Blacks, historical disadvantage, and engineering education: Lessons learned from the United States of America

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This paper examines participation in engineering education of an historically disadvantaged group in the United States (US)—Blacks. Currently, the US federal government designates Blacks as underrepresented in engineering education because the percentage that they comprise of the US population, 14%, is well above their percentage among engineering degrees awarded at all levels. For example in 2010, Blacks earned 4.8 % of engineering baccalaureate degrees, 5.1% engineering master's degrees, and 4.3% of engineering doctorates awarded to US citizens and permanent residents. This underrepresentation persists despite considerable governmental and private-sector efforts to address Blacks' low rates of participation in engineering education.

To advance the engineering education knowledge base, this paper examines those policies and programs that show considerable promise for broadening the participation of US Blacks in engineering education. Using a mixed methods approach, this paper analyzes both quantitative and qualitative data. Quantitative data are derived from a variety of sources including the American Society of Engineering Education (ASEE), US Department of Education, National Center for Education Statistics (NCES), National Center for Science and Engineering Statistics Studies (NCSESS), US National Science Foundation (NSF), and the US National Science Board (NSB). Qualitative data are derived from scholarly literature, blue-ribbon panel reports, and other papers and reports published over the past decade. Due to the gendered nature of engineering, the analysis is disaggregated by sex (when possible). Organized around critical transition stages in the engineering education pathway, secondary-to-college, and college-to-graduate school, the paper concludes with a discussion of policies, programs, practices and institutions that appear to be most effective in increasing enrollment and persistence to degree among US Blacks.

Introduction

Over the last two decades there has been a plethora of private and public sector "blue ribbon" reports warning of the precarious state of the US STEM (science, technology, engineering, mathematics) education and future workforce. One such report *Rising Above the Gathering Storm* (2007) asserted that "This nation must prepare with great urgency to preserve its strategic and economic security..." (p. 4), and issued a stern warning concerning:

> Complacency about the threat to US pre-eminence in science and technology (p. 12). Market forces are already at work moving jobs to other countries often better educated, highly motivated workforces and friendlier tax policies. For the first time, children could face poorer prospects than their parents and grandparents (p. 13).

Many observers thought that the combination of the bi-partisan government and the private sector dire warnings would lead the charge to systemic and transformative change in US STEM education preparing the next generation of STEM professionals. Despite receiving considerable

public attention and significantly influencing the passage of the *America Competes ACT*, the report has yet to have the intended immediate impact. Consequently, the authors issued another stern warning of an impending storm if policymakers fail to act in a more judicious manner. The warning was in the form of a report entitled: *Rising Above the Gathering Storm, Revisited: Rapidly Approach*ing *a Category 5* (2010), which concluded that advances in STEM will be the catalyst for innovation that drives both the future economy and job creation. Page (2007) found evidence that innovative ideas are most likely to emerge through the interaction of people with different perspectives. Yet, despite agreement on the need for fundamental changes among leaders at all levels of government, industry, and education, far too many calls to action went unheeded.

This paper is organized into four sections. The first section provides a brief review of the relevant literature; next, there is a discussion of the mixed-methods approach used to gather qualitative and quantitative data; findings are presented in the third section and discussed in the fourth section; and the last section presents conclusions.

Literature Review

Many reports, including the initial Storm report, did not pay attention to the rapidly changing demographics of the US population, especially among those most underrepresented in STEM education and professions. Building on the *Storm* report, another National Academies' report, *Expanding Underrepresented Minority Participation* (2011) cautioned that if the US is to strengthen its STEM education and future workforce, racial and ethnic minority groups currently underrepresented will need to be a significant part of talent development (See, National Research Council, 2007; Maton & Hrabowski, 2004; National Science Foundation, 2011; and Pearson, 2005). Lord et al. (2009) assert that

> The low participation of women and minorities in engineering is well known and has attracted attention not only because of the needs of a modern, technology-driven economy, but also because it calls into question issues of social justice, gender equity, and diversification of the profession… (p. 167).

Leggon and Malcom (1994) argue that increasing the participation in engineering of underrepresented groups not only addresses issues of social justice but also enhances the quality of the engineering enterprise. Similarly, Zarske et al. (2012) argue that for the US to just maintain its technological capability, the engineering profession will have to draw much more heavily on underrepresented groups.

Many studies tend to frame the issues of underrepresentation in engineering in terms of race/ethnicity OR gender. Few studies focus on underrepresented racial/ethnic minority students, fewer disaggregate by race and ethnicity—e.g., Blacks and Hispanics, and fewer still disaggregate race/ethnicity by gender. Such disaggregation is crucial because multiple layers of difference are not mutually exclusive. The results of the confluence of race, ethnicity and gender are greater than the sum of the statuses. Gender is inextricably intertwined with race and ethnicity: race/ethnicity impacts how one experiences being male or female, and gender impacts how one experiences belonging to a particular race and/or ethnic group (Leggon 2006; Hrabowski & Pearson, 1993). According to Lord et al. (2009), not disaggregating data on women by race in analyses of persistence in engineering produces findings that are erroneous, over generalized, and counterproductive. Disaggregating data by race and gender reveal that the "problem" for women is recruitment rather than retention. To enhance both recruitment and retention across and within racial, ethnic, and gender groups, it is important to use the research literature on engineering education to inform practice.

Recruitment

Examining trends in engineering degree production is a starting point. What accounts for differences among groups in degree production? Is it a matter of recruitment or retention—or both? Answers to these questions vary by group in terms of race, within race by gender, and within gender by race. Findings from research conducted by Malcom-Piqueux and Malcom (2013) attributed the lack of diversity in the engineering workforce to such pre-college factors as lack of access to high quality teaching and science infrastructure, and to career information and counselling. These gaps in access contribute to inadequate levels of academic preparation and lack of awareness of engineering as a profession (See also Pearson and Miller, 2012). Similarly, Fletcher and Tienda (2010) found that differences in the quality of high schools do contribute to the racial differences in college achievement. Therefore, narrowing the achievement gaps across high schools highly segregated by race and ethnicity will substantially reduce the racial gap in college performance. By contrast, Killewald and Xie (2013) found no evidence that US science education has deteriorated; however, they failed to disaggregate by race/gender. There is substantial evidence of racial and ethnic disparities in the quality of K-12 science and mathematics education in the US, especially in urban areas (See, for example National Science Board, 2012; Malcom-Piqueux & Malcom, 2013; and Anderson, 2013).

Moore and Richards (2012) research found that the US has been unable to consistently recruit Blacks to engineering. Research on Black engineering students at Howard University (an historically Black or disadvantaged university) found two factors that motivated students to pursue engineering—enjoyment of science and engineering, and financial concerns (Fleming et al. 2005).

Persistence

Many of the factors associated with persistence in engineering revealed by studies of other populations also apply to racial and ethnic minority students, such as student dissatisfaction with first year academic advising (see also, Ohland et al., 2008). Although Black and white students are equally likely to major in STEM fields of study and to persist for three years, only 62.5% of Blacks graduate within six years compared to 86.7% for whites and 94.8% for Asians.

The engineering community has become increasingly concerned about the structure, content, and delivery of engineering due to data on low rates of engineering student retention. Despite the fact that students are rigorously pre-screened before being accepted into an engineering program, only 56% of engineering undergraduates are retained (Fontenberry et al., 2007. See also Case & Jawitz, 2003). Cheville and Bunding (2011) attribute low retention rates in engineering to students' perceptions of disconnects between course content and the applications of that content, and suggest using a two-pronged approach that addresses what and how students learn, and how faculty can support the learning environment.

Shehab et al. (2007) point out that despite experiencing some of the same struggles and using some of the same coping strategies as majority students, racial and ethnic minority students tend to experience these struggles more deeply. Racial and ethnic minority students cited faculty as a major cause of academic problems, and reported that some faculty did not know how to teach, other faculty were poor teachers, and still other faculty seemed to delight in making courses difficult (Shehab et al., 2007:3). Although poor teaching negatively impacts all students, studies suggest that it has a greater impact on students from racial and ethnic groups that are underrepresented in engineering. Racial and ethnic minority students tend to face additional struggles that majority students tend not to face, such as 'isolation.' In Shehab's study, Black engineering students defined isolation as not having a colleague with similar cultural

experiences who understands them.

