Who enrolls in electrical engineering? A quantitative analysis of U.S.A. student trajectories

Susan M. Lord and Michelle Madsen Camacho
University of San Diego
San Diego, CA U.S.A.

Richard A. Layton
Rose-Hulman Institute
Terre Haute, IN, U.S.A.

Matthew W. Ohland
Purdue University
West Lafayette, IN, U.S.A.

Abstract **Electrical Engineering (EE) is one of the largest engineering disciplines. Analysis of the student population specifically within EE provides insights into a large segment of the undergraduate engineering population. Using a dataset from universities in the United States of America that includes over 70,000 students who majored in engineering, this work considers the subset of that population matriculating in EE. The rates of EE matriculation and six-year graduation vary by race and gender. The relevant findings are that males out number females at all levels of undergraduate EE. EE is the most popular choice for Asian and Black males at matriculation and the second choice (after ME) for Hispanic and White males. EE is much more popular for Asian and Black females than Hispanic and White females at matriculation and graduation. In fact, more Black females graduate in EE than in any other engineering discipline. The six-year graduation rate of EE matriculants is higher than that of students of other engineering disciplines. These findings suggest the importance disaggregating by engineering sub-discipline and examining how such information is useful in improving recruitment and retention overall.**

Keywords-Electrical Engineering, retention, race, gender

I. INTRODUCTION

There have been numerous calls to diversify the engineering profession [1, 2]. Electrical Engineering (EE) is one of the oldest engineering disciplines dating back to the 1880s [3] and also one of the largest. Thus analysis of the student population within EE provides insights into a significant segment of the undergraduate engineering population. Despite having high enrollments of students, EE has one of the lowest percentages of women students around the world including in the U.S.A. [4], Canada [5], and Israel [6].

Many studies of undergraduate student persistence aggregate all engineering disciplines [7, 8, 9, 10, 11]. This may often be a practical limitation imposed by the available data that results in small datasets when disaggregated by engineering discipline. For example, York Young and Redlinger [12] analyzed the student flow for 23 EE matriculants at one institution over six years. They found that 14 (61%) of the EE matriculants graduated in six years. Six of these were in EE, three in Computer Science, and one each in five other majors. Humphreys and Freeland [13] found that 68% of 422 EECS matriculants at one institution were still in the major after four years. They note that women were a small fraction of the cohort and persisted in engineering at lower rates than men and switched out of the major at higher rates than males.

Given our extensive dataset, we are able to disaggregate not only by engineering discipline but also by race and gender. This permits an investigation of EE students at an unprecedented scale and detail. In this paper, we examine how the matriculation and six-year graduation patterns of EE matriculants in the U.S.A. vary by both race and gender.

Research on retention of women in science, technology, engineering, and mathematics (STEM) disciplines in general and engineering in particular contains "conflicting evidence" regarding gender differences in persistence [14, p. 23]. A variety of studies have reported that women matriculating in engineering majors persist at the same rates as men [8, 9, 14, 15, 16, 17, 18, 19]. Other studies found lower persistence for women in engineering [7, 10] although these contained unique metrics for success which are difficult to compare with others.

Despite the sparse evidence supporting the claim that there is a gender gap in engineering persistence, there is a pervasive popular belief that women persist at lower rates than men. One source of this assumption is the inclusion of studies that measure persistence from pre-college STEM intention rather than college matriculation. Starting at this earlier point reduces the overall persistence rate and conflates the gender gap in pre-college choices regarding college STEM enrollment with the persistence after matriculation. Another likely reason for the belief in a gender gap in persistence is the severe gender gap in the enrollment-presence of women, which may be confused with the persistence of women. Overall, a careful investigation reveals that amidst some conflicting evidence, most research finds no significant difference in men's and women's engineering persistence rates. The gender gap in engineering is not a problem of persistence; rather, it is the result of fewer women enrolling in engineering compared with other majors.

This work has been sponsored by a U. S. A. National Science Foundation Gender in Science and Engineering Research collaborative Grant (0734085 and 0734062). The opinions expressed in this article are those of the authors and do not necessarily reflect the views of the NSF.

