

Essay

Underrepresentation by Race–Ethnicity across Stages of U.S. Science and Engineering Education

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Submitted December 11, 2012; Revised May 6, 2013; Accepted May 8, 2013
Monitoring Editor: Erin L. Dolan

Blacks, Hispanics, and American Indians/Alaskan Natives are underrepresented in science and engineering fields. A comparison of race–ethnic differences at key transition points was undertaken to better inform education policy. National data on high school graduation, college enrollment, choice of major, college graduation, graduate school enrollment, and doctoral degrees were used to quantify the degree of underrepresentation at each level of education and the rate of transition to the next stage. Disparities are found at every level, and their impact is cumulative. For the most part, differences in graduation rates, rather than differential matriculation rates, make the largest contribution to the underrepresentation. The size, scope, and persistence of the disparities suggest that small-scale, narrowly targeted remediation will be insufficient.

Most scientists and engineers take great pride in their reliance on logic and empirical evidence in decision making, and they reject the use of emotional, parochial, and irrational criteria. Prejudices of any sort are abjured. The prevalence of laboratory personnel and research collaborators from diverse national origins is often cited as an example of this meritocratic ideal. Therefore, the U.S. biomedical research community was shocked when a study revealed that Black Americans and other groups were substantially underrepresented in the receipt of grants from the National Institutes of Health (NIH), even after other correlates of success were controlled (Ginther *et al.*, 2011). This picture clashed dramatically with the standards the community claimed. In the wake of this revelation, NIH created a high-level advisory group to examine the situation and make recommendations to address it (NIH, 2012).

Concern about underrepresentation of Black Americans and other race–ethnic groups in science is not new (Melnick and Hamilton, 1977), and many attempts have been made to

ameliorate or eliminate the gaps. While there have been some gains—underrepresented racial minority (URM)¹ students rose from 2% of the biomedical graduate students to more than 11% since 1980 (National Research Council, 2011)—disparities remain in all fields of science and engineering at all education levels and career stages (National Academy of Science, 2011).

Given the limited progress in correcting this situation, it is essential to have a better understanding of the origin and extent of the problem. Especially in the current fiscal climate, with insufficient funding for education programs, interventions must be accurately targeted and appropriate to reach their goals. How large are the race–ethnic differences in science enrollments at each level of education? Are there general patterns that can help guide policy? Using data from 2008 and 2009, a recent National Science Foundation (NSF) report illustrates the underrepresentation of Blacks, Hispanics, and American Indians/Alaskan Natives at various education levels (NSF, 2011a). While informative and illustrative of the extent of the problem, this single-year, cross-sectional perspective does not capture the conditions encountered by recent doctorate earners as they progressed through earlier stages in their education. Looking at graduation rates in the life sciences, Ginther *et al.* (2009) found that minority participation is increasing in biology, but minority students are not transitioning between milestones in the same proportions as Whites.

DOI: 10.1187/cbe.12-12-0207

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¹URM is defined in this paper as Black, Hispanic, and American Indian/Alaskan Native.

METHODS

For obtaining a broader and more inclusive perspective on where race–ethnic disparities in science and engineering arise, rates of transition from one educational stage to the next were compared across race–ethnic groups. For this analysis, it would have been optimal to track a large cohort of individuals from different race–ethnic groups over time as they moved through the education system. Because this information does not exist, however, a “synthetic cohort” was created by combining cross-sectional data from different sources. Data were taken from large-scale, national surveys of the U.S. population that were regularly administered by the U.S. Census Bureau, the U.S. Department of Education, NSF, and the University of California, Los Angeles, Higher Education Research Institute (HERI).

The synthetic cohort approach used in this study compares data collected at different points in time, requiring assumptions about the length of time between matriculation and graduation or (in the case of high school graduation) age at graduation. The matriculation–graduation comparisons assume that it takes 4 years to earn a baccalaureate degree and 6 years for a PhD. There were no provisions made for time between education levels.