Methods

The primary source of data for this analysis was a multiyear, annual survey of engineering colleges and universities administered by the American Society of Engineering Education (ASEE). ASEE annually collects data from nearly 350 engineering colleges and schools across North America and publishes these data on their web site.[1] Data for this study were downloaded from the ASEE Profiles site during June 2012. ASEE data collection generally lags by one year, thus data for this study represent the period ending June 30, 2011.

Data for this analysis include degrees awarded and fall enrollments from 2005 to 2011. Degrees awarded are reported for the entire year (for example, Summer, Fall and Spring semesters), while enrollments are reported for full-time headcounts the Fall term. Each measure (degrees awarded or enrollments) are disaggregated by ethnicity and gender. Data are accepted at the level of disaggregation provided by the survey participant. For example, schools with small numbers of degrees awarded might not report disaggregate ethnicity data, but rather only submit their counts as a single aggregate.

ASEE enrollment and degrees awarded data were merged with basic institutional data available from the Integrated Postsecondary Education Data System (IPEDS).[2] Attributes merged with the ASEE data include Carnegie classification of the institution and an HBCU (Historically Black Colleges and Universities) indicator available from the institutional data file.

Figures and tables were created using data obtained. Data were disaggregated by gender and race/ethnicity across four institutional types: HBCU's, Non-HBCUs, RUs (Research Universities) and MCUs (Master's Colleges and Universities). Data were also categorized into four categories for analysis: 1.) Trends in undergraduate engineering enrollment by race and gender 2.) Trends in bachelor degrees awarded by race and gender. 3.) Trends in institutional type by race and gender. 4.) Trends in post-baccalaureate degrees awarded. The aim is to provide a multi-dimensional landscape of Black engineering education from 2005 to present data availability.

Findings

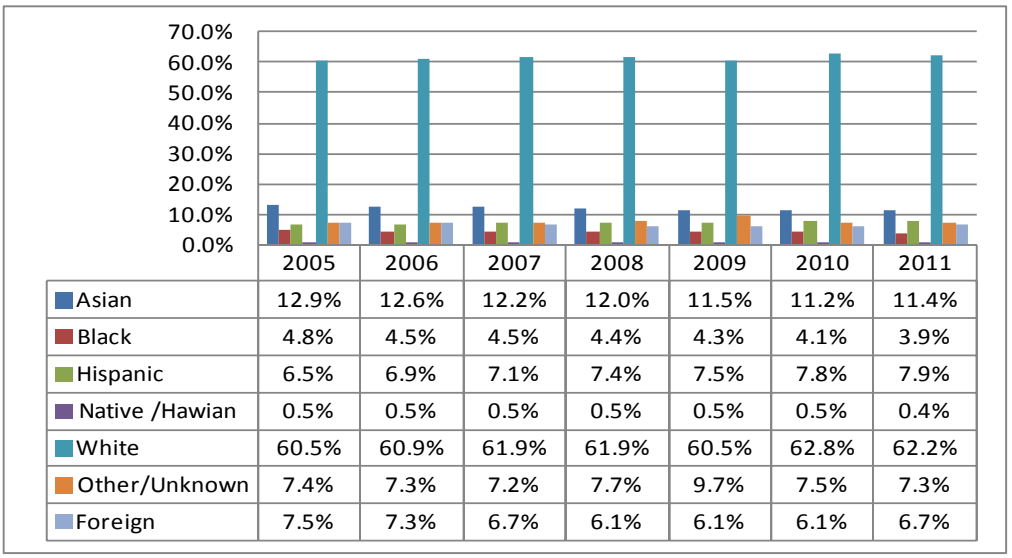
Blacks continue to be underrepresented within engineering education at all levels of higher education in the US. A growing college-age population within the US, led to a noticeable increase in engineering enrollment in 2010 (Gibbons, 2010; National Science Board, 2012) and a yearly gain of 4.8 percent by Fall of 2011 (Yoder, 2011). Despite projections for a growing minority population over the next 20 or more years and a push for initiatives to increase minority talent within engineering, recent data demonstrate that Blacks remain significantly underrepresented in engineering and are experiencing a decline in percentages of both undergraduate engineering enrolment and degrees awarded (National Research Council, 2007; National Science Foundation, 2007; Chubin, May & Babco, 2005). Based on the changing population demographics, barriers to the recruitment, retention, and development of Blacks in higher education needs to be identified and addressed, in order for the US to sustain a leading talent pool in the global market of innovation and knowledge production. A brief review of

[1] ASEE College Profiles, American Society of Engineering Education, http://profiles.asee.org/, data downloaded June, 2012.
[2] US Department of Education. Integrated Postsecondary Education Data System (IPEDS), Institute of Education Sciences, National Center for Education Statistics. http://nces.ed.gov/ipeds/datacenter/Default.aspx. 2011 institutional data file downloaded in March 2013.

engineering enrollment and degree data reveal opportunities to develop Blacks in engineering education. Further, scholarly literature and institutional reports suggest that targeted, rather than general gender or racial based initiatives are required to broaden the participation of Blacks in engineering.

Enrollment

In 2011 there were a total of 512, 957 students enrolled in engineering education at the baccalaureate level (see Appendix A: Table 1.11). Women represented 18% of the enrolled. Asians and Hispanics were 11% of the enrolled and Blacks were merely 5% (Figure 1.1).



	2005	2006	2007	2008	2009	2010	2011
Asian	12.9%	12.6%	12.2%	12.0%	11.5%	11.2%	11.4%
Black	4.8%	4.5%	4.5%	4.4%	4.3%	4.1%	3.9%
Hispanic	6.5%	6.9%	7.1%	7.4%	7.5%	7.8%	7.9%
Native /Hawian	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.4%
White	60.5%	60.9%	61.9%	61.9%	60.5%	62.8%	62.2%
Other/Unknown	7.4%	7.3%	7.2%	7.7%	9.7%	7.5%	7.3%
Foreign	7.5%	7.3%	6.7%	6.1%	6.1%	6.1%	6.7%

Figure 1.1: Engineering Enrollment by Race/Ethnicity, 2005-2011

Blacks are significantly under represented, especially when compared to other racial/ethnic groups. Based on population density, Asians, who comprise 5% of the US population, continue to be overrepresented in terms of engineering enrollment (US Census Bureau, 2012). Hispanics are significantly underrepresented and at the same time they have garnered a greater percentage of engineering enrollments than Blacks. Blacks' engineering enrollment at the baccalaureate level has declined from 4.8% in 2005, to 3.9% in 2011 (Figure 1.1).

Additional complexities materialize when data are disaggregated by gender, as well as race/ethnicity. Barriers and obstacles continue to create gender disparities in engineering education. Women are only 18.4% of students enrolled in engineering education at the baccalaureate level. Black women are 1.2% of total students enrolled, less than White, Asian, and Hispanic women (Table 1.1). Interestingly, however, Black women are 6.7% of the total women enrolled and Black men are 4.9% of the total men enrolled in engineering at the baccalaureate level (Figure 2.1). Whereas White women are 53.5% of the total women enrolled and White men are 60% of the total men enrolled in engineering at the baccalaureate level. Asian and Hispanic women are around 12%, while Asian and Hispanic men are around 10% of enrollment.

