS students. The search terms used in this study included computer science and computing. Although computer science participants were included in some of the sample groups, there were no studies that focused specifically on graduate students in computer science or scoped their analysis in a way that would lead to findings specifically for this group. Unfortunately, this is a common trend found in the literature, regardless of which segment of the education-to-workforce pathway is of interest [52]. This is one of the largest gaps in the literature that was identified through this SLR and represents the area of the greatest potential for advancing our understanding of the experiences of underrepresented groups in engineering and CS.

5.2 Implications for Studying the Problem

5.2.1 There is a need for the use of Different Lenses to Study the Problem

Theoretical frameworks used in these studies were primarily positioned from a socialization or critical lens. Doing so highlighted the impact of the envir-

onment on student performance and perceptions and brought attention to some of the problematic areas in the learning environment or education system. Crumpton-Young and colleagues [27] did not use a theoretical framework; however, the paper was positioned as exploratory in nature. Among other frameworks used were those relating to decision making, student identity, and student persistence. Moving forward, scholars should consider using a variety of other frameworks outside of these common ones.

Frameworks provide a lens for viewing the same social phenomenon from multiple perspectives. Social phenomena include a plethora of complex interactions amongst aspects of interest, including individuals and artifacts. There is no single theoretical framework that can explain these interrelationships. They simply use different tools and methods to explain a phenomenon in various ways [53].

5.2.2 There is Room for the use of Diverse Methods and follow-up Studies that Investigate Impact

Scholars typically use qualitative methods to investigate questions about broadening participation in engineering and computer science for graduate students. They relied heavily on tools such as interviews and focus groups to obtain data on students. Although these are valid and valuable methods of inquiry, there are only certain types of questions that these methods can adequately answer.

Although heavily qualitative, each of our three topic areas contains articles with both qualitative and quantitative methods. Scholars are exhibiting an understanding that there is more than one way to approach and understand a problem and it is reflected in their methodological choices. Two of the 11 utilized secondary analysis as a means to abstract data [23, 28]. Even though different scholars used different methods, none of the scholars used a mixed-methods design to investigate their purpose. This would allow researchers to study both qualitative and quantitative-focused questions in a single study and generate insights that provide a more comprehensive solution to a research problem [54].

Lastly, our recommendation for future work is to invest in more long-term student-centered studies. Implementing follow-up studies to determine the impact of support programs on student pursuit and persistence is one place to start. Capturing a student's intent to pursue an advanced degree at the end of an intervention can be valuable if the purpose is to prove that a program makes students consider a graduate degree, however, it does not prove that a program is successful at preparing more African Americans for graduate studies. Longitudinal studies are needed to support this claim. Additionally, trends in the engineering education literature more broadly indicate an increase in scholars seeking to understand impact beyond retention [57]. It would be insightful to understand the degree to which graduate school aided graduates in obtaining the success they hoped graduate school would prepare them for. This can inform how we market graduate school and/or inform professional development for current students.

5.2.3 There is a need for Larger and more Intentional Samples

All studies contained participants who identified as Black or African American. Studies including other underrepresented minorities (e.g., Hispanic/Latino, African American/Black, American Indian, Pacific Islander) were often using big data sets. Some studies also disclosed that their participants were also from low socioeconomic status or first-generation backgrounds [21, 23, 24]. Most studies focused on students enrolled or planning to pursue a doctoral degree; master's students were usually only included if they expressed a plan to pursue a PhD in the future. Progress toward degree completion is slow at both levels, so it is unclear as to why these studies have chosen to emphasize one over the other. Masters and PhDs serve different purposes, each context and experience is unique (timeline, classes in each) therefore, we cannot assume that if we know more about one that we fully understand the other. The dearth of scholarship focused on either type of graduate student warrants more research.

Of 11 studies, only two focused specifically on the experiences of African American women [22, 29] and none focused on African American men. The remaining studies may have presented findings that were specific to the women or men of color in the study, though it was uncommon. In fact, some studies did not disclose their participant's gender at all. While this SLR was underway, scholarship by Burt, Williams, and Smith [20] has since been published highlighting factors that pose a threat to the persistence of Black men in engineering. They bring attention to "structurally racialized policies within the engineering college (e.g., admissions) and racialized and gendered interactions with peers and advisors" [20, p. 1] as experienced by the participants. African American men and women are not monolithic, but their experiences are typically different from the majority, and each other, and thus deserve separate consideration in future scholarship.

