Diversity in physics

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The underrepresentation of women and minorities among recipients of physics degrees is a manifestation of systemic educational problems. Corrective measures must begin in the primary grades and continue through university schooling and beyond.

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Physics stands out among the sciences for its inability to attract enough women or minorities that their representation in physics will, in the foreseeable future, be commensurate with their proportions in the general population. True, among the so-called hard sciences, physics has experienced over the past decade the most significant rate of increase in women PhDs. But the baseline number of women PhDs, say from the 1970s, is small. In 2003, women received only 22% of bachelor's degrees and 18% of PhDs awarded in physics by US colleges and universities; those numbers include degrees awarded to non-US citizens. In the same year, African Americans received 3.5% of bachelor's degrees and 2.3% of PhDs awarded in physics to US citizens. For Hispanic citizens, the numbers are 3.4% of bachelor's degrees and 2.5% of PhDs. In 2004, women received 184 of 1186 total physics doctorates, or 15.5%. African American students who were citizens or permanent residents accounted for 13 doctorates, about 1% of the total. Hispanic citizens and permanent residents also received 13 doctorates. A single PhD was awarded to an American Indian in 2004. For additional statistics, see figure 1 and tables 1 and 2.[1]

Low though they are, the percentages of physics degree recipients who are women represent significant increases from 30 years ago. Those gains were achieved through the efforts of many in the science community to promote more diversity in physics, and they track the modern civil-rights movement for women that dates from the early 1970s. Intervention programs introduced girls and young women to the possibilities of nontraditional careers and encouraged them to take more mathematics and science courses. Underrepresented minorities (URMs), defined as African Americans, Hispanics, and American Indians, have received increasing numbers of bachelor's degrees in physics since the 1970s, except for a serious decrease in production for African Americans that began in the late 1990s and continues to this day, albeit with significant fluctuations. The statistics for PhDs paint a less optimistic picture: Both African Americans and Hispanics have earned stagnant or declining numbers of PhDs during the past decade.

Physicists need to be aware that the figures I have quoted compare rather unfavorably with those for chemistry. Chemistry doctorates awarded to women by US institutions grew from 6.4% of the total in the 1960s to 10.4% of the total in the 1970s to nearly 20% of the total in the 1980s. In 2004, women received almost 32% of all US chemistry doctorates awarded, a proportion that has been relatively stable since the mid-1990s. At the bachelor's level, women and men receive an approximately equal number of chemistry degrees.

Since the 1960s, URMs have increased their percentage of chemistry doctorates, albeit at a slower rate than women. In 2004, African American citizens and permanent residents received 2.3%, Hispanic citizens and permanent residents earned 2.2%, and American Indians received 0.2% of all doctorates awarded. Collectively, URMs accounted for 7.9%, or 93 of 1180 doctorates in chemistry awarded to US citizens and permanent residents. The 27 physics PhDs awarded to URMs in 2004 were 4.8% of physics doctorates awarded to all US citizens and permanent residents.

Institutions that serve minorities

Historically black colleges and universities and Hispanic-serving institutions have had a disproportionate impact in producing URM baccalaureate degree holders. Between 1992 and 2001, HBCUs granted 45–50% of bachelor's degrees in the physical sciences awarded to all African Americans and 48–56% of the degrees conferred on African American women. The 10 institutions awarding the most bachelor's degrees to African Americans in 2003–04 were all HBCUs. According to American Institute of Physics data, the eight departments that awarded an average of at least three physics bachelor's degrees to African Americans for the classes of 2001, 2002, and 2003 were all at HBCUs.[2]

Of the 10 colleges and universities awarding the most bachelor's degrees in the physical sciences to Hispanics in 2003–04, most were Hispanic-serving institutions. The exceptions are all research universities: University of Texas at Austin; University of California, Santa Cruz and San Diego campuses; and MIT. An institution could appear on *Diverse* magazine's top-50 lists for African American and Hispanic physical sciences baccalaureates by awarding 5 and 4 degrees, respectively.[3]

It is not reasonable to expect growth in the URM PhD population without first addressing the small number of physics bachelor's degrees awarded. And perhaps it is not reasonable to expect an increased number of bachelor's degrees in light of experiences in K–12 schools, uneven career guidance, small numbers of visible role models, and few institutions with significant degree output. Those factors combine to decrease the pool of interested and well-prepared students who can consider advanced study in physics.

