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Missed Opportunity for Diversity in Engineering: Black Women and Undergraduate Engineering Degree Attainment

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Abstract

Efforts dedicated towards broadening participation for Black and other underrepresented groups in engineering at post-secondary institutions has intensified in recent decades. However, Black women have not yet reached parity in undergraduate engineering degree attainment. To elucidate this trend, data from the U.S. Department of Education was analyzed to investigate postsecondary completion for Black women in engineering. Results indicate that the percentage of degrees awarded to Black women has slightly decreased during the last five years when compared to women of all races. However, the percentage of Black women obtaining engineering degrees has increased when compared to the general Black engineering population, with a larger percentage of Black women obtaining engineering degrees compared to their male counterparts than any other ethnicity. Thus, the purpose of this paper is to

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provide recommendations for research avenues that may strengthen knowledge around the enrollment and retention of Black women in engineering at post-secondary institutions.

Keywords
engineering, race, gender, bachelor's degrees, undergraduate, HBCUs

The ability for the United States (U.S.) to successfully compete in science and engineering fields, within a rapidly changing technological landscape and global innovation, has become a growing source of concern among government and industry leaders. Moreover, U.S. companies and organizations have turned to outsourcing labor to foreign countries as a means to generate the required human capital necessary towards ameliorating the shortage of science and engineering skills and help maintain global competitiveness (Varma, 2018). However, investing in, and the leveraging of, the diversity of the U.S. workforce by broadening participation of women and minorities in engineering is a promising path forward in resolving these issues (Peixoto et al., 2018; Strachan et al., 2018; Varma, 2018).

In fact, utilizing diverse teams can have a positive impact on productivity. That is, actualizing the fullest potential for a team's productivity and innovation rests on the ability of a team to successfully integrate contributions among all members who may vary in their diversity of thought and background (Cross & Paretti, 2020; Smith-Doerr et al., 2017). The emergent benefits of working on well-integrated, diverse, and multicultural teams is well known. For example, the Accreditation Board for Engineering and Technology (ABET) encourages the need to develop social and communication skills in educational spaces to prepare young professionals in creating collaborative and inclusive environments within engineering (Blosser, 2020; Shuman et al., 2005). However, to invest in the diversity of the potential pool of aspiring engineering professionals, one must immediately recognize the challenges posed by the stagnating representation of women and minorities across the majority of U.S. institutions, which poses a substantial challenge in strengthening STEM (science, technology, engineering, and mathematics) as a whole. As such, calls for increased diversity in STEM workplaces, as well as educational institutions, have sparked investigations to examine the issues that result in fewer women and racial minorities obtaining STEM degrees and pursuing related careers (Frierson & Tate, 2011; Myers & Pavel, 2011; National Science Board, 2007).

Within engineering specifically, there continues to be a challenge for Black students reaching parity regarding degrees conferred along with stagnant and, in some cases, declining representation in the field. In fact, from 2008 to 2016, a downward trend was seen in Black engineering degree attainment, before a small rise emerged in 2018, when 4.2 percent of the engineering degrees conferred were to Black students, compared to 4.1 percent the previous year (Roy, 2019). Furthermore, Blacks are the least well represented racial/ethnic group in engineering, accounting for just 5% of undergraduate enrollment in engineering, 4% of bachelor's degrees awarded in engineering, and 4% of engineering occupations, despite making up 13.4% of the U.S. residential population according to 2017 U.S. Census data (U.S. Census Bureau, 2018). Despite Black women outnumbering Black men in most higher education contexts (e.g., enrollment, graduation), the numbers are typically reversed in engineering. Data from the National Science Board's *2018 Science and Engineering Indicators* reveals that only 24% of Black engineering undergraduates were women in 2013. Similarly, the American Society for Engineering Education's (ASEE) latest report indicates that Black women still comprise of less than 1 percent of engineering bachelor's degree recipients (Roy, 2019).

These data highlight the need for increasing retention amongst Black students overall. Doing so can strengthen engineering and other STEM related disciplines by helping meet U.S. career demands within these fields. That is to say, there is a missed opportunity to attract and retain more Black women to engineering disciplines (Cross et al., 2017, 2020). Increasing and maintaining retention and persistence numbers for Black women in engineering may simultaneously promote greater overall diversity while potentially averting relevant talent shortages within the discipline (Ong et al., 2020). While there is a larger missed opportunity to intentionally include all women within engineering studies and professional spaces, this paper will discuss how this is most pronounced when considering Black female representation.

Therefore, institutions taking a concerted effort towards retaining Black women may prove a clear path forward toward resolving key educational and industry challenges in engineering. To this end, our study explores the role and representation of Black women in engineering by exploring the following two research objectives: (1) How does recent literature explain why few Black women choose engineering pathways and (2) What data exist to help us better understand the current participation of Black women in engineering indicated by undergraduate degree attainment. We use these data to compare the constructs and themes consistent across the literature with the quantitative analysis to provide an overview or framework to consider moving forward. In doing so, the goal of the paper is to update the literature regarding approaches to increase the number of Black women pursuing and successfully completing undergraduate degrees in engineering. Additionally, there is a dearth of literature that focuses on Black women within STEM, and engineering more specifically

(Morton, 2020). We take an intersectional approach in the study and provide a description on best practices to increase Black female representation in engineering. We do so with consideration to the unique and systemic intersectionality of the challenges and barriers imposed upon Black women in STEM – which are compounded by both their race and gender taken together (Jones & Day, 2018; McGee & Bentley, 2017; Winkle-Wagner et al., 2019). In other words, the biases borne out of the intersecting discrimination of being both a woman and Black are what directly contribute to their underrepresentation in STEM (Ong et al., 2020). Therefore, it is important that a nuanced, intentional approach to unpacking structural bias and discrimination is taken; one that may also potentially consider the other robust dimensions of personal identity and experience (e.g., sexual orientation, disability status). Subsequently, results of previous literature call for action in promoting participation of Black women in engineering and the reform of cultural norms that could potentially stifle their participation.