The study began with the most recent data on PhD earners from the 2010 NSF survey of doctoral recipients (see notes to Table 1 for details). Working backward 6 years from 2010, graduate school enrollment data were obtained from the 2004 NSF graduate student survey. Graduate school enrollees in 2004 were contrasted with college graduates in 2004, who were in turn compared with first-year college entrants in 2000. The baccalaureate data were taken from the Department of Education Integrated Postsecondary Education Data System. Reports of intended major in the freshman year of college came from the 2000 survey of college freshmen administered by HERI. High school graduation statistics for 2000 were taken from the Department of Education *Digest of Education Statistics*, and were then contrasted with baseline data on 17-year-olds in 1999, using data from the U.S. Census Bureau.

The college, graduate school, and doctoral data used throughout this study pertain to U.S. citizens and permanent residents only. The 17-year-old population counts and the high school graduation statistics, however, include all U.S. residents, regardless of citizenship or residency status.

LIMITATIONS

Because this study was conducted using data from existing sources, it was constrained by the decisions made by each organization. There was some variation across surveys in categories used for collecting information on race–ethnicity. The census data on the 17-year-old population and the high school graduation survey classified individuals into one of five categories: White, Black, Asian/Pacific Islander, Hispanic, and American Indian/Alaskan Native. The HERI surveys of intended major during freshman year of college allowed students to report more than one race–ethnicity. The surveys of undergraduate enrollment, bachelor’s degrees, graduate enrollment, and doctoral degrees allowed reporting of “other”

or “two or more” in response to the race–ethnicity questions.² Only those individuals reporting a single race–ethnicity were included in the analysis. Comparisons across surveys, therefore, must be seen as approximations, and only the largest differences are described.

All of the tabulations for science and engineering fields included the behavioral and social sciences. The Department of Education, HERI, and NSF, however, used slightly different taxonomies of science and engineering fields and presented survey respondents with different specific field choices. In the case of NSF, some taxonomies changed slightly over time. But these differences involved small, specialized, or interdisciplinary fields and will have minor effects on the national estimates of the combined science and engineering category.

The analysis used simplifying assumptions about time to degree and immediate progression from one level of education to the next. Some studies have shown that some minority group members take longer to earn a degree (NSF, 2009), and the time-limited comparisons used in this study may slightly overstate the actual disparities.

RESULTS

In 1999, there were more than four million White 17-year-olds in the United States, and they outnumbered their Asian/Pacific Islander age-mates by a 17:1 margin. The comparable ratios in this age group were 5:1 for Blacks, 5:1 for Hispanics, and 67:1 for American Indians/Alaskan Natives (Table 1). As this cohort aged, and its members moved through the education system, the ratios changed substantially. With increasing rates of participation by Asian/Pacific Islanders, the ratio of Whites to Asian/Pacific Islander decreased. On the other hand, the relative number of Blacks, Hispanics, and American Indians/Alaskan Natives decreased, driving up the ratio of Whites to each of these other race–ethnic groups at higher levels of education (Figure 1).

There were large race–ethnic differences in high school graduation rates, with Asian/Pacific Islanders being the most likely to graduate from high school, followed by Whites. American Indians/Alaskan Natives, Blacks, and Hispanics were underrepresented among high school graduates. In 2000, the number of Asian/Pacific Islanders who graduated high school was 78.7% of the Asian/Pacific Islander population of 17-year-olds in the previous year (Table 2). For Whites, the number of high school graduates in 2000 was 66.7% of the White 17-year-old population in 1999. Among the URM groups, the comparable percentages were lower: 56.0% for Blacks, 50.6% for Hispanics, and 63.3% for American Indians/Alaskan Natives. For each URM group—Blacks, Hispanics, and American Indians/Alaskan Natives—the percentage of the 2000 high school graduates was smaller than their respective share of the 17-year-old population in 1999.

²Survey respondents increase their use of the “multiracial” and “other” designation over time and as students move through the various levels of education. In 2004, 8.6% of the first-time, full-time science and engineering graduate students identified themselves as “multiracial” or “other race,” two percentage points higher than their counterparts in 2000. The first-time, full-time graduate students in 2004 were also three percentage points more likely to report “multiracial” or “other race” than science and engineering baccalaureate earners in the same year.