Table 1.1: Female Percent of Total Enrollment by Race/Ethnicity, 2011

Race/Ethnicity	Percent	Number
Asian	2.3%	11836
Black	1.2%	6315
Hispanic	2.2%	11392
Native Am. /Hawaiian	0.1%	760
White	9.9%	50714
Other/Unknown	1.8%	6842

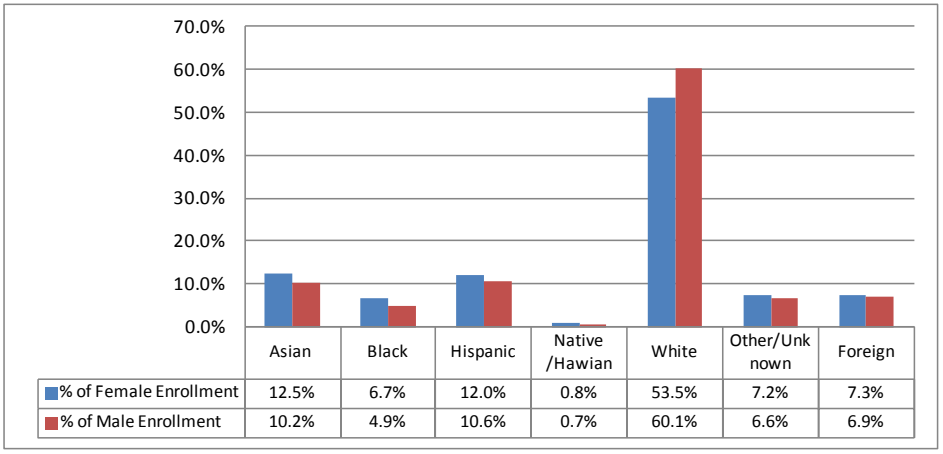


Figure 2.1: Percent Baccalaureate Engineering Enrollment by Race/Ethnicity and Sex, 2011

Ironically, Black women's representation in engineering education reflects unusually high levels of enrollment in comparison to their male counterparts. Black women are 23.5% of Blacks' enrolled in engineering at the baccalaureate levels, higher than any other female representation within a given ethnic group (Figure 3.1). Yet, enrollment trends of Black women have followed those of Black men over the past 6 years, steadily declining (see Figure 4.1)

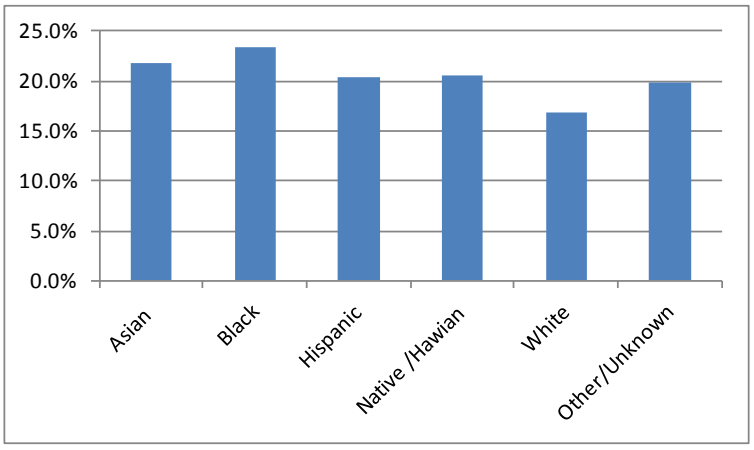


Figure 3.1: Percent Female Enrollment within Racial Demographic, 2011

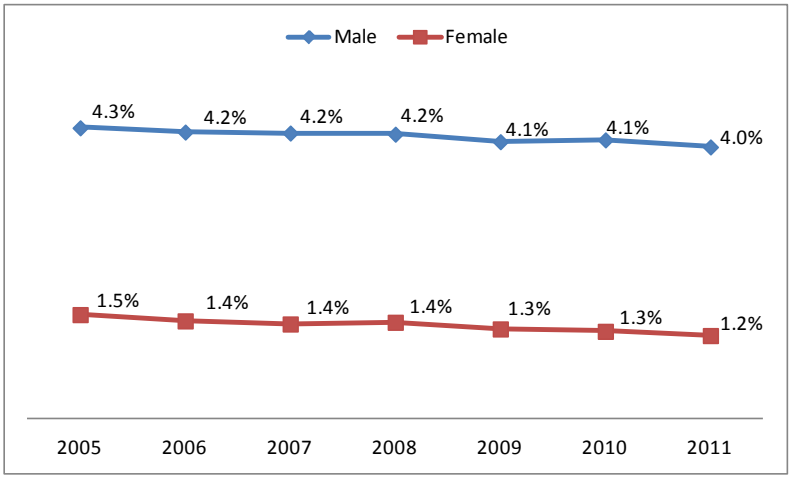


Figure 4.1: Blacks Baccalaureate Engineering Enrollment by Sex, 2005- 2011

Studies suggest that gender continues to plague female enrollment in engineering education at the baccalaurette levels (Lord et al., 2009). On the one hand, enrollment still presents challenges for women, and Black women specifically, within engineering education, generating new opportunties for recruitment. On the other hand, the dynamics between Black males' and Black females' engineering enrollment suggest that Black females' enrollment trends are more closely aligned to those of their male counterparts.

Degrees

Degree data reveal that Blacks are significantly underrepresented among degree recipients in engineering at the baccalaureate, master's and doctoral levels. In 2011, there were 83,494 bachelor degrees awarded in engineering in the US (See Appendix A, Table 2.12). Women represented 18% of bachelor degrees awarded. Asians, Hispanics, and Blacks were 11%, 8%, and 4% respectively (Figure 5.1).

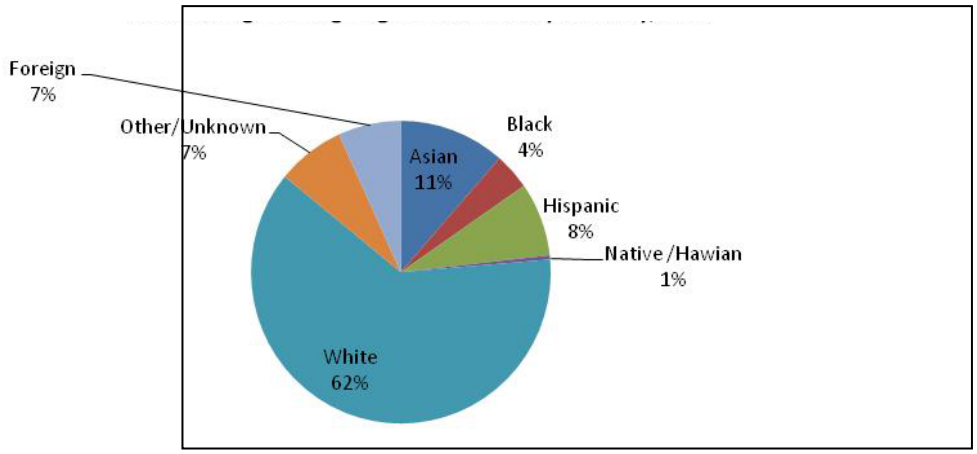


Figure 5.1: Percent Bachelor Engineering Degrees Awarded by Ethnicity, 2011

Trends are compounded when disaggregated by gender. The percentage of total bachelor degrees awarded in engineering to Blacks dropped, from 3.2 % for Black males and 1.6 % for Black females in 2005, to 2.9 % for Black males and 1.0 % for Black females, in 2011 (Figure 6.1).