Background

Black Women in Engineering

Within the past decade, there have been positive and negative trends in the data for African American and Black women as it pertains to undergraduate degree attainment. For example, between 2009 and 2015, the number of bachelor's degrees awarded to Black women consistently increased year over year (U.S. Department of Education, 2020). However, when disaggregating the data by discipline, the positive trends were not observed in engineering. According to the American Society for Engineering Education (ASEE), overall, African Americans earned 4.2% of engineering degrees awarded in 2018, down from 4.6% in 2009 (Roy, 2019). Additionally, while Black women were twice as likely to graduate with a bachelor's degree compared to their male counterparts, they were three times less likely to pursue and complete an engineering degree when compared to their male counterparts (Holland et al., 2019; Slaughter et al., 2015). As of 2015, less than 1% of all engineering bachelor's degrees were awarded to African American and Black women (Yoder, 2016).

Empirical research has identified multiple factors associated with the underrepresentation of Black women for undergraduate engineering attainment. For example, the national report, *Ignored Potential: A Collaborative Road Map for Increasing African-American Women in Engineering,* released by the National Society of Black Engineers (NSBE), the Society of Women Engineers (SWE) and the Women in Engineering ProActive Network (WEPAN), in 2017, highlights various areas linked to how Black women have been *ignored* when it comes to diversifying the field of engineering. The factors included the lack of role models and mentors, stereotype threat, tokenism, biculturism, feelings of

isolation or lack of a sense of belonging, and pay inequities, which referred to a challenge for Black women once they enter industry (Fletcher et al., 2017).

Of those factors, mentors, those who assist in an operational capacity, and role models, those that serve in a more aspirational capacity, are both frequently cited as critical for access and exposure to STEM education and careers for minorities, especially women of color (Demetriou & Schmitz-Sciborski, 2011; Settles, 2020; Settles et al., 2006, 2007). A lack of access to mentors and role models within educational settings have played a role in the stagnant and, in some cases, declining number of minority women pursing engineering (James & Singer, 2016; Mondisa & Adams, 2020). When minority women have the opportunity to interact with STEM professionals and identify with them, it is easier to connect that interaction with their own identity and a STEM education or career (Capobianco, 2011; Mondisa, 2020; Yoon et al., 2014).

Furthermore, institutional culture and climate is an additional area linked to Black women's lack of representation in engineering. Although this topic is frequently researched and referenced within the higher education context, research has shown that this barrier begins in pre-college settings. For example, according to the African American Policy Forum and Department of Education, Black girls are 53 times more likely to be expelled from schools in New York and on a national level, six times more likely to be suspended versus their White counterparts (Crenshaw et al., 2015; Smith-Evans et al., 2014). Additionally, Black girls are often steered away from math and science classes and encouraged to take classes that promote and focus more on communication and dialogue rather than traditional STEM courses. Therefore, Black girls are underrepresented in Advanced Placement STEM courses and are one of the lowest performing groups on the ACT and SAT exams (Smith-Evans et al., 2014). Although Black high school girls intend to study STEM in college at a greater rate than their White counterparts, they still are underrepresented within STEM at the higher education level (Espinosa, 2011; Joseph, 2012; Smith-Evans et al., 2014). For young Black women that do matriculate into undergraduate STEM programs, those who persist frequently mention diverse and inclusive settings, with mentors and individuals who look like them, as playing a significant role in their success to degree completion (Perna et al., 2009; Seymour & Hunter, 2019).

When reviewing the list provided within Fletcher et al. (2017), several of these areas have a connection back to educational settings. Specifically, institutional culture and climate plays a significant role on whether or not Black women would be interested and stay interested in engineering degree programs, thus determining either persisting or leaving (Geisinger & Raman, 2013; Seymour & Hunter, 2019). This is not only true for Black women but for most other racial groups and gender identities as well (Ong et al., 2020). The next section will further explore the role of institutional climate and culture with a particular focus on Black women in engineering.

Institutional Culture and Climate

A social justice framework to understanding higher education places the onus on institutions and organizations to reflect deeply on which structural and systemic barriers to academic success should be eliminated in order to best promote student success (Ong et al., 2020). In doing so, this shifts academic narratives away from "fixing" individuals or communities of students to resolve some perceived deficit, which unfortunately only serves to conform diverse students into the dominant culture of their campus (Fletcher et al., 2017). This is of important note because STEM disciplines may perpetuate potentially threatening environments to women and minorities (Casad et al., 2019), with scholars noting the longstanding history of engineering culture in particular as being discouraging and resistant to female participation (Simmons & Lord, 2019). Thus, in striving towards equity for Black female students it is important to focus on structural changes, such as an environment's culture and climate, rather than continue to require aspiring Black female STEM professionals to conform to an academic experience that does not inherently welcome and celebrate their involvement.

In this regard, institutional climate and culture can play a major role in influencing the success of Black students, especially within STEM fields (Hurtado et al., 2012, Yi, 2008). For example, Seymour and Hewitt (1997) found that several factors negatively impact students of color in undergraduate STEM programs at Predominately White Institutions (PWIs). The researchers identified four categories that caused these outcomes: (1) differences in ethnic cultural value and socialization, (2) internalization of stereotypes, (3) ethnic isolation and perceptions of racism, and (4) inadequate programmatic support to address these issues. Additionally, programs that actively recruited ethnic and racial minorities without having proper retention related measures in place, left students feeling "angry and abandoned" (Seymour & Hewitt, 1997, p. 383). Over three-quarters of students that switched to a non-STEM discipline noted lack of support from their programs/institution. Whereas, all students of color that remained in their major described a program vital to their education. Unfortunately, there still appears to be challenges amongst programs ascribed to students of color that continue to negatively impact retention through marginalization: part-time staff, lower-qualified staff, remote campus location, and "segregate[ion] from the institutionalized mainstream" (Leath & Chavous, 2018; Tinto, 1993, p. 185).

It can be theorized that, based on this information, PWIs face unique retention challenges when it comes to undergraduate students of color that differ from institutions that are not predominately or historically white. For example, themes that have emerged from the analysis of Black female student experiences in STEM at PWIs include feelings of alienation (Winkle-Wagner & McCoy, 2018), hypervisibility (Blosser, 2020), and racial stigmatization (Leath &

Chavous, 2018). These challenges, taken together, reveal a lack of belonging for Black undergraduate females that may occur and can erode their sense of STEM identity within their major at PWIs. This imbues further exhaustion and fatigue into the Black female academic experience as these students continue to fight to fit into largely white spaces within their STEM major while encountering a double marginalization rooted in the concerted negative impact of both racism and sexism (Dortch & Patel, 2017; McGee & Bentley, 2017).