Table 1. Distribution of U.S. population in science and engineering education by race-ethnicity^a

Education level	Population counts										Ratio of White to:			
	Total	White	Asian/ Pacific Islander	Black	Hispanic	American Indian/ Alaskan Native	Two or more races/ other	Asian/ Pacific Islander	Black	Hispanic	American Indian/ Alaskan Native	Black	Hispanic	American Indian/ Alaskan Native
Population 17-year-olds in 1999 ^b	4,017,000	2,677,000	156,000	586,000	558,000	40,000		17	5	5	67	5	5	67
Elementary/secondary														
Public high school graduates 2000 ^c	2,544,754	1,785,866	122,759	328,182	282,610	25,337		15	5	6	70	5	6	70
Undergraduate														
First-time, first-year undergraduate enrollment 2000 ^d	1,813,172	1,245,642	99,737	208,355	167,164	16,596	75,678	12	6	7	75	6	7	75
Percent freshmen intending science and engineering major 2000 ^{e,f}	33.1	30.7	45.3	37.5	34.1	30.5								
All bachelor's degrees 2004 ^g	1,362,834	962,887	86,030	122,618	105,165	9,914	76,220	11	8	9	97	8	9	97
Science and engineering bachelor's degrees 2004 ^g	437,228	296,576	41,178	38,369	33,437	3,231	24,437	7	8	9	92	8	9	92
Graduate students in science and engineering														
First time, full-time science and engineering grad enrollment 2004 ^h	58,853	40,617	5,566	3,832	3,421	342	5,075	7	11	12	119	11	12	119
Science and engineering PhD degrees 2010 ⁱ	21,279	15,824	2,276	1,026	1,204	78	871	7	15	13	203	15	13	203
Postdoctoral study commitments for 2010 PhDs (all fields)														
Number ⁱ	7,546	6,012	763	319	452			8	19	13	NA	19	13	NA

^aAll data except population counts and high school graduates are for U.S. citizens and permanent residents only.

^bU.S. Bureau of the Census (1998).

^cU.S. Department of Education (2001).

^dNSF (2007).

^eHERI data on intended major allow students to report multiple race-ethnic categories.

^fNational Science Board (2012).

^gNSF (2010).

^hNSF (2011c).

ⁱNSF (2011b).

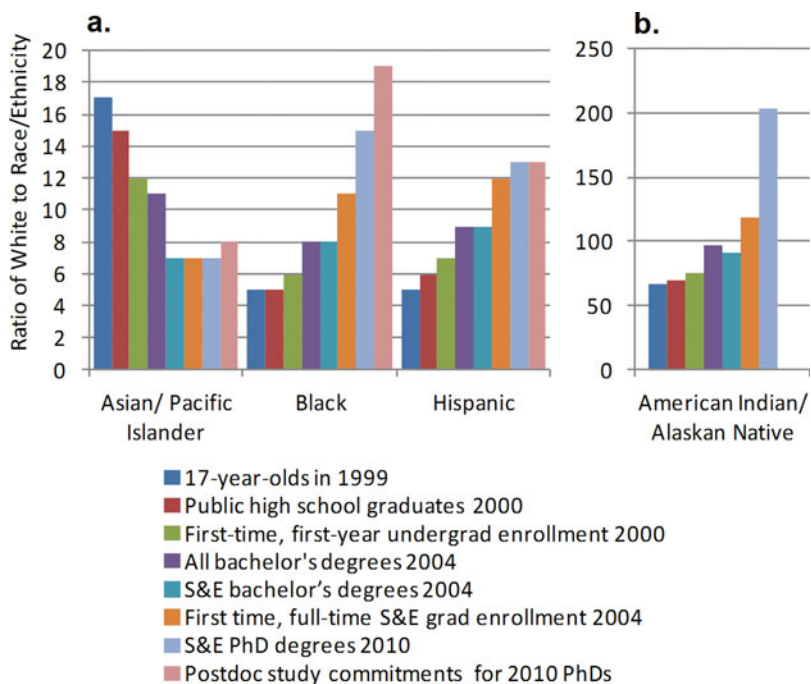


Figure 1. Ratios of Whites to other minority groups at stages in science and engineering education showing increasing disparities for Blacks, Hispanics, and American Indians/Alaskan Natives.