Among those graduating high school in 2000, only 26% of African Americans and 26% of Hispanics took any physics classes. In comparison, 62% of African Americans and 56% of Hispanics took chemistry courses.[4] Behind those numbers is the issue of the nature and quality of science education at elementary- and middle-school levels, including the extent to which physics concepts are being taught. Research suggests that K–12 schools largely attended by minority students have higher proportions of instructors teaching subjects they were not trained to teach.[5] The problems related to the nation's overall scarcity of certified physics teachers are likely magnified for schools with significant African American, Hispanic, and American Indian enrollment.

The gap between males and females taking at least some physics classes in high school is closing; 36% of males in the class of 2000 reported taking some physics, as did 32% of females. But both overall numbers remain unacceptably low. Compare them with the 58% of males and 67% of females who took chemistry.

Clearly, most students graduate high school with no formal instruction in physics. That means low levels of physics literacy among the adult population. Or does it?

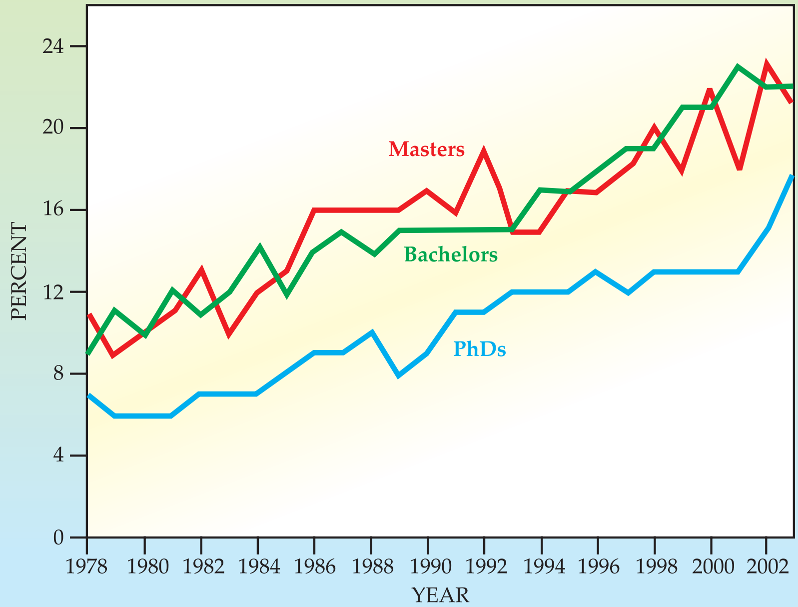

Figure 1. Women received an increasing percentage of the physics degrees from US colleges and universities from 1978 to 2003. Still, in 2003, women received far less than one-fourth of the bachelor's, master's, and PhD degrees conferred in the US. (Chart adapted from the American Institute of Physics Statistical Research Center, *Enrollments and Degrees Report, 2003*.)

A human activity

Opportunities exist for adults to develop a physics sense, even if they have not been exposed to a significant number of physics concepts. A trip to the local science museum can be enlightening, but one can also learn a good deal just by paying attention to everyday events—how a car responds during a drive around town, the forces at play when one assembles something, the trajectory of a ball from bat to glove. In observing everyday physics, adults are doing what some cognitive scientists argue is a natural component of child development. As children experience the physical, living, and social worlds, they develop assumptions about how those worlds work. Consider, for example, the following discussion of how babies reflect on issues of cause and effect, from *The Scientist in the Crib* by Alison Gopnik, Andrew Meltzoff, and Patricia Kuhl:

> There are other reasons to think that, at about a year, babies understand how objects can influence each other. You can show babies a classic case of "billiard ball" causality: a toy car rolling along and bumping into another toy car, which then moves off. Or you can show them almost the same sequence, with just a slight difference—the first car gets close to the second car, and the second car rolls away, but the two cars don't actually touch. Although this is very similar to the first sequence, it violates a basic causal principle. Usually, at least, objects can't act on each other at a distance. Ten-month-olds look longer at the second scene than the first one. This suggests that they recognize just how peculiar it really is. And this, in turn, suggests that they know something about how objects can causally influence each other, quite independent of their own actions.[6]

The book cites other examples, including toddlers providing appropriate explanations about what caused what and making predictions about how simple mechanical systems will work.