In analyses of engineering persistence, it is important to adopt a critical race theory framework [20] and consider the intersectionality of race and gender. Intersectionality refers to how gender operates together with race, not independently, to produce multiple, overlapping forms of discrimination and social inequality [21]. Failing to disaggregate data on women by race produces results that are over-generalized rendering minority women "invisible". Women in engineering do not necessarily share common experiences of marginality. For example, women of color may experience both sexism and racism, compounding their experiences of exclusion.

Reichert and Absher [22] reported data on minority retention rates from the National Action Council for Minorities in Engineering (NACME), but they neither tracked individual students nor disaggregated by race or gender. May and Chubin's significant 2003 study for NACME [23] spoke clearly to the issue of representation of underrepresented minorities disaggregated by race and gender, but did not disaggregate by engineering major and did not track individual students to address the issue of persistence or graduation rate. Cook and Córdova [24] also disaggregated by race in their study of representation. Each of these studies provided valuable data relating the importance of examining race within engineering. Yet, understandably, each study was limited in scope because of the difficulty involved in examining all relevant variables: race, gender, cohort, major, matriculation status and persistence to graduation.

The vast majority of undergraduate engineering degrees in the U.S.A. are awarded to students who identify as "White"[1]. In 2004, Whites received 65% of the engineering bachelor's degrees. Asians received about 12% of engineering bachelor degrees). Hispanics received about 7% of these degrees. Blacks received 5% of all engineering degrees while Native Americans account for less than 1% [25]. Except for Asians, each group received about the same proportion of non-engineering STEM degrees. In 2005 [26] about 1/3 of the bachelor's degrees for Whites, Blacks, Hispanics, and Native Americans were in science and engineering fields. By contrast, almost half of the Asian graduates earned bachelor's degrees in science and engineering. There is a wealth of literature on the experiences of people of color within science and engineering, yet much of this research aggregates science, math and engineering (SME) and/or underrepresented minorities: Blacks, Hispanics, and Native Americans and does not disaggregate race and gender.

A comprehensive study [27] found that Black and White students are as likely to select STEM fields of study and to persist for three years, but that differences accrued to graduation—62.5% of Blacks persisting for three years graduate within six years compared with 94.8% for Asian Americans and 86.7% for Whites. Yet these persistence issues may not be related to majoring in STEM disciplines alone. Rather, low minority persistence in STEM is a microcosm of low persistence in higher education. Research by Elliott et al. [28] found that ethnicity was not a predictor of persistence beyond what could be explained by ability as measured by scholastic aptitude tests (SAT) math (SATM) scores and achievement (high school grades). The SATM scores of Blacks and Hispanics are known to be substantially lower (1 and 0.75 standard deviations respectively) than those of Whites [29]. Large differences in persistence result when comparing high-performing Blacks' (62% persistence per Hilton et al., 1989) to a broader cross-section of Black students (34% persistence per Ref 28).

Asian students are unique among students of color in engineering because they are not underrepresented, and they demonstrate the highest persistence [13, 30, 31]. They show the strongest predilection for engineering and the smallest proportionate losses in SME majors during their undergraduate years [7]. Smyth and McArdle [32] reported a 63% graduation rate for Asians matriculating in SME, as compared to 55% for Whites and 38% for underrepresented minorities including Black, American Indian, and Hispanic students (p.371). Similarly, research by Bonous-Hammarth [33] indicated that Whites and Asians had similar attritions rates from SME majors (25% and 26%, respectively) considerably less than the 44% for African American, Hispanics and Native Americans.

The Hispanic population is the U.S.A.'s fastest-growing minority group [34]. Demographic predictions suggest Hispanics may be poised to have the greatest effect on engineering education [35]. Yet the educational gap between Hispanics and other groups continues to widen, especially in engineering [36], possibly as a result of factors affecting Hispanics' participation in education generally, such as health care, nutrition, adequacy and stability of housing, neighborhood environments, and a lack of engineering role models [37, 38]. Similar to women and Blacks, among Hispanics the proportion of bachelor degrees awarded in engineering has only marginally increased since 1991 [39]. Nonetheless, there is room for the numbers of Hispanics to increase in engineering because this major is the third most popular destination (after social sciences and psychology) among Hispanic bachelor degree recipients.