Alternatively, Historically Black Colleges and Universities (HBCUs) were founded for the sole purpose of educating Black students during a time in the U.S. when Blacks were legally not allowed to attend PWIs. In the context of institutional culture and climate, HBCUs may offer some relief from the previously mentioned issues as their origin, mission, values, and strategic plans specifically cater to African American students (Allen, 1992; Brown et al., 2005). After integration began in the 1960's, Black students have been able to attend any institution and have more options, especially with increased numbers of scholarships awarded to minority students across all institution types. Even with those changes, HBCUs have continued to enroll a large percentage of Black students and make significant contributions towards ensuring Black student participation, retention, and success in STEM, despite challenges such as limited resources and financial cuts from federal and state agencies (Toldson, 2018). This on-going success is greatly attributed to the culture and climate that exists at HBCUs, especially within STEM disciplines.

Additionally, HBCUs have been shown to have a disproportionate role in preparing Black students in STEM, by graduating 15% of Blacks who obtain STEM undergraduate degrees while only making up 3% of the country's higher education institutions (Gasman & Nguyen, 2016). However, little research examines the role of HBCUs specifically in engineering, and even less consider their contributions in preparing Black female engineers (Morton, 2020). Thus, our paper aims to explore the discrepancy in the graduation of Black women in higher education overall compared to engineering specifically, as well as between different institutional types as detailed below to better fill this critical gap within the literature.

Research Study

The summary of statistical data and literature shared within the previous sections highlight the importance of further understanding why Black women continue to be underrepresented in undergraduate engineering degree attainment especially while women, overall, are seeing consistent increases (Roy, 2019). Additionally, further investigation into the phenomena of Black women graduating with twice as many bachelor's degrees as their male counterparts but three times less likely to pursue and complete an engineering degree when compared to them would add to the body of literature. Given that educational settings are

well documented as key variables in determining Black women's success and persistence in engineering degree programs, our study investigated engineering degree attainment for Black women across post-secondary institutions. Furthermore, this paper discusses the potential mechanisms underlying our findings. That is, we connect how the culturally relevant pedagogical approaches and supportive and intersectional spaces for underrepresented minorities within higher education settings contribute towards the production and success of Black women in the engineering fields. Additionally, connecting graduation rates in engineering to topics of campus climate and institutional support affords us robust explanation moving forward for how we understand these statistics and differences across the institutional types evaluated in our study.

The study is organized around the following three research questions that were designed to address the previously stated objective:

Research Question (RQ) #1: How are Black women currently represented regarding engineering degree attainment within the overall female student population?

Research Question (RQ) #2: How are Black women currently represented regarding engineering degree attainment within the overall Black student population?

Research Question (RQ) #3: What are the current trends within engineering bachelor's degrees and overall attainment amongst Black women from HBCUs and non-HBCUs?

Methodology

Data Collection and Sources

Data from the U.S. Department of Education National Center for Education Statistics' (NCES) Integrated Postsecondary Data System (IPEDS) was used for the current project. The public national dataset includes a comprehensive system of interrelated surveys conducted annually by NCES that comprise of institutional-level data from all college, university, and technical/vocational institutions. The dataset used was accessed through the IPEDS website (i.e., https://nces.ed.gov/ipeds/) and was selected to provide a broader context in understanding Black female student participation in engineering by first evaluating bachelor's degree attainment across ethnicity/race and gender respectively.

Data Analysis

SPSS was used to conduct the statistical analyses necessary to answer the research questions. The investigation of the data set began with the total number of bachelor's degrees reported at postsecondary institutions, followed by a breakdown of bachelor's degrees awarded by race/ethnicity within the

female student population. Then, the overall bachelor's degrees awarded by gender within the Black student population only were compared. All comparisons include the total number (and percentage representation) of STEM and engineering bachelor's degrees awarded as well. The descriptive statistics reported are based on data obtained from the 2015–2019 academic years and were used to help answer the first two research questions.

Furthermore, data regarding bachelor's degree attainment between institutional types and engineering majors were exported from NCES IPEDS in an effort to address the final research question. Data collected therein reflects the total number of engineering bachelor's degrees awarded (first and second majors), disaggregated by gender, race/ethnicity, institutional type (HBCU and non-HBCUs), year (2011–2019), and field of study. For field of study, data from engineering generally, as well as four specified areas of engineering disciplines (i.e., chemical, civil, electrical, and mechanical) were examined to explore differences between groups. Additionally, a series of Chi-Square Goodness of Fit tests were used to determine if degrees awarded at HBCUs were significantly different than expected frequencies based on the overall representation of HBCUs as engineering degree-granting institutions.

Quality

The use of secondary data was critical for the current project, as it enabled access to comprehensive reporting from post-secondary institutions awarding baccalaureate degrees. This robust national dataset was beyond the scope of what the researchers were able to collect on their own. Multiple methodological tactics were used to ensure the quality of the data selected and the subsequent methods used. First, the accuracy of the data obtained by IPEDS was considered. Data released by NCES must meet set quality control procedures and clear standards for IPEDS data collection procedures, as well as steps to release data, are shared publicly (U.S. Department of Education, 2020). As such, identifying a dataset from a dependable source, like NCES, enabled the researchers to carry out the current project. Similarly, the data collection purpose and consistency of the information provided by IPEDS aligned with the intended use of the dataset for the current project (Johnston, 2017). Thus, the secondary data used allowed for investigation of the research questions, while recognizing the limitations the raw data provided (e.g., original survey purpose, interpretation of data provided; E. Smith, 2008).

Results

The total number of bachelor's degrees awarded to undergraduate students has steadily risen by 6.22% through the period 2015–2019 (see Table 1).

Table 1. Total Bachelor's Degree Awarded at Postsecondary Institutions.