Young children explore, try things out, and try to make sense of the world. Their natural experiments are coupled with social interactions that reinforce their proclivity for sense making. On the topic of how babies learn about the external world, Gopnik and coauthors note: "They start out with some crucial assumptions, assumptions that seem to be built in. But, just as important, they are endowed with powerful abilities to learn, and even more powerful motivations."[7]

How do children move from behaving in ways that are so clearly consistent with learning about the physical world to avoiding courses that can support their understanding of it? Put a different way, how does physics move from being an inclusive domain for learning to an exclusive or exclusionary one?

Fixing the system

Sixty-five percent of undergraduate students are female or URMs. Clearly, their reduced interest in physics and the barriers to their entering the field do not bode well for the long-term health of the discipline. It is important to consider how the current patterns of participation might be changed. The problems that have led from physics as a part of what it means to be human to physics as a community lacking diversity can be fixed. But, I contend, the issue of diversity in physics is a systems problem, and it can respond only to a thoughtful suite of interventions that begins at the earliest grade level and moves through the professional life span. Those interventions would include at least the following components:

▶ Education and professional development so that those who teach physics are confident and comfortable teaching physics *concepts*.

▶ High-quality, hands-on, inquiry-based science for the primary grades.

▶ Development and dissemination of high-quality, research-based curricula for the middle grades.

▶ Experimentation with curriculum and instructional models, including such strategies as "physics first," to increase the number and diversity of students taking physics in high school (see reference 8 and the Reference Frame column by Leon Lederman, PHYSICS TODAY, September 2001, page 11).

Table 1. Doctorates by field, sex, and race, class of 2004

Field	All	US*	Women	American Indian*	Asian*	African American*	Hispanic*
Physics	1186	559	184	1	44	13	13
Chemistry	1987	1180	629	4	110	46	43
Mathematics	1075	510	305	0	54	10	26
Computer & Information Science	949	448	195	2	72	17	13
Engineering	5776	2182	1014	6	354	94	88

Source: T. B. Hoffer et al., ref. 1
*US citizens and permanent residents

Such experimentation may be especially valuable in schools that serve a significant number of URMs.

▶ Recruitment of minority students at all levels to take physics classes and to engage in informal physics experiences such as those offered in science and technology centers, after-school programs, and camps.

▶ Support of physics programs in institutions that serve URMs.

▶ Increased recruitment of bachelor's-level URM and women students for summer internships and research opportunities.

▶ Transfer of effective models from high-production to low-production institutions.

▶ Exploration of the efficacy of mentoring or a community of colleagues to improve the retention of women and URMs in graduate school.

▶ Understanding of the departmental climate as a factor in increasing student diversity.

▶ Awards and recognition for individuals and departments that effectively mentor URMs.

▶ Support, through professional organizations, for the professional development of women, URMs, and persons with disabilities as well as for those who teach and advise them.

▶ Equal opportunities for employment and advancement.

▶ Focused attention on the needs of female URMs in physics at all levels.

Some of the interventions are general and would have a positive impact on the study of physics for all students; ensuring that teachers are comfortable with physics concepts is one example. Other proposals, including focused attention on the needs of female URMs, are targeted. In many instances, people's ability or willingness to implement targeted programming has been dampened by concerns about legal challenges.[9] Rather than seek ways to legally and effectively serve populations most in need, institutions have tended to cancel their efforts or make them "for all," a move that neither increases the number being served nor addresses the special needs faced by those in the minority. Legally responding to the concerns of women and URMs is an issue that deserves more discussion in the physics community.