Native American women are much more likely to participate in higher education and to earn bachelor's degrees than Native American men. Yet, like all women, they are less likely to choose science and engineering fields as college majors [40, 41]. In 2004, Native American women accounted for only 0.5% of engineering students in the U.S. A. [25]. From 1995 to 2005, Native Americans remained steady at approximately 0.65% of all undergraduate engineering students [42]. Of those Native American students receiving bachelor's degrees, approximately 4% were in engineering [26]. Besides Lord et al. [16], no other references with details on the persistence of Native Americans in engineering could be found.

[1] In the U.S.A., the racial category "White" refers to people of European, Middle Eastern, and North African descent "Asian" refers to people with origins in any subcontinents of the Far East, Southeast Asian, or India. "Hispanic" refers to those who trace their origin or descent to Mexico, Puerto Rico, Cuba, Spanish speaking Central and South America countries, and other Spanish cultures. "Black" refers to Americans of African descent. "Native American" include American Indians and Alaska Natives. More details are available at http://www.census.gov/

II. METHODS

This study uses the Multiple-Institution Database for Investigating Engineering Longitudinal Development [11, 43], a dataset with more than 79,000 students matriculating in engineering at nine southeastern institutions that awarded 1/12 of all U.S. engineering bachelor's degrees from 1987 to 2004. The results should be generalizable to large public institutions. We focus on first-time-in-college U.S.A. citizens / permanent residents matriculating directly in an engineering discipline including Electrical (EE), Mechanical (ME), Chemical (ChE), Civil (CE), and Industrial (IE). Due to the small numbers, Computer, Materials, and other engineering fields including Bioengineering are not considered. In the population studied, the number of students in Bioengineering is two orders of magnitude smaller than the largest majors preventing disaggregation by race and gender. Students self-report gender and race choosing among Asian, Black, Hispanic, Native American, and White (as well as Non-Resident Alien and Other, each of which are not included in this study). Since we have whole population data, inference is unnecessary—all reported differences are valid. Note that students who matriculated into "first-year engineering" are not included here, since we are studying the disciplinary character of matriculation. Graduation is defined as having graduated by the sixth year following a standard of reporting by the Integrated Postsecondary Education Data System (IPEDS) [44]. Thus, in this paper, we consider students who matriculated from 1988-1998 and graduated six years later.

III. RESULTS

A. Context and Rationale for Studying EE

To contextualize our results for EE students, we begin by showing the numbers of students enrolled in various engineering disciplines at semesters 1 and 12. Women and men prefer different engineering disciplines at matriculation and graduation [45]. Table 1 shows the number of women and men at matriculation (Sem 1) and six-year graduation (Sem 12) for Asian, Black, Hispanic and White students. The top two choices of men at matriculation and graduation are Mechanical (ME) and Electrical (EE), yet the order varies by race. At matriculation and graduation, Asians and Blacks prefer EE to ME while Hispanics and Whites prefer ME to EE.

For women of all races, Chemical is the top choice at matriculation. EE is the second choice at matriculation for Asian and Black women while ME is the second choice for Hispanic and White women. Similar to the men, at matriculation and graduation, Asian and Black women prefer EE to ME while Hispanic and White women prefer ME to EE. By graduation, IE is the most popular major for Hispanic and White women, Asian women still prefer Chemical, and Black women prefer EE. The large number of students matriculating in EE results in a large number of students of all race-gender combinations in that population, making it suitable and interesting for detailed study. We next consider those EE matriculants in more detail disaggregating by race and gender.

TABLE 1
NUMBERS OF STUDENTS MATRICULATING IN (SEM 1) AND GRADUATING IN (SEM 12) ENGINEERING DISCIPLINES BY RACE AND SEX.