Year	Overall Bachelor's	STEM Bachelor's	Engineering Bachelor's
2019	2,012,854	441,598	126,687
2018	1,980,667	422,800	121,953
2017	1,956,114	403,504	115,671
2016	1,920,750	381,165	106,789
2015	1,894,969	362,097	97,852

While the total number of graduates at post-secondary institutions exceeded 2 million in 2019, Black women only comprised 6% of these bachelor's degree recipients. Within engineering specifically, Black female representation was slightly below 1% in 2019.

Degree Attainment Amongst Female Undergraduate Students

RQ #1: How are Black women currently represented regarding engineering degree attainment within the overall female student population?

Black women obtained more bachelor's degrees than women of any ethnicity, except for White and Hispanic/Latinx women (see Table 2). When compared to their White and Hispanic/Latinx counterparts, fewer Black women graduated from 2015–2019. Furthermore, percentage representation decreases overtime across all disciplines for Black and White women, while increasing for Hispanic/Latinx women. Additionally, Black female representation averages 10.7% across all disciplines from 2015–2019. However, the average representation of Black women in engineering during this same period drops by over half to approximately 4.6%. Table 2 further shows the differences of representation in degree completion between these groups.

Degree Attainment Amongst Black Undergraduate Students

RQ #2: How are Black women currently represented regarding engineering degree attainment within the overall Black student population?

We found that within the 2015–2019 period, more Black women graduated than Black men overall from post-secondary institutions (see Table 3). However, men begin to graduate at higher rates when evaluating STEM degrees, and even more so when considering only engineering degrees awarded. These data indicate a reversal in graduation rates by gender for Black students when comparing degree fields.

Of the bachelor's degrees awarded in 2015 to Black students, 64.1% were earned by women and 35.9% were earned by men. However, when focusing on STEM degrees only, the percentage for each gender group reverses. Black

Table 2. Comparison of Bachelor's Degrees Awarded to Women.

	Black Women		Hispanic/Latinx Women		White Women		
Overall	Total (#)	Representation (%)	Total (#)	Representation (%)	Total (#)	Representation (%)	Total (#)
2019	121,268	10.5%	167,465	14.5%	649,858	54.5%	11,55,309
2018	120,257	10.6%	156,607	13.8%	639,642	57.2%	11,35,687
2017	120,722	10.8%	146,903	13.1%	648,139	57.9%	11,20,093
2016	119,070	10.8%	136,127	12.4%	645,670	58.8%	10,99,004
2015	117,307	10.8%	124,869	11.5%	647,034	59.8%	10,82,276
STEM	#	%	#	%	#	%	#
2019	12,267	7.4%	19,995	12.1%	86,498	52.5%	1,64,867
2018	11,519	7.4%	18,013	11.5%	83,746	53.6%	1,56,387
2017	11,070	7.5%	16,264	11.0%	80,594	54.6%	1,47,534
2016	10,335	7.4%	14,414	10.4%	77,916	56.1%	1,38,843
2015	9,853	7.5%	12,965	9.9%	74,441	57.0%	1,30,518
Engineering	#	%	#	%	#	%	#
2019	1,303	4.5%	3,133	10.9%	15,639	54.2%	28,838
2018	1,240	4.6%	2,911	10.7%	14,661	54.0%	27,108
2017	1,092	4.4%	2,609	10.5%	13,668	54.9%	24,913
2016	1,033	4.6%	2,217	9.9%	12,395	55.5%	22,333
2015	951	4.9%	1,895	9.7%	11,106	56.7%	19,603

Table 3. Comparison of Bachelor's Degrees Awarded to Black Women and Men.

	Black Women		Black Men		
Overall	Total (#)	Representation (%)	Total (#)	Representation (%)	Total (#)
2019	121,268	64.0%	68,044	36.0%	1,89,312
2018	120,257	64.0%	67,655	36.0%	1,87,912
2017	120,722	64.1%	67,544	35.9%	1,88,266
2016	119,070	64.1%	66,580	35.9%	1,85,650
2015	117,307	64.1%	65,685	35.9%	1,82,992
STEM	#	%	#	%	#
2019	12,267	45.5%	14,714	54.5%	26,981
2018	11,519	45.3%	13,904	54.7%	25,423
2017	11,070	45.3%	13,372	54.7%	24,442
2016	10,335	44.9%	12,694	55.1%	23,029
2015	9,853	44.0%	12,520	56.0%	22,373
Engineering	#	%	#	%	#
2019	1,303	26.6%	3,592	73.4%	4,895
2018	1,240	26.4%	3,461	73.6%	4,701
2017	1,092	25.1%	3,267	74.9%	4,359
2016	1,033	25.0%	3,100	75.0%	4,133
2015	951	25.0%	2,848	75.0%	3,799

Table 4. Comparison of Bachelor's Degrees Awarded to Hispanic/Latinx Women and Men.

	Hispanic/Latinx Women		Hispanic/ Men		
Overall	Total (#)	Representation (%)	Total (#)	Representation (%)	Total (#)
2019	167,465	61.0%	107,230	39.0%	2,74,695
2018	156,607	60.8%	101,058	39.2%	2,57,665
2017	146,903	60.7%	95,196	39.3%	2,42,099
2016	136,127	60.5%	88,768	39.5%	2,24,895
2015	124,869	60.2%	82,465	39.8%	2,07,334
STEM	#	%	#	%	#
2019	19,995	39.6%	30,491	60.4%	50,486
2018	18,013	39.3%	27,784	60.7%	45,797
2017	16,264	38.8%	25,673	61.2%	41,937
2016	14,414	38.5%	23,042	61.5%	37,456
2015	12,965	38.6%	20,598	61.4%	33,563
Engineering	#	%	#	%	#
2019	3,133	22.8%	10,599	77.2%	13,732
2018	2,911	23.4%	9,513	76.6%	12,424
2017	2,609	22.7%	8,882	77.3%	11,491
2016	2,217	21.8%	7,952	78.2%	10,169
2015	1,895	21.6%	6,889	78.4%	8,784

women see a drop to 44% while Black men increase to 56%. Also, when focusing only on engineering, Black women decrease to only 25% of the degrees awarded for their ethnic group while Black men represent 75% of the group.

These trends are similarly present when comparing degrees awarded between men and women among Hispanic/Latinx (see Table 4) and White (see Table 5) students.