It is crucial that science educators work to maintain the early excitement, interest, and curiosity that children bring with them when they begin school. Nonexistent or poor early science instruction can affect students' attitudes toward science and their future willingness to take elective courses in science. Professional development that allows teachers to learn in the same way they should teach is demonstrably effective. Programs such as the Teachers Academy of Math and Science in Chicago and La Main à la Pâte, begun in France but now operating worldwide, focus on enhancing the interactions between scientists and educators and encourage the use of hands-on, inquiry-based strategies that move from phenomena to concepts. Many of the topics they recommend are from physics. Wherever the projects are in use, their results are universally engaging for children.

Lederman's physics-first concept, in which physics is a required first course rather than an elective capstone course, changes how the student relates to the disciplines of physics, chemistry, and biology. When he proposed the idea in the mid-1990s, I asked Lederman to look at the patterns of course-taking for different demographic groups in the schools that reordered their sequence. He found more students, and a more diverse group of students, were taking more science classes.

After the degree

Why are some institutions effective in recruiting, retaining, and graduating physics students from diverse populations while others are not? Student potential, the reality of student capacity, the learning environment, the curriculum, and expectations all play a role. But the fact is URM baccalaureate degree recipients in physics come disproportionately from HBCUs and Hispanic-serving institutions.

A 2005 talk-back session with newly minted African American PhDs who participated in the Packard graduate scholars program provided insights into the success of

Table 2. Physics degrees granted to US citizens by race and ethnicity, class of 2003

	Bachelor's		Exiting Master's		PhD	
	Number	Percent	Number	Percent	Number	Percent
African American	152	4	15	4	12	2
Hispanic	144	3	14	4	13	2
White	3711	87	332	83	465	88
Asian	171	4	20	5	29	6
Other	110	3	18	4	11	2
Total US Citizens	4288	100	399	100	530	100

Source: American Institute of Physics Statistical Research Center, *Enrollments and Degrees Report, 2003*

Figure 2. Packard scholars exchange ideas during their July 2005 annual meeting held in Monterey, California. In the foreground, with his back to the camera, is James Stith of the American Institute of Physics.

minority-serving institutions. The program supported the graduate-level education of science and engineering students who had received their undergraduate degrees from HBCUs (see figure 2). In the talk-back session, scholars contrasted the communities of the black colleges with those of their graduate schools and noted that the HBCUs gave them confidence, encouragement, and tangible proof that African Americans could succeed in science. In a February 2006 *Inside Higher Education* editorial, Daryl Chubin, who moderated the talk-back session, summarized the students' messages and their implications.[10] Gender and race bias, the students found, is a graduate-school reality that has to be managed, and even though successful students devise their own ways to cope, institutions need to consider formal systems to address discrimination. In particular, institutions need to reward outreach and work to develop student diversity. The Packard scholars also noted that they must stay focused on completing the requirements for their doctorate.

One important comment Chubin made in his editorial was that any institution of higher education can effectively serve minorities. A recent article by Michael Summers and Freeman Hrabowski in the journal *Science* gives an example of a predominantly majority institution, the University of Maryland, Baltimore County, that aspired to and became a minority-serving school.[11] I must note, though, that any prospect for success in increasing diversity is predicated on leadership—having it and nurturing it.

In 1876 Edward Bouchet received the first PhD awarded to an African American from a US university.[12] His degree, from Yale University, was in physics. Little in Bouchet's background would have led one to predict that outcome. The son of former slaves, he was able to demonstrate his capacity to achieve in physics by being given the opportunities for education up to the highest levels. And yet, when he completed his doctorate, he found no employment opportunities appropriate to his level of preparation.

Subsequent African American doctorates, at least through the civil-rights years of the 1960s, worked in HBCUs or in government. But until employment opportunities opened more broadly in the 1970s, one could not have reasonably expected a significant influx of African Americans into the study of physics. A feedback loop exists between the opportunities for employment and advancement in a field and the ability to attract and retain people. At least for women in physics, appointments to faculty positions seem to track with the number of women in the overall pool. That is not the case for women in chemistry, at least at the major research universities. Industry has done a better job at offering women with chemistry degrees employment in proportion to their numbers.

It will not be easy to change the system of education and career opportunities in physics to one that is fully supportive of diversity. But failing to consider change is unacceptable to the health of the field.

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