Even with searching specifically for graduate-level focused research, many of the results included in the SLR still included undergraduate partici-

pants. The literature suggests that even when we do think about the graduate education level, we are still thinking about undergraduates. Undergraduates were used to understand the factors that influenced student pursuit of graduate school [25], understand the characteristics of students likely to pursue graduate school [23], and understanding the influence of summer intervention programs on student pursuit of graduate school [29]. We suggest that future scholarship on graduate education include the voices of graduate students, not only prospective graduate students (i.e., undergraduates).

The studies included participants from a wide variety of institution types – namely, PWIs, HBCUs, and HSIs. Few studies recruited participants from all three types of institutions in one study. Seeing a wide representation of institutional types represented among the participants is something that should be celebrated and should continue in future scholarship.

Similarly, participants were recruited from a wide range of engineering disciplines. This was also good to see; but also has a limitation. Existing literature talks about the differences in subcultures among engineering disciplines [55]. This reality speaks to the need for more scholarship that also takes an in-depth look at underrepresented groups within a discipline.

6. Conclusion

If researchers want to broaden participation, attention must be given to every segment of the STEM pathway. This study brings attention to scholarship focused on the barriers to participation and persistence factors experienced by African Americans pursuing graduate degrees in engineering and computer science. Results of this SLR identified three major themes in the existing literature: (1) *recruitment and persistence*, (2) *student identity*, and (3) *student perceptions of graduate school.* Within each topic area, we discussed trends in how this problem is investigated and insights that emerged from the articles. The cross-case analysis summarized the most salient factors influencing persistence – namely, the presence of support structures, elements associated with race and/or gender identity, and the availability of financial resources.

It was unsurprising that factors like race/gender and department/institution characteristics (i.e., support structures, climate, and cultures) were mentioned, as undergraduates and graduates attend the same institutions, and by extension, are navigating the same policies, structures, and interpersonal dynamics. However, it is important to note that although the naming of these factors is similar and may suggest that they are the same, these barriers manifest themselves differently at the two levels.

Constant issues permeating through to the graduate level pinpoints the presence of systemic and structural problems that cause the appearance of the same phenomena to play out regardless of who or what level we are considering. This points to systemic problems for the field and society as a whole to wrestle with. Lastly, as departments and institutions take note of major barriers and implement initiatives to combat them, assessment should be used to track changes in perceptions, climates, and student performance. It is important that we collect information about what is and is not working for broadening participation in engineering and computer science and in what contexts. Without such insights, it will continue to be difficult to monitor and celebrate progress toward parity.

References

1. T. K. Holloman, W. C. Lee, J. S. London, A. B. Hakiyo, G. Jew and B. A. Watford, A historical and policy perspective on broadening participation in STEM: Insights from national reports (1974–2016), *Am. Soc. Eng. Educ.*, 2018.
2. National Academies of Science Engineering and Medicine, *Graduate STEM Education for the 21st Century*, Washington, DC: The National Academies Press, 2018.
3. National Research Council, *Proceedings of a workshop for program directors in engineering education of minorities*, pp. 1–88, 1976 [Online]. Available: http://www.nap.edu/catalog.php?record_id=20635.
4. National Academy of Engineering and American Society for Engineering Education, *Surmounting the Barriers: Ethnic Diversity in Engineering Education: Summary of a Workshop*, Washington D.C., 2014.
5. Task Force on Women Minorities and the Handicapped in Science and Technology, *Changing America: The new face of science and engineering*, 1989. [Online]. Available: https://archive.org/stream/changingamerican00unit#page/n1/mode/2up.
6. B. L. Yoder, *2017 Engineering by the numbers*, 2018.
7. National Science Foundation, *Award Abstract #1647281 Collaborative Research: Pushing Students Away: Developing a Research Agenda for Broadening Participation of African Americans in Engineering and Computer Science*, 2016. https://www.nsf.gov/awardsearch/showAward?AWD_ID=1647281&HistoricalAwards=falses (accessed Sep. 07, 2020).
8. M. J. Grant and A. Booth, A typology of reviews: An analysis of 14 review types and associated methodologies, *Health Info. Libr. J.*, **26**(2), pp. 91–108, 2009.
9. J. S. London, W. C. Lee, C. Phillips, A. S. Van Epps and B. A. Watford, A systematic mapping of scholarship on broadening participation of African Americans in engineering and computer science, *J. Women Minor. Sci. Eng.*, **26**(3), pp. 199–243, 2020.