	Women at Matriculation (Sem 1)				Women at Sem 12			
Major	**Asian**	**Black**	**Hispanic**	**White**	**Asian**	**Black**	**Hispanic**	**White**
Chemical	147	711	48	1110	91	330	19	448
Civil	45	370	42	699	21	179	22	412
Computer	68	183	18	224	34	31	2	71
Electrical	107	701	33	502	79	339	14	242
Engineering, Other	37	72	24	428	13	34	8	158
Industrial & Systems	51	365	40	480	56	316	37	527
Materials	11	32	6	244	6	29	8	161
Mechanical	75	402	44	1048	35	237	18	444

	Men at Matriculation (Sem 1)				Men at Sem 12			
Major	**Asian**	**Black**	**Hispanic**	**White**	**Asian**	**Black**	**Hispanic**	**White**
Chemical	282	432	77	2355	146	173	35	1042
Civil	131	645	132	2931	65	250	70	1759
Computer	373	302	133	2174	219	74	64	1041
Electrical	674	1695	248	4646	453	714	121	2331
Engineering, Other	68	77	40	1044	27	26	19	418
Industrial & Systems	96	350	116	993	120	231	113	1160
Materials	58	44	28	633	35	31	22	478
Mechanical	522	1220	329	7053	279	530	130	3275

B. Matriculation in EE

Table 2 shows the number of EE matriculants and their percentage among engineering matriculants disaggregated by race and gender. The top panel of Figure 1 emphasizes that men of each racial group are more likely than women to matriculate in EE. A similar gender gap is found for ME and Computer Engineering but not other engineering disciplines studied [45]. Overall, 12% of women and 19% of men choose EE at matriculation. Of all racial groups, Black students choose EE at matriculation at the highest percentages of all subpopulations. Of Black men who matriculate in engineering, 30% choose EE, the highest of any group. The second highest percentage is 24% for Asian males. EE attracts 21% of Black women in engineering, the highest of any group of women with the second highest percentage being 14% of Asian women. Notably, only 8% of White women matriculate in EE resulting in a smaller number of White women than Black women despite the greater presence of White women in Engineering.

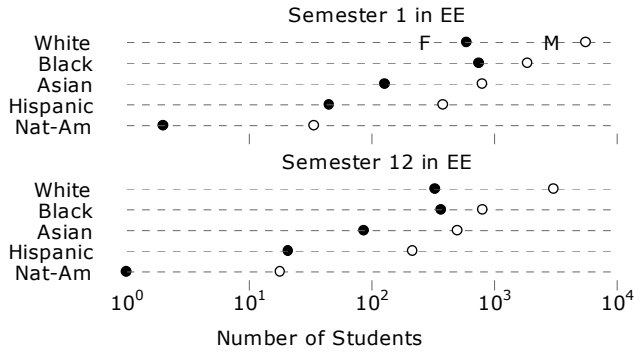

Figure 1. For all races, more men (open circles) than women (filled circles) matriculate and graduate in EE.

C. Six-year Graduation

The bottom panel of Figure 1 emphasizes that more men of each race also graduate within six years in EE than women [45]. Table 3 shows the number and percentage of EE matriculants who graduate in six-years in EE, percentage who switch from EE to another engineering major, and percentage who graduate in any engineering major. As shown in Figure 2 (for populations greater than 30 to avoid computing percentages of small numbers) the percentage of EE matriculants who graduate within six years in EE varies by race and gender from a low of 30% for Hispanic women to a high of 57% for Asian women. Asian students do particularly well in EE as evidenced by their high EE graduation rates. Asian and Black women EE matriculants graduate in six years in EE and engineering (ENGR) at a rate equal to or higher than men of the same ethnic group. Black women graduate at 43% compared to 38% for Black men. White men and women EE matriculants have very similar graduation rates: 41% of White men and 40% of White women EE matriculants graduate in EE. 56% of White women graduate in some engineering discipline compared to 55% of the White men. Except for Hispanic women, the graduation rates of female EE matriculants is consistent with other reports of performance of engineering matriculants disaggregated by race [16].

TABLE 2
NUMBERS OF STUDENTS MATRICULATING IN EE AND ENGINEERING BY RACE AND SEX. DATA ORDERED BY % CHOOSING EE.