Disparities increased at the college entry level. Asian/Pacific Islanders were the most likely to enroll in college, again followed by Whites, Blacks, and American Indians/Alaskan Natives. Hispanics had the lowest college matriculation rates. In 2000, the number of Whites who were first-time, first-year college students was 69.8% of the population of Whites who graduated high school in 2000. For Asian/Pacific Islanders, the comparable figure was higher: 81.2%. The percentages for Blacks (63.5%), Hispanics (59.2%), and American Indians/Alaskan Natives (65.5%) were lower than the percentage for Whites and substantially below that of Asian/Pacific Islanders. The difference in first-time col-

lege enrollment rates—along with the differential rates of high school graduation—contributed to the race/ethnic disparities in the 2000 freshman class.

With the exception of Asian/Pacific Islanders, choice of major field in the freshman year of college did *not* contribute to race-ethnic disparities in science and engineering. For students in the freshman class of 2000, there was virtually no difference in the percentages of Whites and American Indians/Alaskan Natives planning to major in science or engineering. In these two groups, ~31% of the college freshmen planned to major in a science or engineering field. The percentage of Black freshmen with plans to major in a science or

Table 2. Transition percentages^a

Education level	Transition percentages for:				
	White	Asian/ Pacific Islander	Black	Hispanic	American Indian/ Alaskan Native
Public high school graduates in 2000 as percentage of 17-year-olds in 1999	66.7	78.7	56.0	50.6	63.3
First-time, first-year undergraduate enrollment in 2000 as percentage of 2000 high school graduates	69.8	81.2	63.5	59.2	65.5
2000 freshmen intending to major in science and engineering fields ^b	30.7	45.3	37.5	34.1	30.5
2004 bachelor's recipients as percentage of 2000 first-time, first-year enrollees	77.3	86.3	58.9	62.9	59.7
2004 bachelor's degree recipients with science and engineering degrees	30.8	47.9	31.3	31.8	32.6
2004 science and engineering bachelor's degree recipients as percentage of 2000 first-time, first-year enrollees	23.8	41.3	18.4	20.0	19.5
First-time, full-time science and engineering graduate school enrollees in 2004 as percent of 2004 science and engineering bachelor's recipients	13.7	13.5	10.0	10.2	10.6
2010 science and engineering PhDs as percentage of 2004 first-time, full-time science and engineering graduate school enrollees	39.0	40.9	26.8	35.2	22.8
2010 PhDs with commitment for postdoctoral study (all fields)	38.8	47.4	28.2	40.4	NA

^a All data except population counts and high school graduates are for U.S. citizens and permanent residents only.

^b HERI data on intended major allow students to report multiple race-ethnic categories.

engineering field (37.5%), along with the percentage of Hispanics planning to major in these fields (34.1%), exceeded the comparable percentage for their White classmates. Among college freshmen who identified themselves as Asian/Pacific Islanders, 45.3% planned to be science or engineering majors. Thus, while large race-ethnic differences in high school graduation and college matriculation rates contributed to the underrepresentation of Blacks, Hispanics, and American Indians/Alaskan Natives in the freshman class of 2000, choice of major in the freshman year of college did not increase the underrepresentation of these groups in science and engineering.

For most of the race-ethnic groups, the percentage of 2004 college graduates with degrees in science and engineering fields was similar to that group's percentage of freshmen planning to major in these fields in 2000.³ Among those who earned baccalaureate degrees, differential rates of persistence in science and engineering majors does not seem to be a factor in the underrepresentation of Blacks, Hispanics, and American Indians/Alaskan Natives in these fields.

But the similarity in the percentage of freshmen science and engineering majors *within* each race-ethnic group and the percentage of science and engineering baccalaureate earners *within* each group 4 years later does not tell the whole story. Differences in college graduation rates across race-ethnic groups (for all baccalaureate recipients, regardless of major) were substantial and made a major contribution to the race-ethnic difference in the total number of science and engineering bachelor's degree earners.