10. C. Wendler, B. Bridgeman, R. Markle, F. Cline, N. Bell, P. McAllister and J. Kent, *Pathways Through Graduate School and Into Careers Executive Summary Pathways Through Graduate School and Into Careers,* 2012. [Online]. Available: www.pathwaysreport.org.
11. B. C. Lockard and M. Wolf, *Occupational employment projections to 2020*, 2012.
12. K. J. Bunker, L. E. Brown, L. J. Bohmann, G. L. Hein, N. Onder and R. R. Rebb, Perceptions and influencers affecting engineering and computer science student persistence, *Proc. – Front. Educ. Conf. FIE*, pp. 1138–1144, 2013.
13. R. M. Rincon and N. Yates, Women of color in the engineering workplace: Early career aspirations, challenges, and success strategies, *Soc. Women Eng.*, 2018.
14. M. Borrego, M. J. Foster and J. E. Froyd, Systematic literature reviews in engineering education and other developing interdisciplinary fields, *J. Eng. Educ.*, 2014.
15. M. Petticrew and H. Roberts, *Systematic reviews in the social sciences: A practical guide*, Malden, MA: Blackwell Publishing, 2006.
16. C. M. L. Phillips, J. S. London, W. C. Lee, A. S. Van Epps and B. A. Watford, Reflections on the messiness of initiating a systematic literature review on broadening participation in engineering and computer science, *Front. Educ. Conf.*, 2017.
17. P. D. Mullen and G. Ramírez, The promise and pitfalls of systematic reviews, *Annu. Rev. Public Heal.*, **27**, pp. 81–102, 2006.
18. J. P. Higgins and S. Green, *Cochrane Handbook for Systematic Reviews of Interventions version 5.0*, Chichester, UK: John Wiley & Sons, 2008.
19. D. J. Cook, C. D. Mulrow and R. B. Haynes, Systematic reviews: Synthesis of best evidence for clinical decisions, *Ann. Intern. Med.*, **126**(5), pp. 376–380, 1997.
20. B. A. Burt, K. L. Williams and W. A. Smith, Into the Storm: Ecological and Sociological Impediments to Black Males' Persistence in Engineering Graduate Programs, *Am. Educ. Res. J.*, p. 000283121876358, 2018.
21. S. F. Bancroft, S. K. Benson and E. Johnson-Whitt, McNair scholars' science, technology, engineering, and mathematics (STEM) graduate experience: A pilot study, *Mid-Western Educ. Res.*, **28**(1), pp. 3–27, Mar. 2016, [Online]. Available: http://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=114283894&site=ehost-live.
22. S. M. Squires, *A study of the lived experiences of African American women STEM doctoral degree completers*, ProQuest Information & Learning, US, 2016.
23. K. Chatman, *A study of the University of Tennessee Ronald Mcnair Post-Baccalaureate Achievement Program: Factors related to graduate school enrollment for first-generation, low-income and under-represented college students*, ProQuest Information & Learning, US, 1995.
24. M. C. Tran, *How can students be scientists and still be themselves: Understanding the intersectionality of science identity and multiple social identities through graduate student experiences*, ProQuest Information & Learning, Ann Arbor, 2011.
25. S. M. Bradford, *Patching the pipeline: Identifying salient characteristics of academic intervention programs that increase the number of underrepresented minorities pursuing graduate level biomedical research*, ProQuest Information & Learning, US, 2010.
26. M. Brazziel and W. Brazziel, Factors in decisions of underrepresented minorities to forego science and engineering doctoral study: A pilot study, *J. Sci. Educ. Technol.*, **10**(3), pp. 273–281, Sep. 2001, [Online]. Available: http://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=15604730&site=ehost-live.
27. L. L. Crumpton-Young, S. Etemadi, G. E. Little and T. D. Carter, *Supportive practices used with underrepresented minority graduate students*, 2016, vol. 2016-June.
28. T. Figueroa, *Underrepresented raciallethnic minority graduate students in science, technology, engineering, and math (STEM) disciplines: A cross institutional analysis of their experiences*, ProQuest Information & Learning, US, 2016.
29. D. Jackson-Smith, The summer was worth it: Exploring the influences of a science, technology, engineering, and mathematics focused summer research program on the success of African America females, *J. Women Minor. Sci. Eng.*, **21**(2), pp. 87–105, 2015, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84936868730&partnerID=40&md5=77d3c5af1259154c999c934b0feeca0c.
30. S. D. Little, *The Ph.D. as a contested intellectual site: A critical race analysis of the personal and institutional factors that influence the persistence and retention of academically successful Black doctoral students*, ProQuest Information & Learning, US, 2015.
31. T. M. Simon, *Engineering success: Persistence factors of African American doctoral recipients in engineering and applied science*, ProQuest Information & Learning, US, 2009.
32. R. Delgado and J. Stefancic, *Critical race theory*, New York, NY: NYU Press, 2012.
33. G. Ladson-Billings and W. F. Tate, Toward a critical race theory of education, *Teach. Coll. Rec.*, **97**(1), pp. 47–68, 1995.
34. G. R. Lopez, The (racially neutral) politics of education: A critical race theory perspective, *Educ. Adm. Q.*, **39**(1), pp. 68–94, 2003.
35. W. S. Swail, *Retaining Minority Students in Higher Education: A Framework for Success. ASHE-ERIC Higher Education Report. Jossey-Bass Higher and Adult Education Series.* San Francisco, CA: Jossey-Bass, 2003.
36. V. Tinto, *Leaving college: Rethinking the causes and cures of student attrition*, 2nd ed. Chicago: The University of Chicago Press, 1993.
37. J. S. Antony, Reexamining doctoral student socialization and professional development: Moving beyond the congruence and assimilation orientation, in *Higher education: Handbook of theory and research*, J. C. Smart and W. G. Tierney, Eds. New York: Agathon Press, pp. 349–380, 2002.
38. A. W. Boykin and F. D. Toms, Black child socialization: A conceptual framework, in *Black children: Social, educational, and parental environments*, **72**, H. P. McAdoo and J. L. McAdoo, Eds. Thousand Oaks, CA, US: Sage Publications, Inc, pp. 33–51, 1985.
39. G. T. Allison, *Essence of Decision: Explaining the Cuban Missile Crisis, Little, Brown and Company, Boston, MA*. Boston, MA: Little, Brown, and Company, 1971.
40. D. Hossler and K. S. Gallagher, Studying student college choice: A three-phase model and the implications for policymakers, *Coll. Univ.*, **62**(3), pp. 201–221, 1987.
41. R. Olsen, Self-selection bias, *Encycl. Surv. Res. methods*, pp. 809–811, 2008.
42. M. S. Artiles and H. M. Matusovich, Examining doctoral degree attrition rates: Using expectancy-value theory to compare student values and faculty supports, *Int. J. Eng. Educ.*, **36**(3), pp. 1071–1081, 2020.
43. A. W. Astin, *Minorities in American higher education. Recent trends, current prospects, and recommendations*. San Francisco State UniversityAmerican Society of Civil EngineersStructural Engineers Association of CaliforniaNASA Ames Research Center, Mountain View, CA: Jossey-Bass, Inc., 1982.