Race & Sex	No. in EE	No. in ENGR	Percent EE
Black Male	1695	5707	**30%**
Asian Male	674	2799	**24%**
Black Female	701	3365	**21%**
Native-Am. Male	26	136	**19%**
Hispanic Male	248	1416	**18%**
White Male	4646	29286	**16%**
Asian Female	107	757	**14%**
Hispanic Female	33	332	**10%**
White Female	502	6673	**8%**
Native-Am. Female	2	39	**5%**
All Female	1345	11166	12%
All Male	7289	39344	19%
ALL	8634	50510	17%

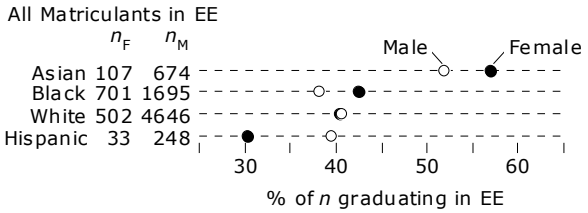

Figure 2. Except for Hispanics, more women (filled circles) matriculating in EE graduate in EE within six years compared to men (open circles).

If EE matriculants graduate in an engineering discipline, they are most likely to graduate in EE of any engineering major for all races and genders. By six years from matriculation, fewer than 16% of EE matriculants switch from EE to another engineering major. Within that 16%, women and men of each ethnic group are equally likely (within 2%) to switch from EE to another engineering major, except for Native Americans where our sample population is quite small. For those who switch, Computer Engineering is the most popular destination within Engineering for Asian, White, and Hispanic males. Industrial Engineering (IE) is the most popular second choice for White females, Black males, and Black females. Populations of other subgroups have less than 5 students switching to another engineering destination.

EE matriculants are a successful group among engineering matriculants. As shown in Table 4 for populations with sample sizes greater than 10, EE matriculants graduate in six years in engineering at higher rates than all engineering matriculants. Asian women show the greatest difference: 69% for EE matriculants and 62% for engineering matriculants. White women, Hispanic men, Black men and women are all have differences less than 2%. The only exception to this is White males who graduate at equal rates. This suggests that EE matriculants are similar to all engineering matriculants. Given that this is whole population data, the differences seen here are real. However, more study is needed to determine if they are meaningful for particular race-gender combinations. For example, what is different about Asian women who matriculate in EE versus those matriculating in engineering?

TABLE 3
NUMBERS OF EE MATRICULANTS GRADUATING IN SIX-YEARS IN EE AND ENGINEERING BY RACE AND SEX. ORDERED BY % RETAINED IN EE.

Race & Sex	Number in EE	Retained in EE	Switching from EE to another ENGR	Graduating in ENGR
Asian Female	61	**57%**	12%	69%
Asian Male	350	**52%**	12%	64%
Native-Am. Male	12	**46%**	8%	54%
Black Female	298	**43%**	7%	50%
White Male	1889	**41%**	14%	55%
White Female	203	**40%**	16%	56%
Hispanic Male	98	**40%**	14%	54%
Black Male	646	**38%**	5%	43%
Hispanic Female	10	**30%**	12%	42%
All Female	2359	43%	11%	54%
All Male	1209	41%	12%	53%
ALL	3568	41%	12%	53%

TABLE 4
PERCENTAGE OF MATRICULANTS GRADUATING IN SIX-YEARS IN ENGINEERING BY RACE AND SEX. ORDERED BY DIFFERENCE BETWEEN EE AND ENGR.