The data in Tables 4 and 5 are presented to further contextualize our findings in Tables 2 and 3. That is, gender disparities in degree attainment in STEM, and engineering specifically, are less pronounced among the Black student population when compared to other racial/ethnic student populations. However, *within* gender comparisons across racial/ethnic groups indicate that Black women overall are considerably less represented than their Hispanic/Latinx female peers.

Degree Attainment and Institutional Type

RQ #3: What are the current trends in engineering bachelor's degrees attainment amongst Black women from HBCUs and non-HBCUs (as well as across engineering majors)?

Figure 1 illustrates how degree attainment differs by engineering major at HBCUs and non-HBCUs. The nine-year average percent representation of

Table 5. Comparison of Bachelor's Degrees Awarded to White Women and Men.

	White Women		White Men		
Overall	Total (#)	Representation (%)	Total (#)	Representation (%)	Total (#)
2019	649,858	56.6%	496,828	43.4%	11,46,686
2018	649,642	56.6%	497,772	43.4%	11,47,414
2017	648,139	56.5%	4,99,799	43.5%	11,47,938
2016	645,670	56.4%	4,99,439	43.6%	11,45,109
2015	647,034	56.2%	504,047	43.8%	11,51,081
STEM	#	%	#	%	#
2019	86,498	35.7%	155,976	64.3%	2,42,474
2018	83,746	35.2%	153,999	64.8%	2,37,745
2017	80,594	34.8%	1,51,045	65.2%	2,31,639
2016	77,916	34.7%	1,46,396	65.3%	2,24,312
2015	74,441	34.2%	1,43,147	65.8%	2,17,588
Engineering	#	%	#	%	#
2019	15,639	21.7%	56,368	78.3%	72,007
2018	14,661	20.8%	55,810	79.2%	70,471
2017	13,668	20.2%	54,069	79.8%	67,737
2016	12,395	19.4%	51,357	80.6%	63,752
2015	11,106	18.5%	48,797	81.5%	59,903

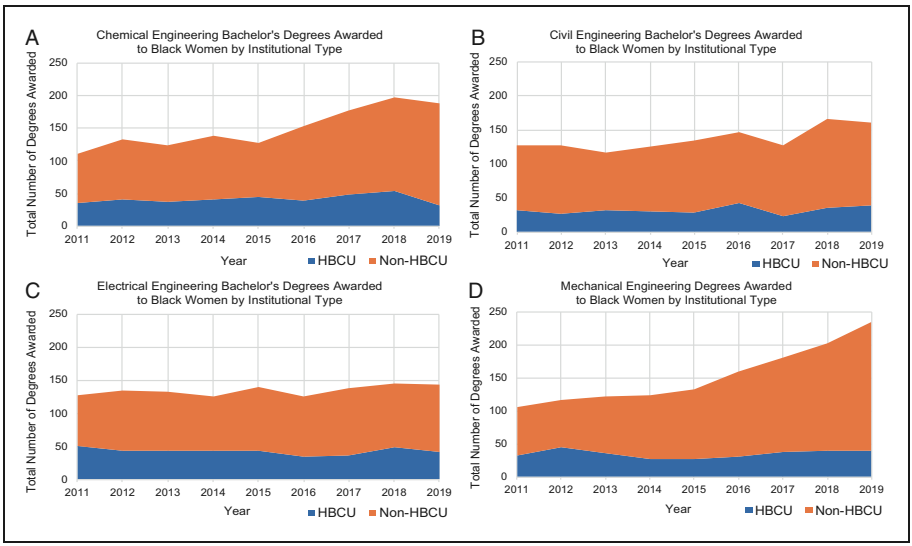

Figure 1. Bachelor's Degrees Awarded to Black Women by Major and Institution Type.

Table 6. Degrees Conferred by Institutional Type.

Year	Institution Type	Total Degrees Awarded (%)	Total Institutions (%)	Percentage Deviation*	Standardized Residual	Chi-Square Statistic
2019	HBCU	240 (18.5%)	30 (4.5%)	+309.3%	+23.68	$\chi2 = (1, 1{,}303) = 548.18$,
	Non-HBCU	1063 (81.5%)	644 (95.5%)	−14.6%	−5.14	$p < 0.0001$
2018	HBCU	246 (19.8%)	29 (4.5%)	+340.9%	+25.46	$\chi2 = (1, 1{,}240) = 675.3$,
	Non-HBCU	994 (80.2%)	614 (95.5%)	−6.1%	−5.53	$p < 0.0001$
2017	HBCU	219 (20.1%)	29 (4.7%)	+326.7%	+23.41	$\chi2 = (1, 1{,}092) = 571.4$,
	Non-HBCU	873 (79.9%)	588 (95.3%)	−16.1%	−5.2	$p < 0.0001$
2016	HBCU	224 (21.7%)	29 (4.8%)	+352.7%	+24.79	$\chi2 = (1, 1{,}032) = 641.74$,
	Non-HBCU	808 (80.3%)	571 (95.2%)	−17.8%	−5.57	$p < 0.0001$
2015	HBCU	222 (23.3%)	27 (4.7%)	+402%	+26.73	$\chi2 = (1, 951) = 745.35$,
	Non-HBCU	729 (76.7%)	554 (95.3%)	−19.6%	−5.9	$p < 0.0001$
2014	HBCU	215 (23.4%)	27 (4.8%)	+386.9%	+25.71	$\chi2 = (1, 920) = 690.19$,
	Non-HBCU	705 (76.6%)	536 (95.2%)	−19.5%	−5.77	$p < 0.0001$
2013	HBCU	213 (25.4%)	27 (4.8%)	+429.6%	+27.24	$\chi2 = (1, 838) = 775.04$,
	Non-HBCU	625 (74.6%)	531 (95.2%)	−21.7%	−6.12	$p < 0.0001$
2012	HBCU	213 (25.2%)	24 (4.5%)	+459.5%	+28.35	$\chi2 = (1, 846) = 836.87$,
	Non-HBCU	633 (74.8%)	505 (95.5%)	−21.7%	−6.15	$p < 0.0001$
2011	HBCU	198 (24.9%)	23 (4.5%)	+452.8%	+27.1	$\chi2 = (1, 796) = 764.16$,
	Non-HBCU	598 (75.13%)	486 (95.5%)	−21.3%	−5.88	$p < 0.0001$

Note. From 2011 to 2019, observed bachelor's degrees conferred to Black female engineering (first) majors at HBCUs were significantly different than expected frequencies.