44. J. Fleming, *Blacks in College. San Francisco, CA: Josey-Bass*, Jossey-Bass, 1984.
45. W. R. Allen, Black student, White campus: Structural, interpersonal, and psychological correlates of success, *J. Negro Educ.*, **54**(2), pp. 134–147, 1985.
46. M. T. Nettles, Black, Hispanic, and White Doctoral Students: Before, During, and After Enrolling in Graduate School, ERIC, Princeton, NJ, 1990.
47. J. B. Rotter, Generalized expectancies for internal versus external control of reinforcement, *Psychol. Monogr. Gen. Appl.*, **80**(1), pp. 1–28, 1966.
48. H. B. Carlone and A. Johnson, Understanding the science experiences of successful women of color: Science identity as an analytic lens, *J. Res. Sci. Teach.*, **44**(8), pp. 1187–1218, 2007.
49. S. R. Jones and M. K. McEwen, A conceptual model of multiple dimensions of identity, *J. Coll. Stud. Dev.*, **41**(4), pp. 405–414, 2000.
50. L. I. Rendon, Validating culturally diverse students: Toward a new model of learning and student development, *Innov. High. Educ.*, **79**(1), pp. 33–51, 1993.
51. McNair Scholars Program, https://mcnairscholars.com/ (accessed Sep. 21, 2020).
52. P. H. Collins, *Black feminist thought: Knowledge, consciousness, and the politics of empowerment*, New York: Psychology Press, 2000.
53. M. S. Artiles, R. C. Waters, A. R. Taylor, K. Boyd-Sinkler, S. A. Williams, C. Hampton, A. L. Hermundstad, W. C. Lee and B. D. Lutz, Action on Diversity: A Content Analysis of ASEE Conference Papers, 2015–2016, 2017, [Online]. Available: https://jee.org/27533.
54. J. London, W. C. Lee, B. Watford, T. Holloman, A. Halkiyo, G. Jew, C. Hawkins Ash, and C. Phillips, Toward a National Agenda for Broadening Participation of African Americans in Engineering & Computer Science: Insights from Year One, in *2018 American Society for Engineering Education Annual Conference*, pp. 1–5, 2018.
55. S. M. Ravitch and M. Riggan, *Reason & rigor: How conceptual frameworks guide research*, 2nd ed. Sage Publications, 2017.
56. J. W. Creswell and V. L. P. Clark, *Designing and conducting mixed methods research*, Sage publications, 2017.
57. Y. Genc, G. Altuger-genc and A. Tatoglu, Systematic Review of ASEE Conference Proceedings (2007–2016) with A Machine Learning Approach, **36**(5), pp. 1722–1735, 2020.
58. E. Godfrey, Understanding disciplinary cultures, in *Cambride Handbook of Engineering Education Research*, Cambridge, UK: Cambridge University Press, pp. 437–457, 2014.