Race & Sex	EE matriculants	ENGR matriculants	Difference %EE – %ENGR
Asian Female	69%	62%	**+7%**
Native-Am. Male	54%	47%	**+7%**
Asian Male	64%	61%	**+3%**
White Female	56%	54%	**+2%**
Black Male	43%	41%	**+2%**
Black Female	50%	49%	**+1%**
Hispanic Male	54%	53%	**+1%**
White Male	55%	55%	**0%**

IV. DISCUSSION

Researchers have begun to explore the reasons why women prefer some engineering disciplines over others. Early socialization, influence of parents and teachers, academic preparation and success, work experience and networks have been cited as important factors [46, 47]. Some research suggests that women prefer majors with a clear benefit to society; thus researchers advocate providing meaningful contexts for problem solving and applications to help attract women [48]. However, Hartman, Hartman, and Kadlowec [49] surveyed 83 first year female engineering students in mechanical and electrical engineering and compared them with those in chemical and civil/environmental engineering. They found that background differences, differences in general academic and math/science self-confidence, attributions of success, and expectations about the engineering degree did not account for the differences in proportions of women in the different engineering majors. No statistically significant differences were found between women and men in all majors regarding their expectation that their engineering degree would help them make an important contribution to society. The researchers did find differences in the reported engineering self-confidence of women entering the different majors. "Work needs to be done on raising the self-confidence of other qualified women, so that they too will consider the most non-traditional engineering disciplines." They also call for more research on the persistence of women in these majors. Our work addresses this quantitatively. Further qualitative analysis is necessary to understand the reasons why students matriculate and graduate in EE.

Interesting recommendations for promoting EE for women have been suggested by Hazzan, Levy and Tal [6]. They developed a one-day introduction to EE for female high school students and showed a dramatic change in the students' perception of the field and willingness to study it. They argue that it is important to show prospective students a realistic image of EE including the multidisciplinary nature and its connection to many aspects of society rather than dwelling on EE as an "exceedingly difficult" topic. Such workshops indicate the importance of diversifying images of engineering presented to potential students. For minority students and women students, exposure to similar role models and cultivating potential mentorships are also important. Many universities successfully host summer workshops designed to attract and immerse potential students into the field of undergraduate engineering.

EE is relatively successful at attracting students including women and minorities especially Blacks. This might be related to the large number of electrical engineers so that the chances of students having heard of EE or seen an EE role model are greater than for other engineering disciplines. Qualitative research examining differentiation by engineering major, race and gender is necessary.

V. SUMMARY/CONCLUSIONS

Based on the findings presented here, the trajectories of students matriculating in EE are gendered and racialized. This merits further study to better understand who EE students are and identify potential recruiting opportunities to draw more students into the field. Further qualitative research is needed to understand the reasons behind these enrollment and graduation numbers. This work raises questions for discussion among the EE education community where the input of many is vital to addressing the issues and enhancing the profession.

REFERENCES

[1] National Academy of Engineering, "Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future," 2006, http://www.nap.edu/catalog/11463.html

[2] National Academy of Engineering (2008), "Changing the Conversation: Messages for Improving Public Understanding of Engineering".

[3] F. E. Terman, "A Brief History of Electrical Engineering Education," Proceedings of the IEEE, vol. 86, no. 8, pp. 1792-1800, August 1998.

[4] American Society for Engineering Education (ASEE). Engineering data management system, 2008 [accessed 2009 October 29]; Available from: http://www.asee.org/datamining/reports/ .

[5] L. S. Anderson and K. A. Gilbride, "Pre-university Outreach: Encouraging Students to Consider Engineering Careers," Global J. of Engng. Educ., Vol.7, No.1, 87-93, 2003.

[6] O. Hazzan, D. Levy, and A. Tal, "Electricity in the Palms of Her Hands-The Perception of Electrical Engineering by Outstanding Female High School Pupils," IEEE Transactions on Education, Vol 48, No.3,. 402-412, August 2005.