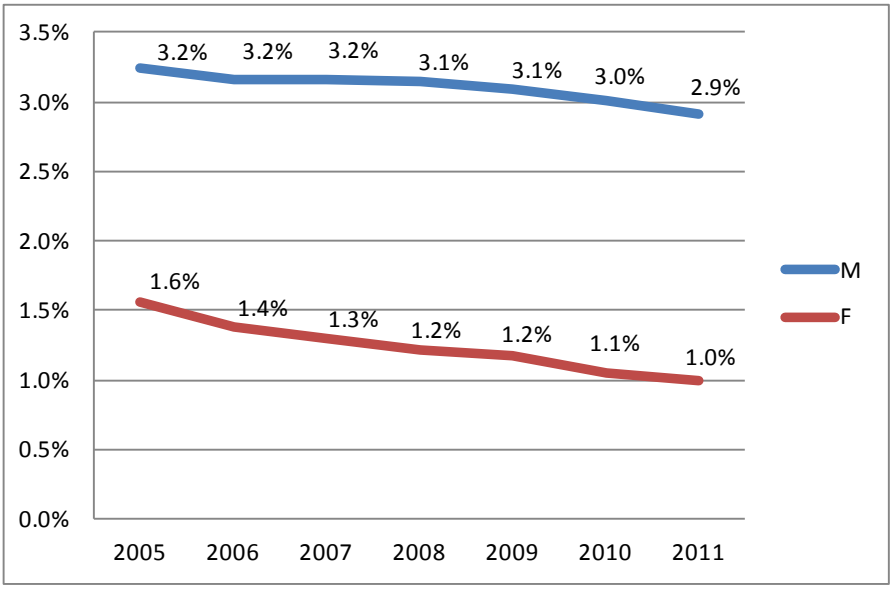


Figure 6.1: Bachelor Degrees Awarded to Blacks by Sex, 2005-2011

Conversely, compared to their male counterparts, Black females comprise a larger percentage of females in engineering than all other racial/ethnic groups (see Figure 7.1). Yet, Black females received only 5.4% of the 18% of bachelor degrees awarded to women in engineering (see Figure 7.2).

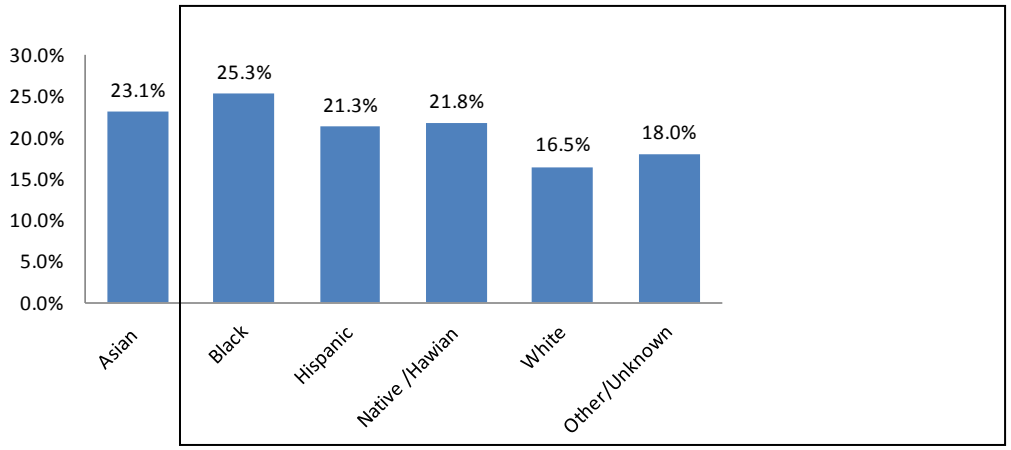


Figure 7.1: Percent Female Representation within Racial Demographic by Ethnicity, 2011

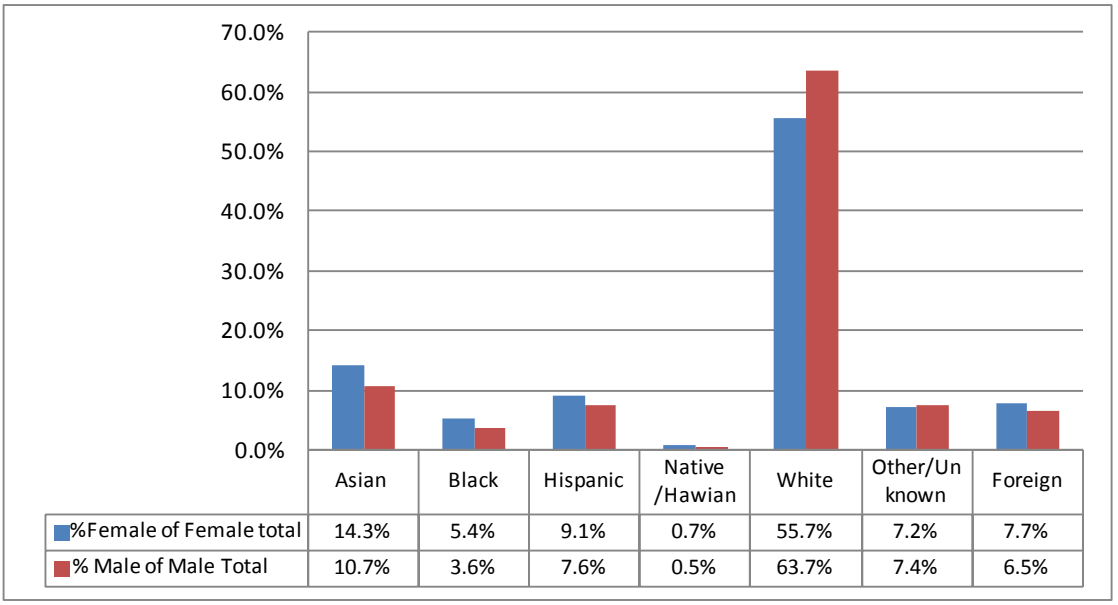


Figure 7.2: Gender Representation of Bachelor Engineering Degrees by Ethnicity, 2011

Black women receive less than 1% of engineering degrees awarded at all levels of engineering education (Table 2.1). While women of any racial/ethnic group recieve less than 11% of engineering degree awards, Black women recieve fewer bachelor (825) and master's degrees (365) in 2011 than all other women, except Native Americans/Hawaiians. At the doctoral level, Black women received 59 of the 9702 doctoral degrees awarded.

Table 2.1: Female Percentage of Engineering Degrees by Degree level and Race/Ethnicity, 2011

	Bachelor		Master's		Doctoral	
Race/Ethnicity	Percent	Number	Percent	Number	Percent	Number
Asian	2.6%	2194	2.4%	1114	2.1%	202
Black	1.0%	825	0.8%	365	0.6%	59
Hispanic	1.7%	1408	0.9%	424	0.5%	50
Native /Hawian	0.1%	104	0.1%	24	0.1%	5
White	10.3%	8573	6.0%	2862	5.8%	559
Other/Unknown	1.3	1101	1.7%	808	1.6%	154
Foreign	1.4	1185	10.8%	5124	11.2%	1090

Black women continue to have the highest percentage of female representation among degree recipients at both the master's and doctoral level, when compared to their male counterparts. At the doctoral level, the percentage of female representation, within ethnic groups, increase, except for Native Americans/ Native Hawaiians (See Figure 8.). Black women acquire approximately 39% of the 153 doctoral degrees awarded to Blacks in engineering at the doctoral level (Figure 8.1).