Teirra Holloman is a doctoral student in engineering education at Virginia Polytechnic Institute and State University, where she serves as a graduate research assistant. She is concurrently pursuing an MS in Industrial and Systems Engineering at Virginia Tech with a focus on Management Systems. Teirra received her BS in Industrial Engineering from Clemson University. Her research interests revolve around race-conscious organizations in educational contexts, organizational responses to external forces, inclusion, and equity in engineering.

Dr. Jeremi London is an assistant professor in the Engineering Education Department at Virginia Polytechnic Institute and State University. London is a mixed-methods researcher with interests in research impact, broadening participation, cyberlearning, and instructional change in engineering education. Prior to being a faculty member, London worked at the National Science Foundation, GE Healthcare, and Anheuser-Busch. She earned BS and MS degrees in Industrial Engineering, and a PhD in Engineering Education from Purdue University.

Dr. Walter Lee is an associate professor in the Department of Engineering Education and the Director for Research in the Center for the Enhancement of Engineering Diversity (CEED), both at Virginia Tech. His research interests include co-curricular support, student success and retention, educational equity, and diversity. Lee received his PhD in engineering education from Virginia Tech, his MS in industrial & systems engineering from Virginia Tech, and his BS in industrial engineering from Clemson University.

Crystal Pee is a graduate student at Virginia Polytechnic and State University pursuing a PhD in Engineering Education, where she also serves as a graduate research assistant. Her research interests include broadening participation in industry and vocational behavior. Prior to attending Virginia Tech, she received a Bachelor of Science degree in Chemical Engineering with a minor in Business Administration from Clemson University.

Dr. Chaneé Hawkins Ash is a former postdoctoral researcher at Virginia Polytechnic and State University in the Department of Engineering Education. She currently serves as the co-founder and principal of Foresight Strategy Solutions, a P-12 and higher education consultancy committed to supporting education organizations as they reinvent their operating frameworks to better serve all students, especially those who have been disproportionately impacted by the education system. Chaneé holds a Bachelor of Arts in English from Truman State University (Kirksville, MO) and received her Master of Arts and PhD in Education Policy, Organization, and Leadership from the University of Illinois at Urbana Champaign.

Dr. Bevlee Watford is a Professor of Engineering Education, Associate Dean for Equity and Engagement, and Executive Director of the Center for the Enhancement of Engineering Diversity in the College of Engineering at Virginia Tech. Her research activities have focused on the recruitment and retention of students in engineering, with a particular emphasis on under-represented students. She was also the 2017–18 President of ASEE. She received her BS in Mining Engineering and her MS and PhD in Industrial Engineering and Operations Research from Virginia Tech.