*Expected frequency was determined using the percentage representation of HBCUs among all engineer degree-granting institutions in total institutions column.

HBCU students among total students awarded degrees is as follows: A) Chemical Engineering: 28.31%, B) Civil Engineering: 23.85%, C) Electrical Engineering: 31.93%, D) Mechanical Engineering: 24.33%.

Less than 5% of HBCUs offer at least one of these specific engineering programs. Nevertheless, Black women from HBCUs comprise a disproportionate amount of the degrees awarded in these disciplines. While most degrees awarded to Black female undergraduate engineering majors come from non-HBCUs, we found that approximately 4.6% of engineering degree granting institutions overall are HBCUs and they graduate an average of 22.5% of Black female undergraduates across all of engineering (see Table 6). Our findings indicate that the engineering degrees awarded to Black women at HBCUs are significantly higher than expected given the overall representation of HBCUs within the engineering discipline.

General Discussion

The data presented showcases the current state of Black women in STEM and engineering specifically. We presented these data as intersectional, across race

and gender, to better characterize how graduations trends of Black women track along these dimensions of identity. Regarding within race comparisons, Black women earn bachelor's degrees at a higher rate than their male counterparts – and do so at rates higher than women in any racial/ethnic group reported above. However, this trend reverses considerably when evaluating strictly engineering degrees conferred. This inverse trend between total, STEM, and especially engineering degrees conferred is present for women across all three racial/ethnic groups. Although, Black women have the lowest graduation rate among all six groups for each kind of bachelor's degree conferred. Additionally, graduation rates reveal an alarming trend when considering only female representation. That is, while White female representation is approximately equal for each degree group, Black female representation drops by over 50% when comparing total degrees conferred to engineering degrees conferred. Furthermore, engineering degrees comprise 2.4% of all bachelor's degrees awarded to White women, but only 1% of the overall degrees awarded to Black women.

Previous reports have demonstrated that Black women have the highest proportion of college enrollment relative to their overall representation than any other group across both race and gender (9.7% of all Black women; U.S. Census Bureau, 2011). However, we have demonstrated that the underrepresentation of Black women in STEM suggests a profound missed opportunity of various leadership to tap into this historic achievement of Black women in higher education. This missed opportunity is problematic for the continued success of U.S. STEM fields. That is, an overall continued lack of access for Black women to train in STEM, and thus the resulting lack of diversity at professional levels, is a leading contribution to the unmet intellectual need for U.S. technology and innovation (Cross et al., 2020; Fletcher et al., 2017).

To be intentional about providing institutional support to Black women in STEM and ensuring their success is to recognize that these students' identities represent a complex, multifaceted layering of life experiences. Therefore, the research discussed within the following sections provides insight towards a new opportunity for course-correcting these current trends in engineering. These practices can also strengthen the STEM disciplines by implementing changes to institutional culture and climate that improve access and support for Black female students.

Creating Inclusive Environments

There is an increasing call to action in addressing representation issues in engineering, and within STEM more broadly. However, there remains a practical, and nevertheless important, question regarding these possible pathways toward improved diversity, equity, and inclusion. An initial first step is to consider how participation efforts that are already in place at an institution or organization are perceived by the very communities to which these efforts were designed to

support and uplift. As Winkle-Wagner and McCoy (2018) note, promoting diversity for diversity's sake can be viewed as potentially inauthentic by students, which can undermine the overall effectiveness of these practices to lead to real causal change. Additionally, preventative care can be taken in avoiding the challenges aspiring Black female engineers face at PWIs. Preventative care can include an institutional commitment, collaboration, and formation of multiyear relationships with K-12 schools and their faculty to improve recruitment (Fletcher et al., 2017; Ong et al., 2020). Not only can these relationships reinforce a direct pathway from early K-12 STEM experiences to advanced scholarship in engineering, but this information exchange between higher education and K-12 faculty and administrators will help establish effective strategies for the encouragement and culturally relevant support of young Black girls (McPherson, 2017). For example, educators can take concerted steps towards developing a sense of cultural identity and well-being for Black girls, which can be achieved by discussing Black female role models in the classroom that can include more modern and diverse portrayals of Black female leadership and accomplishments (Fletcher et al., 2017; Jones & Day, 2018).

Nevertheless, it is important to underscore the fact that best practices should by no means end at recruitment, as increasing diversity and inclusion is but one pre-requisite to allowing Black women to thrive on college campuses. One factor described by Ong et al. (2011) as crucial in fostering a welcoming environment for women of color overall is developing a sense of familial closeness within institutions and departments. However, successfully achieving such an environment at a PWI may require deep reflection around the extent to which the culture and climate present on campus represent a *White space*, as well as to what degree *counterspaces* may need to be created to combat the problematic characteristics of such a space. White space may feature or lead to judgement, hostility, discrimination, and microaggressions borne out of prejudice and stereotypes about minorities, whereas counterspaces are physical or social settings which may help provide relief from these issues (Blosser, 2020; Ong et al., 2018). For example, multicultural offices and diversity programs represent counterspaces on campus that address the needs and concerns of different students. Moreover, while some campus organizations may be centered on race or gender, it is recommended that future centers be intentionally formed around the intersectionality of students, with innovative efforts targeted on the unique experiences of Black female students specifically (Winkle-Wagner et al., 2019). Examples of counterspaces at the professional development level include participation in the National Society of Black Engineers (NSBE) as well as Society of Women Engineers (SWE) (Fletcher et al., 2017). Additionally, engineering professors and administration should celebrate and encourage Black women to participate as members at these organizations' conferences and events in order to achieve further professional and STEM identity development (Ong et al., 2020).