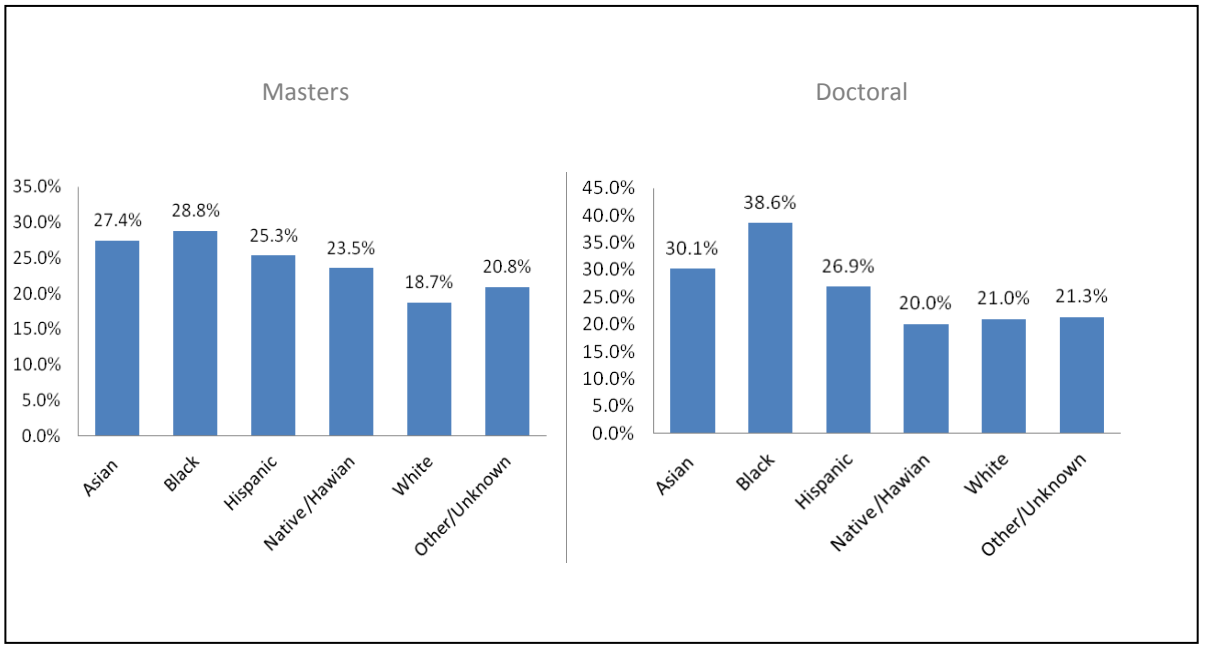
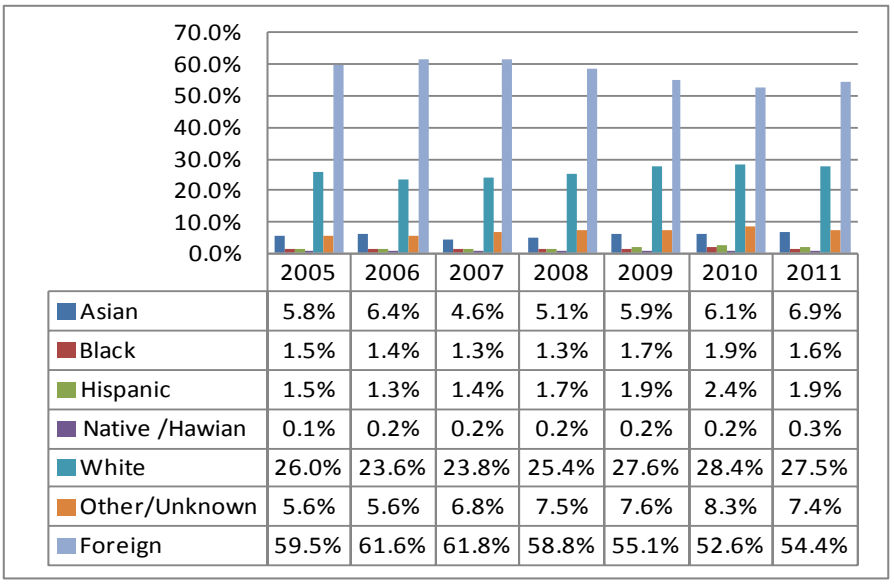


Figure 8.1: Percent Female degrees Awarded within Racial/Ethnic Demographic by degree type, 2011

The shift in female representation at the doctoral level may reflect disparities in employment opportunities between men and women with a master's degree in engineering. Men may be afforded a wider spectrum of competitive employment in corporate America, rather than academia, and thus choose to opt-out of pursuing doctoral degrees. Future studies that explore variances in race and gender, rather than race or gender, are required before more substantial conclusions can be drawn.

Additionally, at the doctoral level it appears that not only race and gender are significant factors in engineering education but residency also plays a major role in US engineering education. While Blacks have consistently remained below 2% of doctoral engineering degree recipients, foreign nationals have obtained greater than 50% of doctoral engineering degrees (see Figure 9.1). When disaggregated by gender, data show that the percentages of doctoral degrees awarded to Black men and Black women have not fluctuated more than 0.3% since 2005 (see Figure 10.1).



	2005	2006	2007	2008	2009	2010	2011
Asian	5.8%	6.4%	4.6%	5.1%	5.9%	6.1%	6.9%
Black	1.5%	1.4%	1.3%	1.3%	1.7%	1.9%	1.6%
Hispanic	1.5%	1.3%	1.4%	1.7%	1.9%	2.4%	1.9%
Native /Hawian	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%
White	26.0%	23.6%	23.8%	25.4%	27.6%	28.4%	27.5%
Other/Unknown	5.6%	5.6%	6.8%	7.5%	7.6%	8.3%	7.4%
Foreign	59.5%	61.6%	61.8%	58.8%	55.1%	52.6%	54.4%

Figure 9.1 Doctoral Engineering Degrees by Race/Ethnicity, 2005-2011

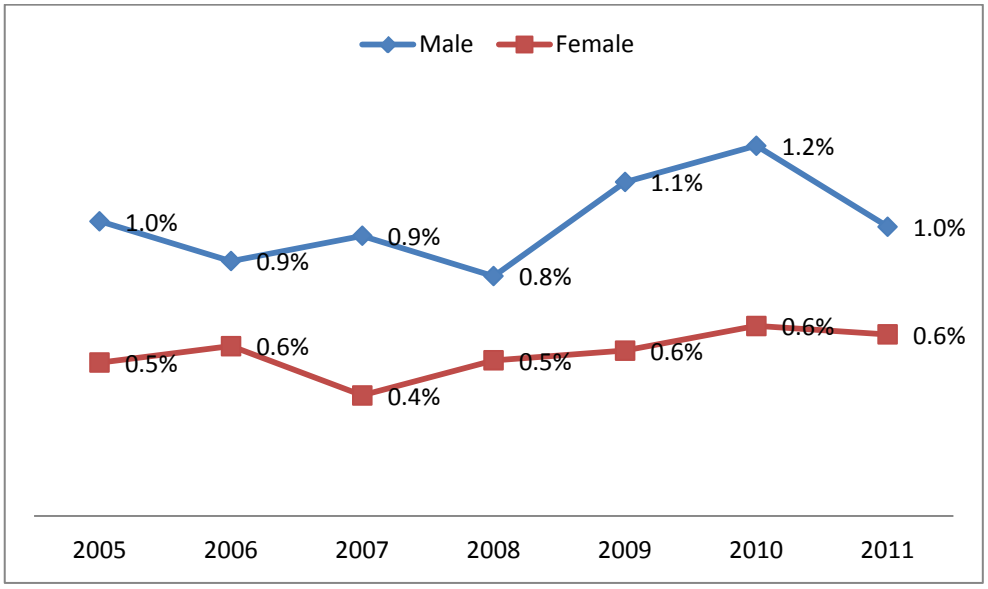


Figure 10.1 Doctoral Engineering Degrees Awarded to Blacks by Sex, 2005-2011

Institutions

The types of institutions awarding engineering degrees are changing as well as initiatives towards diversity recruitment and retention. Georgia Institute of Technology (Georgia Tech) has awarded the most bachelor degrees in engineering to minorities (*Diverse Issues in Higher Education*, 2012). They have also awarded the most bachelor degrees to women in engineering (Yoder, 2011). Yet, North Carolina A&T State University has continually been noted as awarding the most bachelor degrees to Black students.[3] While the number of Blacks earning S&E degrees from historically Black colleges and universities (HBCUs) has declined over time, from 35% in 2000 to approximately 31% in 2008 (NSF, 2011) there are over 30% of Black doctorate recipients whose baccalaureate-origin institution was an HBCU (NSF, 2011).

The number of bachelor degrees awarded in engineering to Black women declined from HBCUs, Non-HBCUs, Research Universities (RU), and Master's Colleges and Universities (MCU). The number of bachelor engineering degrees awarded to Black women by Non-HBCUs decreased from 854 in 2005 to 637 in 2011—approximately a 7% difference (Figure 8.1). During the same time period, the number of bachelor degrees in engineering awarded to Black men by Non-HBCUs, increased from 1844 to 1963—an 8% difference (Figure 11.1). The number of bachelor degrees awarded by HBCUs decreased for both Black males and Black females from 2005 to 2011. The number of bachelor degrees awarded to Black males by RUs and MCUs increased from 1504 to 1555, and 432 to 472, respectively (Figure 11.1).