As was the case for college enrollment in 2000, Asian/Pacific Islanders were the most likely to earn bachelor's degrees in 2004, followed by Whites. There was very little attrition among Asian/Pacific Islander college students. For Asian/Pacific Islanders, the number of college graduates in 2004 was 86.3%, as large as the freshman class of 2000. The comparable percentage for Whites was 77.3%. For Blacks, Hispanics, and American Indians/Alaskan Natives, the number of college graduates in 2004 was a much smaller fraction of the first-time, first-year matriculants in 2000. The number of Black college graduates in 2004 (122,618) was 58.9% of the population of Black first-time, first-year college students in 2000 (208,355). For American Indians/Alaskan natives, the comparable figure was 57.7%, and for Hispanics, it was 62.9%. The substantially higher college graduation rates for Asian/Pacific Islanders and Whites increased the gap between these groups and the URM populations.

While White and URM college freshmen reported similar intentions to major in science and engineering fields, there were large differences in college graduation rates for each race-ethnic group. The graduation rates had a major impact on the number of Blacks, Hispanics, and American Indians/Alaskan Natives earning bachelor's degrees in science and engineering fields.

Among 2004 college graduates with science and engineering degrees, the ratios of Whites to Blacks (8:1) and Whites to Hispanics (9:1) were the same as the ratios for all baccalaureate degree earners.

Race-ethnic differences in the decision to go to graduate school in science and engineering fields further con-

tributed to the underrepresentation of URM groups, but not nearly to the same degree as differences in college graduation rates. In 2004, the graduate school transition rates for 2004 science and engineering bachelor's degree recipients were 13.7% for Whites, 13.5% for Asian/Pacific Islanders, 10.0% for Blacks, 10.2% for Hispanics, and 10.6% for American Indians/Alaskan Natives.

In graduate school, once again discrepancies in degree completion rates dramatically increased the amount of underrepresentation, particularly for Blacks and American Indians/Alaskan Natives. In 2010, the number of Whites earning science or engineering doctorates was 39.0% of the number of first-time, full-time White science and engineering graduate students in 2004. Asian/Pacific Islanders had a nearly identical rate: 40.9%. The percentage for Hispanics (35.2%) was lower, and they lost ground relative to Whites and Asian/Pacific Islanders. Black science and engineering PhD earners in 2010 were a much smaller fraction (26.8%) of the Black first-time, first-year graduate school entrants in 2004. For American Indians/Alaskan Natives, the percentage was lower still: 22.8%. Differences in 6-year PhD degree completion percentages made a substantial contribution to underrepresentation of Blacks, Hispanics, and American Indians/Alaskan Natives in science and engineering. Among 2010 doctoral recipients, the ratio of Whites to Blacks was 15:1, well above the ratios for these two groups at graduate school enrollment (11:1) and college graduation (8:1). For Whites and Hispanics, the ratio among 2010 doctoral recipients was 13:1, a slight increase over the ratio for new graduate students (12:1) and college graduates (9:1). At the PhD level in 2010, the ratio of Whites to American Indians/Alaskan Natives was more than 200:1, substantially higher than the comparable ratios for first-time, full-time graduate students in science and engineering (119:1) and college graduates (92:1).

Race-ethnic differences increased again at the postdoctoral level. In 2010, Asian/Pacific Islander PhD earners were the most likely to have definite commitments for further training upon graduation (47.4%). Among Hispanics and Whites, nearly equal percentages (40.4% and 38.8%, respectively) had definite postdoctoral study plans. The fraction of Black PhD earners with definite commitments for postdoctoral study was 28.2%, much lower than the fraction for other groups. (Survey samples were too small to report the figure for American Indians/Alaskan Natives.) The difference in plans for postdoctoral study increased the cumulative disparity between Whites and Blacks from 15:1 at the PhD level to 19:1 at the postdoctoral level.

In general, differences in graduation rates (high school, college, and graduate school) make a larger contribution to race-ethnic disparities in science than variations in choice of major field or differential matriculation rates (college, graduate school, and postdoctoral study). A recapitulation of these findings by race-ethnic group underscores this general pattern, while also highlighting some important variations across the URM group (Figure 2).

Asian/Pacific Islanders increased their representation relative to other groups at each step, from high school graduation through college graduation. They were the only group with a substantially higher percentage planning to major in science and engineering fields and the only group to have a higher fraction of their baccalaureates earning degrees in science or engineering. At every education level except

³The analysis did not, however, examine changes from one science and engineering field to another.