Furthermore, greater representation of Black female faculty in engineering programs can also leave a long-lasting positive impact on Black female retention and persistence, especially as it relates to providing familial closeness and stronger support systems (Ong et al., 2020; Rice, 2011). Additionally, increasing the inclusion and representation of Black female faculty in engineering can help set an empowering and motivating precedent to aspiring Black female engineers about the professional success they can achieve in their field. The presence of Black female faculty in engineering may combat the consequences of systemic racism and sexism through mentorship, as well as from representation on committees, boards, panels, and other professional commitments. However, these contributions often do not go rewarded despite the disproportionality to which these obligations are placed on Black female faculty compared to their demographic counterparts. For engineering departments to leverage these unique contributions towards greater Black female student retention in an equitable and sustainable way, the departmental leadership must recognize this "invisible work" by factoring it into assessments for tenure and other career promotions (Fletcher et al., 2017; Ong et al., 2020). Additionally, by restructuring social space other causal factors can transform institutional culture and climate and help increase the retention of Black women. These include designing more inclusive web pages for engineering departments (Wilson & Meyer, 2009) and investing in best practices for helping engineering faculty guide the development of study groups in and out of the classroom. The latter may enable the informed and respectful collaboration of, and exchange between, diverse student peers, fostering greater inclusion for minority students (Blosser, 2020).

Call to Action for White Allies at PWIs

Engaging White administrators, faculty, and staff on how to actualize their fullest potential as a White ally and co-conspirator will help transform campuses into a more diverse and welcoming academic space (Cross, 2020). A promising first step for White faculty is to shift from a colorblind perspective of social injustice and actively engage in dismantling the racial and gendered hegemony that is ubiquitous throughout STEM. In this context, group-level transformative changes for an institution are contingent on individuals' willingness for personal growth and development towards a more culturally aware and nuanced understanding of why these changes are necessary. As a result, PWIs should make strong commitments toward providing training for all faculty because the success of any given department will rest on that department's ability to move forward together. Otherwise, problematic factors that compromise student success and academic outcomes will be allowed to persist, reinforcing the trends in underrepresentation of Black women presented in this paper. The transition into a well-informed champion of equity and social justice can be potentially challenging, but as Simmons and Lord (2019) note, there are various training

opportunities for White men and women, including the ASEE's Safe Zone Training website. However, replicating these materials, resources, and standards within an individual department can help with a more sustainable and long-term cultural shift necessary in ensuring the positive well-being of students (Ireland et al., 2018).

Furthermore, there are workshops that can help shape White male faculty's understanding of their own privilege into a powerful tool that leads to practical and positive changes in departmental culture at PWIs (Simmons & Lord, 2019). For example, training may help White male faculty recognize how their peers perpetuate toxic behaviors while also developing the confidence, skills, and tact required to act on these harmful situations. In doing so, White colleagues can help mitigate the negative impact of racial and gender discrimination by actively and explicitly rejecting preconceived notions of Black female students as less capable or qualified (Blosser, 2020). This may help reduce stereotype threat brought on by these notions, which can play a significant negative impact on Black women's participation in STEM courses (McKoy et al., 2020). Additionally, training on cultural responsiveness and effective mentoring processes (Ireland et al., 2018) as well as on addressing the influences of potential power dynamics in the classroom (Litzler et al., 2014) can help to improve academic experiences and outcomes. Consistency and accountability will be crucial for institutional leaders as they strive towards implementing best practices (Ong et al., 2020). Periodic campus climate assessments and equity scorecards are also recommended as mechanisms for evaluating and rewarding progress towards inclusivity (Bensimon, 2004; Harris & Bensimon, 2007; Longanecker, 2012).

Cases of Success with Black Women Retention

Finally, our results have indicated the outsized role HBCUs have played in graduating Black women in engineering. Similarly, scholars have noted the importance in looking to HBCUs as an example in retaining Black women, as insights may help PWIs with retention issues stemming from the problematic aspects of their culture and climate (Toldson, 2018; Winkle-Wagner & McCoy, 2018). For example, Toldson (2018) asserts that the key strengths of HBCUs are centered in providing an environment that fosters positive support for STEM students. The author asserts that this is achievable via 1) policies and practices that help develop the professional and scholarship acumen of STEM students from non-traditional backgrounds and 2) the pedagogical approaches rooted in cultural relevance and understanding of HBCU STEM students. Additionally, the development of student relationships with faculty, which in turn promotes a greater sense of departmental and institutional belonging, is also highlighted as a core strength of HBCUs (Esters & Toldson, 2013; Toldson, 2013). These principles and values tied to the HBCU experience are reflective of the

importance and benefits of familial closeness espoused by Ong et al. (2020). Taken together, HBCUs represent institutions that take concerted and intentional steps towards providing a supportive environment of diverse racial identities.

In fact, Strayhorn (2016) has demonstrated the unique ability of HBCUs to strengthen students' Black identity. The role of identity in navigating STEM experiences is not trivial and can factor significantly in how Black female STEM experiences unfold. For example, Morton and Parsons (2018) demonstrated how conceptualizing one's identity as a "Black woman" was used in positive and protective ways by Black female students to engage in, and find empowerment within, STEM. Moreover, Winkle-Wagner et al. (2019) noted Black female college students' ability to negotiate identity pressures and discrimination in ways that allow for the expression of an authentic self, borne out of self-definition and self-valuing they practiced in academic spaces, as they completed their degrees. However, as previously mentioned, the representation issues concerning Black women in engineering faculty positions is ubiquitous, with the deleterious implications of underrepresentation noted by Black female engineering majors at HBCUs as well (Morton, 2020). This finding further underscores the need to explore the complex relationship of race and gender at all institutions, but also highlights the opportunity to investigate the still understudied relationship these qualifiers have with the less explored STEM identity of Black women (Fletcher et al., 2017; McKoy et al., 2020; K. C. Smith et al., 2019).

While understanding where and how these intersecting identities unite may reflect a critical gap in the literature, embracing and balancing such complexities in route to ensuring high-level academic accomplishment is an everyday success of the number one HBCU in the nation, Spelman College. Spelman College, an all female institution, is a unique case of excellence in institutional culture and climate that may serve as the quintessential reference point for how all institutions may be able to achieve academic parity and equity for Black women in STEM (Perna et al., 2009; Winfield et al., 2019). The success of Spelman College is reflected in their asset-based approaches that define their culture of excellence (Winkle-Wagner et al., 2020) as well as the "superhero" level energy, commitment, and leadership their STEM faculty bring to the classroom experiences (Johnson et al., 2020). These strengths serve to champion their students and thus help prepare the next generation of Black female professionals as well as remind us that amidst all the societal challenges brought on by systemic racial and gender barriers lies an enduring opportunity, one that the rest of higher education can no longer afford to miss.