[3] See Engineering the Numbers, ASEE (2010-2011) and Chubin, May, and Babco, 2005.

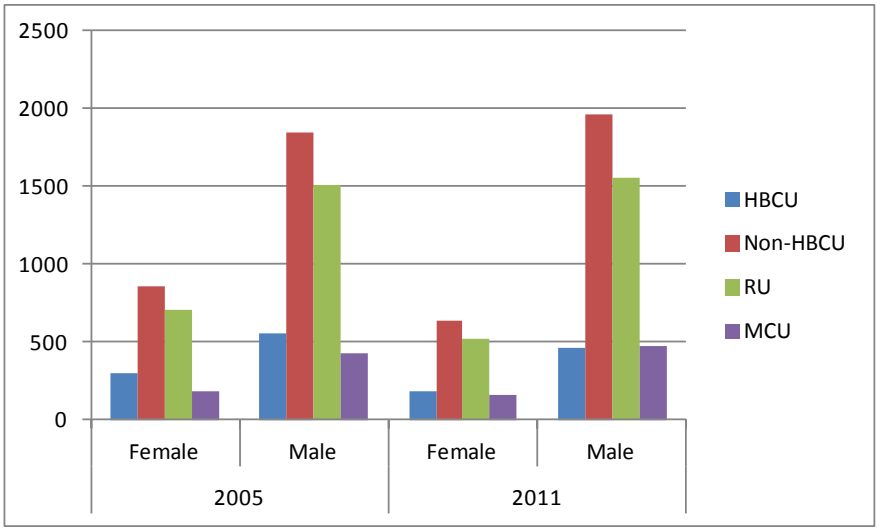


Figure 11.1: Number of Bachelor Degrees Awarded by Sex and Institution Type, 2005, 2011

The list of the Top 25 colleges and univerisities awarding bachelor degrees to Blacks varies by gender. Further, several top awarding schools experienced a significant drop in ranking among top producers of Black engineers. Three HBCUs, Florida A& M University (FAMU), Morgan State University (MSU), and Tennesee State University (TSU) experienced almost a 50% drop in the number of bachelor degrees they awarded to Black women in 2011, compared to 2005 (See Appendix A, Table 5.15). Similary. FAMU and TSU experienced almost a 50% reduction in the number of bachelor degrees awarded to Black men between 2005 and 2011. University of North Texas, a non-HBCU, almost quadrupel the number of bachelor degrees awarded to Black men in 2011, increasing from 8 to 30.

At the doctoral level, Georgia Tech was the top producer of Black male and female PhDs in 2011. Between 2005 and 2011 Georgia Tech granted 18 and 42 doctoral degrees to Black women and men, respectively (Table 3.1 and 4.1). For Black women there are no HBCUs among the top doctoral granting institutions, although Spelman College is noted for being the top producer of Black females who go on to earn a doctoral degree in engineering.

Table 3.1 Top 15 Producers of Black Female Engineers at Doctoral Level by School

School		Total Number '05-11
Georgia Institute of Technology	non-HBCU	18
Virginia Polytechnic Institute and St Univ	non-HBCU	13
Auburn University	non-HBCU	10
Texas A&M University	non-HBCU	8
Purdue University	non-HBCU	8
The George Washington University	non-HBCU	7
The University of Iowa	non-HBCU	7
University of Maryland-College Park	non-HBCU	7
Massachusetts Institute of Technology	non-HBCU	7
Princeton University	non-HBCU	6
The Johns Hopkins University	non-HBCU	5
Mississippi State University	non-HBCU	5
University of Notre Dame	non-HBCU	4
Carnegie Mellon University	non-HBCU	4
Clemson University	non-HBCU	4

*Total number reflects the total number of doctoral degrees granted during the 2005-2011 time period.

Table 4.1 Top 15 Producers of Black Male Engineers at Doctoral Level by School

School		Total Number '05-11
Georgia Institute of Technology	non-HBCU	42
University of Michigan	non-HBCU	26
Massachusetts Institute of Technology	non-HBCU	25
North Carolina A&T State University	HBCU	23
FAMU-FSU College of Engineering	HBCU	15
Purdue University	non-HBCU	13
University of Illinois at Urbana-Champaign	non-HBCU	12
University of South Florida	non-HBCU	9
City College of the City University of New Yo	non-HBCU	8
The George Washington University	non-HBCU	8
University of North Texas	non-HBCU	7
Northwestern University	non-HBCU	6
University of Central Florida	non-HBCU	5
The State University of New York at Binghan	non-HBCU	5
University of Missouri	non-HBCU	4

*Total number reflects the total number of doctoral degrees granted during the 2005-2011 time period.

Quantitative and qualitative data on engineering enrollment and degrees awarded by institutional type (research, HBCU, Non-HBCU, etc.), race, and gender, enhance understanding of the impact of institutional climate and structure on the retention of Blacks in engineering education. Further institutional data reveal opportunities for institutional partnerships and cross-institutional initiatives in recruiting and retaining Black talent within engineering.

Discussion

Disaggregating data on engineering degrees earned by both race and gender is critically important to enhance understanding of differences in career pathways and perceived opportunities. For example, Black men may perceive (correctly) that they have a wider range of employment opportunities in corporate America than in academia, and consequently choose not to pursue a doctorate in engineering. By contrast, Black women may perceive that they have better opportunities in academia and, consequently pursue an engineering doctorate. Before drawing conclusions, however, further research that explores variations in perceptions of opportunities is needed. Engineering degree data disaggregated by race and gender facilitate the ability to tailor a policy or program to a specific race/gender group. Such data should be used in two ways: to inform the design of programs, policies and practices designed to enhance the participation of Blacks in engineering careers; and to facilitate periodic assessments of the extent to which such programs, policies, and practices are effective or at least promising.

In addition to disaggregating data on engineering degrees earned by race and gender, it is equally important to disaggregate these data by type/category of degree-granting institution, such as, for example, Historically Black Colleges and Universities (HBCUs) and Research Universities (RU). Disaggregating data by type of institution further enhances understanding differences in degree production by providing an institutional context. A study conducted by Chubin, May and Babco (2005) found no significant indication that Black students in HBCUs have higher or lower rates of persistence in engineering than Black students in nonminority institutions. To increase the rates of student persistence in engineering, the University of

Colorado at Boulder created The First-Year Engineering Projects Course. This course was designed based on what is known to be positively correlated with engineering student retention, including collaborative and team-based learning, and supportive instruction. Evaluation data indicated that regardless of race or ethnicity, students who took the course had a 64% retention rate; this rate was higher than the retention rate for students who did not take the course, and the national retention rate of 56%. Although there were no statistically significant indicators of either gender or ethnic differences in terms of the impact of the course, these findings support other research findings that first-year project-based curricula are positively correlated with promoting the retention of engineering students (Fontenberry et al., 2007).

In 2011, Georgia Tech was the top producer of engineering doctorates awarded to Black males and Black females—largely due to the 3/2 program with two HBCUs—Spelman College (an all-woman's college) and Morehouse College (an all male college). In this program, students from Spelman College and Morehouse College spend their first three years at those institutions, then spend the last 2 years at Tech; students will earn the bachelor's degree in engineering from Georgia Tech. Perhaps other institutions could adopt this model. Moreover, four institutions were among the top 15 institutions awarding engineering doctorates to Black males and Black females: Georgia Tech, Massachusetts of Technology, Purdue University, and the George Washington University. However, although two HBCUs (FAMU and NC A&T) were among the top 15 institutions awarding engineering doctorates to Black males, no HBCU was in the top 15 institutions awarding engineering doctorates to Black females. Anecdotal data suggest that these gender differences could be partially attributed to differences in the demographic composition of engineering faculty at HBCUs and Non-HBCUs. For example, if engineering faculties at HBCUs are comprised of men who are non-US citizens from countries with cultures that devalue women, these cultural differences can negatively impact the persistence rate of Black females in engineering. Comparative research could help identify institutional characteristics that impact persistence rates among Blacks, including: how to engage students in the content of large, required first-year engineering courses; pairing engineering knowledge with skill development; and putting engineering in a wider societal context. Institutional data can reveal opportunities for institutional partnerships and cross-institutional initiatives to recruit, develop, and retain Black talent in engineering.