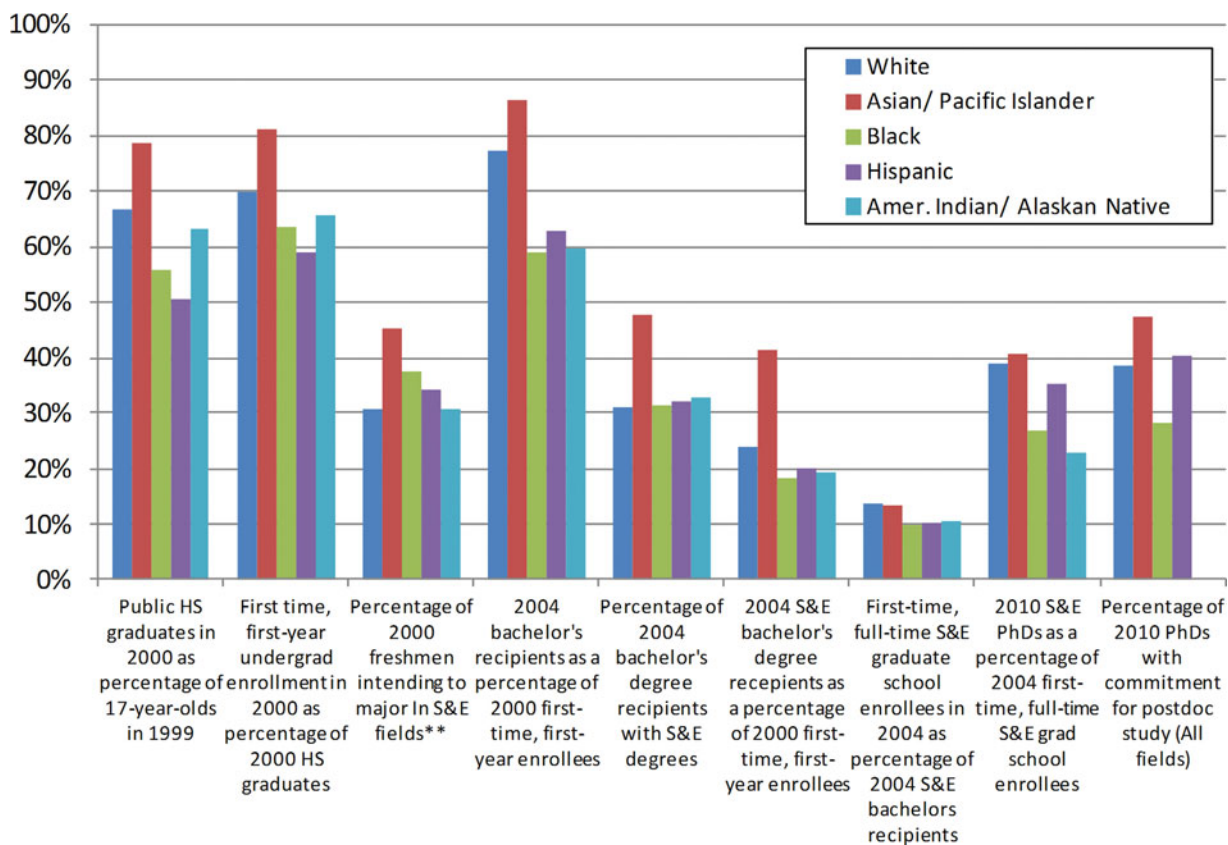


Figure 2. Transition percentages between education levels (as described in Table 2) for race-ethnic groups.

graduate enrollment and earned doctorates, Asian/Pacific Islanders increased their representation relative to other groups.

Blacks lost ground relative to Whites and Asian/Pacific Islanders at every stage except for choice of major field in the freshman year of college, where the percentage of Black freshmen intending to major in science or engineering exceeded that of their White peers. Blacks had lower college and graduate school matriculation rates than Whites and Asian/Pacific Islanders, but the largest Black-White differentials occurred in graduation rates from high school, college, and graduate school.