[7] A. W. Astin and H. S. Astin, "Undergraduate science education: The impact of different college environments on the educational pipeline in the sciences. (Final Report)" Los Angeles, CA: University of California Higher Education Research Institute. (ERIC Document Reproduction Service No. ED362404), 1992.
[8] A. C. Strenta, R. Elliott, R. Adair, M. Matier, and J. Scott, "Choosing and leaving science in highly selective institutions." Research in Higher Education, vol. 35, pp. 513-547, 1994.
[9] E. Seymour and N. M. Hewitt, Talking about leaving: Why undergraduates leave the sciences. Boulder, CO: Westview, 1997.
[10] C. Adelman, Women and men of the engineering path: A model for analyses of undergraduate careers, Washington, DC: Department of Education, 1998.
[11] M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, "Persistence, Engagement, and Migration in Engineering," J. Engineering Education, vol. 97, pp. 259-278, 2008.
[12] D. York Young and L. J. Redlinger, "Modeling Student Flows through the Univeristy's Pipelines," Presented at the 41st Forum of the Association for Instutitional Research, Long Beach, CA, June 2001. Retrieved December 28, 2009 from https://www.utd.edu/ospa/research/Conference%20Presentations/AIR/documents/MODELINGSTUDENTFLOWS.pdf
[13] S. Humphreys and R. Freeland, "Retention in engineering: A study of freshman cohorts," Berkeley, CA: University of CaliforniaPress, Berkeley, 1992.
[14] J. Oakes, "Opportunities, achievement, and choice: Women and minority students in science and mathematics," Review of Research in Higher Education, vol. 16, pp. 153-222, 1990.
[15] C. Cosentino de Cohen and N. Deterding, "Widening the net: National estimates of gender disparities in engineering," Journal of Engineering Education, vol. 98, pp. 211-226, July 2009.
[16] S. Lord, M. Camacho, R. Layton, R. Long, M. Ohland, and M. Wasburn, "Who's persisting in engineering? A comparative analysis of female and male Asian, Black, Hispanic, Native American and White students," Journal of Women and Minorities in Science and Engineering, vol. 15, no. 2, pp. 167-190, 2009.
[17] H. Hartman and M. Hartman, "Leaving engineering: Lessons from Rowan University's College of Engineering," Journal of Engineering Education, vol. 95, no.1, pp. 49-61, 2006.
[18] T. L. Hilton, J. Hsia, D. G. Solorzano, and N. L. Benton, "Persistence in science of high ability minority students," Princeton, NJ: Educational Testing Service, 1989.
[19] K. W. Linden, C. M. Jagacinski, W. K. LeBold, and K. D. Shell, "Predicting persistence in engineering for undergraduate women," Third International Girls in Science and Technology Conference. London: Centre for Science and Mathematics Education, 1985.
[20] R. Delgado and J. Stefancic, Critical Race Theory: An Introduction, New York, NY: NYU Press, 2001.
[21] P. H. Collins, Black feminist thought: Knowledge, consciousness and the politics of empowerment. New York: Routledge, 1990.
[22] M. Reichert and M. Absher, "Taking another look at educating African-American engineers: The importance of undergraduate retention," J. Engineering Education, 86(3), pp. 241-253, 1997.
[23] G. S. May and D. E. Chubin, "A retrospective on undergraduate engineering success for underrepresented mintority students," Journal of Engineering Education, vol. 92, no.1, pp.27-39, 2003.
[24] B. J. Cook, and D. I. Córdova, Minorities in higher education Twenty-second annual status report: 2007 supplement. Washington, DC: American Council on Higher Education, 2007
[25] National Science Foundation (NSF). (2008 tabc-14). Women, minorities, and persons with disabilities in science and engineering. Retrieved August 28, 2008 from http://www.nsf.gov/statistics/wmpd/pdf/tabc-14.pdf
[26] National Science Foundation (NSF) (2008 figc-3) Women, minorities, and persons with disabilities in science and engineering. Retrieved August 28, 2008 from http://www.nsf.gov/statistics/wmpd/figc-3.htm
[27] E. Anderson, and D. Kim, Increasing the success of minority students in science and technology. Washington, D.C.: American Council on Education, 2006.