The pathways to resolution highlighted in this paper only address a fraction of the bias and discrimination that has unfortunately stymied Black female participation in the STEM fields. However, this review adds to the academic literature that exposes power structures in science that have so often aimed to prevent aspiring Black female students from actualizing their own power. The

challenges presented here highlight the still pressing need to explore, describe, and investigate the interplay between identity and academic outcomes. To this end, intentional reform may be achieved that targets the necessary changes required to improve institutional culture and climate. This paper contributes to further insight within STEM, chiefly engineering, so that such spaces for the expression of excellence can become commonplace at all institutions.

Conclusion

The findings shared within this study highlight the need for the U.S. to continue supporting the broadening of participation efforts to include women, especially Black women, in engineering as well as engineering education efforts at HBCUs. According to the on-going gaps shared by the National Academies *Graduate STEM Education for the 21stCentury* (2018) report, it is imperative that HBCUs role in the production of Black women in science and engineering degree attainment is recognized for state, federal, private and public sector funding. National data sets continually document the role HBCUs play in the production of Black women in engineering at all degree levels. When considering institutional type in our own research, HBCUs were found to graduate 22.5% of all Black female engineering students at the undergraduate level, on average, from 2011 to 2019. This is of important note, given that HBCUs themselves only comprise approximately 4.5% of engineering degree granting institutions. We have also demonstrated that the disproportionate contribution of HBCUs in graduating Black women is consistent across four major engineering disciplines (i.e., chemical, civil, electrical, and mechanical). If current funding levels are not maintained at HBCUs, the U.S. is at risk of not maintaining the number of Black women receiving these degrees, potentially causing underrepresentation in engineering to worsen. Additionally, not providing additional support and funding to the ABET accredited HBCUs who are producing these students is providing a disservice to the overarching goals of graduating more underrepresented students in engineering. To increase black women's persistence to graduation in this domain, it is important to consider these missed opportunities to promote their participation in engineering.

Limitations and Future Work

Data used for this study was limited to reports from NCES IPEDS. While the secondary data used was limited to the scope of the current paper, additional data will be needed to investigate the topics discussed in this paper more thoroughly. That is, to strategically contextualize the experiences and address the barriers to engineering degree completion for Black women, future work should include using an intersectionality framework, combined with a sequential mixed-methods approach (K. C. Smith et al., 2019). Specifically, qualitative

(e.g., interviews, focus groups) and quantitative (e.g., survey) research techniques will be used to explore this framework at post-secondary institutions. Moreover, we must consider this research within context and understand which modes of exploration are best suited to address how multiple social and personal identities shape the factors contributing to degree completion for Black women, including, but not limited to, such dimensions as gender identity, sexual orientation, nationality (i.e., international students), and religious affiliation.

The current research focuses strictly on undergraduate graduation rates; however, future work may focus more prominently on the full journey encompassing the experiences of Black girls and women, starting with pre-collegiate K-12 statistics and spanning to data concerning graduate matriculation and experiences as well as entry into post-graduation professional occupations. However, research at these varying educational and professional levels that tie together the incredible, yet still challenging, journey of Black girls and women in STEM remains understudied. As previously highlighted, taking an intersectional approach towards eliminating these barriers experienced from kindergarten to professional careers will give Black girls and women a long overdue space to embrace, enjoy, and express ownership of their commitment to STEM disciplines (Ireland et al., 2018; Jones & Day, 2018; K. C. Smith et al., 2019).

Implications and Contributions to the Field

According to researchers at the U.S. Census Bureau, within the next 20 years, over 35% of the nations' population will be Black and Hispanic (Vespa et al., 2018). This type of demographic data plays a major role in the focus for organizations such as the National Science Foundation and programs such as Broadening Participation. Two particular takeaways, if further investigating and invested in, could play a major role in broadening participation efforts to diversify engineering. One consists of authentically increasing efforts to get more Black women interested in engineering especially given the rate at which they pursue and successfully complete undergraduate degrees. Secondly, according to the National Academies of Science, Engineering and Medicine (NASEM, 2019) report, HBCUs, along with other minority serving institutions (MSIs), have not been adequately utilized and efforts to increase future research at and with these institutions should be prioritized. For example, between 2002 and 2011, HBCUs saw year-over-year increases for the number of Blacks who went on to successfully complete doctorate degrees in science and engineering including all top 10 institutions being HBCUs. Additionally, 5 of the top 10 baccalaureate-origin institutions for engineering were HBCUs, including the top three producers: North Carolina A&T University, Florida A&M University and Morgan State University. This is underscored by the fact only 15 HBCUs have ABET accreditation of the total 631 ABET institutions in the U.S. as of 2016. If the nation's

top investors want to see change, then Black women should be a top priority as well as HBCUs and their role in graduating this group in engineering.

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Kelly J. Cross an Assistant Professor of Chemical Engineering at University of Nevada Reno, is a culturally responsive practitioner, researcher, and educational leader. She earned her Bachelors of Science in Chemical Engineering from Purdue University in 2007 and Masters of Science in Materials Science and Engineering from the University of Cincinnati in 2011. Dr. Cross completed the doctoral program in the Engineering Education department at Virginia Tech in 2015 and worked as a post-doctoral researcher with the Illinois Foundry for Innovation in Engineering Education at the University of Illinois at Urbana-Champaign (UIUC). Dr. Cross worked to redesign the curriculum in Bioengineering department through the NSF program Revolutionizing Engineering Departments (RED) at UIUC. She is a member of the ASEE Leadership Virtual Community of Practice (LVCP) that organizes and facilitates Safe Zone Training workshops. Dr. Cross has conducted online and in-person workshops on managing personal bias in STEM, managing privilege and power in the classroom, and promoting inclusion in higher education. Her research interests include inclusive excellence in STEM, identity construction, intersectionality, teamwork and communication skills, and educational assessment. Her teaching philosophy focuses on student centered approaches such as problem-based learning and culturally relevant pedagogy. Dr. Cross' complimentary professional activities promote inclusive excellence through collaboration.