Conclusions

Variations in persistence suggest the need for further research to explore qualitative differences at the institutional level of analysis. Specifically, research is needed to explore the extent to which courses attempt to create overlap between what engineers need to learn and what motivates students, as suggested by Cheville and Bunting's work (2011). This research could also assess the extent to which there is a balance between the ways in which course content is delivered in terms of both theoretical and applied contexts. Moreover, engineering courses could be structured to simulate the environment in which engineers actually work. Having students work together in teams and groups on projects and assignments facilitates learning as well as enhances the development of skills in team-building and communication. This microcosm of the environment in which engineering is practiced provides opportunities for professional socialization including learning the rules governing the engineering profession and how to use them to one's advantage (Shehab et al, 2007).

Policy, programs, and practices to enhance the participation of Blacks in engineering should be informed not only by the research literature but also the evaluation literature (Leggon & Pearson 2009). Evaluations serve to identify and document two categories of programs, pedagogy, and practices: those that are effective, and those that are promising. Due to inter- and intra-group race and gender differences, it is unreasonable to assume that a single strategy

will be equally effective in addressing these differences; it is also unreasonable to assume that multiple strategies can be tailored to each group. Although the extant knowledge base is far from complete, it can still serve as a guide to: enhance Blacks' participation in engineering careers; build on what is known to be effective in terms of the structure, content, and delivery of engineering education; enhance professional socialization practices; and develop and cultivate the expectation of lifelong learning.

There is limited systematic research on Blacks in engineering. As a result, there are major gaps in the knowledge base—especially concerning the impacts of mentoring and other interventions at various stages of engineering careers (Wilson et al., 2012; National Academy of Engineering, 2005). Although the relationship between having a mentor and persistence in engineering is well documented, many questions remain. To what extent do Black engineering students remain in contact with their academic and/or research mentors? What is the impact—direct or indirect—of having one or more mentors at various stages throughout one's career? Does having had a mentor increase the probability of becoming a mentor?

Much of the research on Blacks in engineering careers consists of "snapshots" of different cohorts—such as, for example, the numbers of engineering degrees earned by level and selected years. To supplement these data, it is critically important to follow the same individuals throughout their careers to assess the short-, medium- and long-term effects of various interventions designed to enhance Blacks' participation in engineering. Longitudinal data on the careers and career pathways of Blacks can make major contributions to filling existing knowledge gaps concerning the impacts of selected interventions at the individual, institutional, and inter-institutional levels targeted to increase and enhance Blacks' participation in engineering at different points in time. Data from longitudinal research on Black engineers can inform the design of new interventions—policies, programs, and practices—and improve the operation of existing ones.

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Appendix A: Tables and Graphs

Table 1.11 Engineering Enrollment by Race/Ethncity and Sex, 2005-2011

Race/Ethnicity	Sex	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Caucasian	M	210490	212605	217662	224446	229187	242516	251401
	F	36839	37427	38843	41417	43395	47192	50714
	Total	247329	250032	256505	265863	272582	289708	302115
African American	M	17312	17286	17787	18448	18974	20189	20601
	F	6204	5908	5907	6262	6159	6338	6315
	Total	23516	23194	23694	24710	25133	26527	26916
Asian American	M	35038	34805	35657	37540	39198	40256	42591
	F	9039	9087	9539	10056	10575	11132	11836
	Total	44077	43892	45196	47596	49773	51388	54427
Hispanic	M	28404	29428	31730	34931	37803	40151	44326
	F	7762	8326	8526	9271	9813	10983	11392
	Total	36166	37754	40256	44202	47616	51134	55718
Native	M	1898	2083	2146	2128	2294	2620	2936
American/Hawaian	F	527	555	609	627	684	783	760
	Total	2425	2638	2755	2755	2978	3403	3696
Other/TwoorMore	M	23344	24838	25572	24133	30732	4774	7346
	F	4928	4632	5229	5404	7350	1386	2266
	Total	28272	29470	30801	29537	38082	6160	9612
Unknown	M	0	0	0	0	0	24102	20135
	F	0	0	0	0	0	5564	4576
	Total	0	0	0	0	0	29666	24711
Foreign	M	16796	17085	18074	19484	22080	25758	28854
	F	4156	4025	4079	4621	5253	6233	6908
	Total	20952	21110	22153	24105	27333	31991	35762
	Mtotal	333282	338130	348628	361110	380268	400366	418190
	Ftotal	69455	69960	72732	77658	83229	89611	94767
	Total	402737	408090	421360	438768	463497	489977	512957

Table 2.12 Bachelor Degrees Awarded by Race/Ethnicity and Sex, 2005-2011

Race/Ethnicity	Sex	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Caucasian	M	37405	38179	38659	39074	38283	41755	43350
	F	7450	7551	7141	7244	7042	7855	8573
	Total	44855	45730	45800	46318	45325	49610	51923
African American	M	2405	2369	2339	2354	2315	2377	2433
	F	1152	1038	961	913	879	831	825
	Total	3557	3407	3300	3267	3194	3208	3258
Asian American	M	7155	7126	7008	6983	6724	6819	7306
	F	2378	2362	2057	2006	1894	2029	2194
	Total	9533	9488	9065	8989	8618	8848	9500
Hispanic	M	3661	3944	4028	4218	4332	4770	5189
	F	1196	1237	1202	1292	1258	1356	1408
	Total	4857	5181	5230	5510	5590	6126	6597
Native American	M	281	284	258	306	277	305	287
	F	77	83	82	61	74	83	83
	Total	358	367	340	367	351	388	370
Hawain	M	0	0	0	0	0	61	86
	F	0	0	0	0	0	16	21
	Total	0	0	0	0	0	77	107
Other/TwoorMore	M	4451	4470	4402	4704	6016	4835	5008
/Unknown	F	1018	998	914	1080	1251	1097	1101
	Total	5469	5468	5316	5784	7267	5932	6109
Foreign	M	4326	4263	3930	3661	3652	3807	4445
	F	1231	1216	1033	895	928	1006	1185
	Total	5557	5479	4963	4556	4580	4813	5630
	Mtotal	59684	60635	60624	61300	61599	64729	68104
	Ftotal	14502	14485	13390	13491	13326	14273	15390
	Total	74186	75120	74014	74791	74925	79002	83494

Table 3.13 Master's Degrees Awarded by Race/Ethnicity and Sex, 2005-2011

Race/Ethnicity	Sex	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Caucasian	M	10929	11045	10770	10942	10879	11224	12466
	F	2762	2672	2504	2533	2519	2515	2862
	Total	13691	13717	13274	13475	13398	13739	15328
African American	M	735	691	703	763	733	820	903
	F	328	335	328	327	351	335	365
	Total	1063	1026	1031	1090	1084	1155	1268
Asian American	M	2732	2606	2622	2483	2475	2452	2948
	F	1405	1223	1116	1007	1052	900	1114
	Total	4137	3829	3738	3490	3527	3352	4062
Hispanic	M	919	904	956	971	1021	1127	1252
	F	345	322	334	375	351	371	424
	Total	1264	1226	1290	1346	1372	1498	1676
Native American/	M	68	73	61	71	74	89	78
Hawaiin	F	21	23	25	24	17	30	24
	Total	89	96	86	95	91	119	102
Other/TwoorMore/	M	2526	2853	2712	2621	3091	3170	3068
Unknown	F	631	701	678	753	873	859	808
	Total	3157	3554	3390	3374	3964	4029	3876
Foreign	M	13729	12224	11048	12412	14179	14801	15946
	F	3786	3582	3391	4029	4544	4838	5124
	Total	17515	15806	14439	16441	18723	19639	21070
	Mtotal	31638	30396	28872	30263	32452	33683	36661
	Ftotal	9278	8858	8376	9048	9707	9848	10721
	Total	40916	39254	37248	39311	42159	43531	47382