[28] R. Elliott, A. C. Strenta, R. Adair, M. Matier, and J. Scott, "The role of ethnicity in choosing and leaving science in highly selective institutions," Research in Higher Education, vol. 37, no. 6, pp. 681-709., 1996
[29] L. Suter, Ed. Indicators of science and mathematics education—1993. Washington, DC: U.S. Government Printing Office (NSF 93-95), 1993.
[30] E. Culotta, and A. Gibbons, "Minorities in science: Two generations of struggle [Special Report]," Science, vol. 258, pp. 1176-1232, 1992.
[31] J. C. Simpson, "Segregated by subject: Racial differences in the factors influencing academic major between European Americans, Asian Americans, and African, Hispanic, and Native Americans," The Journal of Higher Education, vol. 72, pp. 63-100, 2001.
[32] F. L. Smyth, and J. J. McArdle, "Ethnic and gender differences in science Graduation at selective colleges with implications for admission policy and college choice," Research in Higher Education, vol. 45, pp. 353-381, 2004.
[33] M. Bonous-Hammarth, "Pathways to success: Affirming opportunities for science, mathematics, and engineering majors," The Journal of Negro Education, vol. 69, no. 1, pp. 92-111, 2000.
[34] J. Chapa and B. De la Rosa, "The problematic pipeline: Demographic trends and Latino participation in graduate science, technology, engineering, and mathematics programs," Journal of Hispanic Higher Education, vol. 5, no. 3, pp. 203-221, 2006.
[35] C. Millett, and M. Nettles, "Expanding and cultivating the Hispanic STEM doctoral workforce research on doctoral students," Journal of Hispanic Higher Education, vol. 5, no. 3, pp. 258-287, 2006.
[36] A. Johnson, "Graduating Underrepresented African American, Latino, and American Indian Students in Science," Journal of Women and Minorities in Science and Engineering, vol. 13, no.1, pp. 1-22, 2007.
[37] P. Gándara, "Strengthening the academic pipeline leading to careers in math, science, and technology for Latino students," Journal of Hispanic Higher Education, vol. 5, no. 3, pp. 222-237, 2006.
[38] R. Rochin, and S. Mello, "Latinos in science: Trends and opportunities," Journal of Hispanic Higher Education, vol. 6, no. 4, pp.305-355, 2007.
[39] NACME (National Action Council for Minorities in Engineering), (2008) "Confronting the 'New' American Dilemma, Underrepresented Minorities in Engineering: A Data-Based Look at Diversity". Retrieved July 26, 2008 from http://www.nacme.org/news/americandilemma.html
[40] E. L. Babco, The status of Native American in science and engineering, Washington, DC: Commission on Professionals in Science and Technology, 2000.
[41] E. L. Babco, Trends in African American and Native American participation in STEM higher education. Washington, DC: Commission on Professionals in Science and Technology, 2003.
[42] National Science Foundation (NSF). (2008 figb-1). Women, minorities, and persons with disabilities in science and engineering. Retrieved August 28, 2008 from http://www.nsf.gov/statistics/wmpd/figb-1.htm
[43] The Multiple-Institution Database for Investigating Engineering Longitudinal Development. MIDFIELD. 2007 [cited 2007 December 4]; Available from: https://engineering.purdue.edu/MIDFIELD.
[44] U.S. Department of Education (2007). The Integrated Postsecondary Education Data System (IPEDS) glossary. Retrieved November 3, 2009, from http://www.nces.ed.gov/ipeds/glossary/ .
[45] S. M. Lord, C. E. Brawner, M. M. Camacho, R. A. Layton, M. W. Ohland, and M. H. Wasburn, "Work in Progress: Engineering Students' Disciplinary Choices: Do Race and Gender Matter?" Proceedings of the 2009 Frontiers in Education Conference, San Antonio, TX, October 2009.
[46] J. Margolis and A. Fisher, Unlocking the Clubhouse, Cambridge, MA: MIT Press, 2001.
[47] H. K. Tillberg and J. McGrath Cohool, Attracting Women to the CS Major," Frontiers, vol. 26, no. 1, pp. 126-140, 2005.
[48] C.-S. Davis and S. Rosser, "Program and Curriculuar Interventions" Ch 7 in C-S Davis, A. B. Ginorio, C. S. Hollinshead, B. B. Lazarus, P. M. Rayman and associates, The Equity Equation, San Francisco: Jossey-Bass Publishers, 1996.
[49] M. Hartman, H. Hartman, and J. Kadlowec, "Gender Differences Across Engineering Majors," Proceedings of the 2007 ASEE Annual Conference, Honolulu, HI, June 2007.