The disparities between Whites and Hispanics were particularly large at high school graduation. In 2000, the number of Hispanic high school graduates was a smaller percentage of the eligible population than it was for any other group. Large White-Hispanic differentials were found at college graduation as well. Smaller disparities existed for college and graduate school matriculants. Once students were enrolled in graduate school, White-Hispanic differentials decreased. The fraction of Hispanic graduate students earning doctoral degrees and the percentage of Hispanic doctorates with commitments for postdoctoral training were very similar to those of Whites.

American Indians/Alaskan Natives had high school graduation and matriculation percentages (both college and graduate school) that were similar to those of Whites. For these two groups, the degree completion differentials (college and

graduate school) were large and made the greatest contribution to underrepresentation of American Indians/Alaskan Natives in science and engineering.

DISCUSSION

There are race-ethnic disparities at all educational levels in the rate at which groups participate in science and engineering curricula (National Academy of Science, 2011). The loss of URM participants is larger at some stages than at others. Among college freshmen, race-ethnic differences in plans for a science or engineering major are very small and have little impact on the ultimate level of underrepresentation, while disparities in matriculation rates (both undergraduate and graduate) make major contributions to the overall gap across race-ethnic groups. By far, however, differential graduation rates at both the undergraduate and graduate level (along with postdoctoral plans for Blacks) have the greatest impact on the underrepresentation of Blacks, Hispanics, and American Indians/Alaskan Natives in doctoral-level careers in science and engineering. On these points, the data are clear. What the cross-sectional comparisons cannot elucidate are the exact reasons for the differences in graduation rates, which could be due to financial pressures, motivational factors (lack of peer, family, or teacher encouragement), or deficiencies in academic preparation. Nonetheless, the differential graduation rates suggest that programs focused on reducing attrition

(mentoring, financial aid, and educational enrichment) will produce the largest returns.

The participation level of Blacks, Hispanics, and American Indians/Alaskan Natives in science is far from static, and there have been some improvements over time. The percentage of bachelor's degrees in science and engineering earned by URM students rose from 10% in 1989 to 21% in 2010. Their share of earned doctorates rose from 4% to nearly 11% during the same period (NSF, 2011d). But, at this pace, it will take decades to eliminate the remaining disparities. Moreover, the relative gains appear to be slowing after 2000. This may be, in part, the result of court rulings and ballot initiatives limiting affirmative action programs. Several studies have found that URM enrollments at highly selective colleges declined following affirmative action bans in the late 1990s and early 2000s (Backes, 2012; Hinrichs, 2012). Moreover, Garces (2013) finds that the greatest losses in URM graduate enrollments attributable to affirmative action bans were in science and engineering fields.

Federal agencies have created scores of initiatives to increase participation in science, but many of these programs are too small and too narrowly focused to have a substantial impact. A recent study by the U.S. Government Accountability Office found there are 209 federal programs designed to increase knowledge of science, technology, engineering, and mathematics (STEM) fields and attainment of STEM degrees. One-third of the programs had obligations of \$1 million or less in fiscal 2010, and 83% overlapped with at least one other program in terms of their target populations and objectives (U.S. Government Accountability Office, 2012).

Recently, the NIH Working Group on Diversity in the Biomedical Workforce (NIH, 2012) produced 13 recommendations in response to the finding by Ginther *et al.* (2011) that Blacks are significantly underrepresented among NIH grant recipients. The working group's recommendations included more data and analysis on training outcomes, stimulating the interest of K–12 students in science, more undergraduate scholarships, more partnerships with minority scientific associations, an advisory group to the director on diversity issues, bias/diversity awareness training, and new efforts to recruit minority scientists to the intramural program. It is hard to criticize the need for these actions. But the race–ethnic disparities are the legacy of a long history of exclusion and disadvantage, and they pervade all levels of our education system. It is naïve to think that they can be eliminated by simple, inexpensive, and narrowly targeted interventions of short duration. Even after legal exclusions are eliminated and other barriers to participation lowered, the effects of prejudice, negative stereotypes, and isolation often remain. Without a major initiative to provide access to quality education for all students at all levels, small-scale programs at any given stage of the education process will continue to be insufficient.

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