Table 4.14 Doctorate Degrees Awarded by Race/Ethnicity and Sex, 2005-2011

Race/Ethnicity	Sex	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Caucasian	M	1542	1603	1745	1835	1967	2021	2105
	F	379	388	439	506	574	570	559
	Total	1921	1991	2184	2341	2541	2591	2664
African American	M	73	72	86	74	103	113	94
	F	38	48	37	48	51	58	59
	Total	111	120	123	122	154	171	153
Asian American	M	336	392	312	326	398	379	468
	F	93	144	109	144	147	177	202
	Total	429	536	421	470	545	556	670
Hispanic	M	83	76	92	114	133	150	136
	F	29	30	38	41	41	67	50
	Total	112	106	130	155	174	217	186
Native American/	M	5	12	16	11	14	15	20
Hawaiin	F	2	1	5	4	8	7	5
	Total	7	13	21	15	22	22	25
Other/TwoorMore/	M	313	371	464	517	505	557	568
Unknown	F	101	97	161	173	195	202	154
	Total	414	468	625	690	700	759	722
Foreign	M	3689	4208	4551	4399	4135	3794	4192
	F	713	990	1109	1017	937	999	1090
	Total	4402	5198	5660	5416	5072	4793	5282
	Mtotal	6041	6734	7266	7276	7255	7029	7583
	Ftotal	1355	1698	1898	1933	1953	2080	2119
	Total	7396	8432	9164	9209	9208	9109	9702

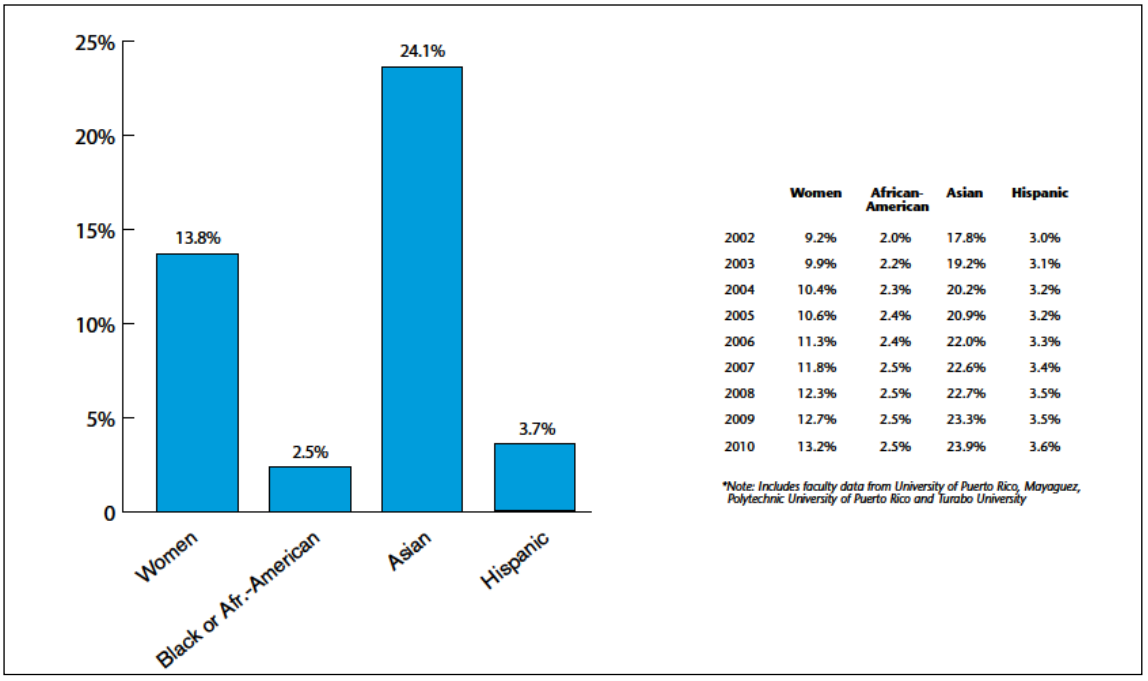
Table 5.15 Top 25 Producers of Black Female Engineers at Bachelor Level by School**,** 2011

School		Number '11	Total Number '05-11
North Carolina A&T State University	HBCU	43	378
Georgia Institute of Technology	non-HBCU	24	225
Prairie View A&M University	HBCU	24	174
Alabama A&M University	HBCU	22	156
Tuskegee University	HBCU	21	123
Howard University	HBCU	20	126
University of Florida	non-HBCU	18	101
University of Maryland-College Park	non-HBCU	17	98
University of Michigan	non-HBCU	17	130
North Carolina State University	non-HBCU	17	121
Auburn University	non-HBCU	16	85
Massachusetts Institute of Technology	non-HBCU	16	77
Tennessee State University	HBCU	14	134
Southern University and A&M College	HBCU	13	91
City College of the City Univ. of New York	non-HBCU	13	59
Clemson University	non-HBCU	13	86
Florida International University	non-HBCU	12	73
University of Central Florida	non-HBCU	11	51
University of South Florida	non-HBCU	10	65
Morgan State University	HBCU	10	151
New Jersey Institute of Technology	non-HBCU	10	66
Rutgers-State Univ. of New Jersey	non-HBCU	10	58
Virginia Polytechnic Institute & St Univ.	non-HBCU	10	65
FAMU-FSU College of Engineering	HBCU	9	169

*Total number reflects the total number of bachelor degrees awarded from 2005-2011

Table 5.16 Top 25 Producers of Black Male Engineers at Bachelor Level by School**,** 2011

School		Number '11	Total Number '05-'11
North Carolina A&T State University	HBCU	92	713
Georgia Institute of Technology	non-HBCU	79	527
Prairie View A&M University	HBCU	66	379
North Carolina State University	non-HBCU	60	347
Alabama A&M University	HBCU	50	375
Florida International University	non-HBCU	42	267
Morgan State University	HBCU	41	312
City College of the City Univ. of New York	non-HBCU	41	238
University of Florida	non-HBCU	40	243
Southern University and A&M College	HBCU	40	280
Virginia Polytechnic Institute & St Univ.	non-HBCU	39	219
FAMU-FSU College of Engineering	HBCU	37	373
University of Maryland-College Park	non-HBCU	37	278
Tuskegee University	HBCU	35	222
University of Central Florida	non-HBCU	33	201
University of Minnesota -Twin Cities	non-HBCU	31	143
Louisiana State University	non-HBCU	30	132
Massachusetts Institute of Technology	non-HBCU	30	196
University of North Texas	non-HBCU	30	63
University of Michigan	non-HBCU	29	213
Tennessee State University	HBCU	27	224
Jackson State University	HBCU	26	117
Rutgers-The State Univ. of New Jersey	non-HBCU	26	142
Clemson University	non-HBCU	26	161
Auburn University	non-HBCU	25	156



	Women	African-American	Asian	Hispanic
2002	9.2%	2.0%	17.8%	3.0%
2003	9.9%	2.2%	19.2%	3.1%
2004	10.4%	2.3%	20.2%	3.2%
2005	10.6%	2.4%	20.9%	3.2%
2006	11.3%	2.4%	22.0%	3.3%
2007	11.8%	2.5%	22.6%	3.4%
2008	12.3%	2.5%	22.7%	3.5%
2009	12.7%	2.5%	23.3%	3.5%
2010	13.2%	2.5%	23.9%	3.6%

*Note: Includes faculty data from University of Puerto Rico, Mayaguez, Polytechnic University of Puerto Rico and Turabo University

Figure 1.12: Percentage of Women and Minority Engineering Faculty, 2002-2011

Source: *Engineering by Numbers*, American Society of Engineering Education (2011)