Chapter 4

Postsecondary Education

The postsecondary system is unique in its mission to create producers of science and technology—scientists, engineers, technologists, and educators—who discover, synthesize, and transmit knowledge that increases understanding of the natural world, enhances the quality of life, and strengthens the economic and social fabric. Recently, however, the postsecondary system has acquired additional roles. (See sidebar on postsecondary education.) These roles involve

- Preparing workers to apply science and technology. To be competitive, workers in nearly all fields must be able to apply a variety of mathematical, engineering, and basic science skills to production of top-quality goods and services. For example, anyone who records and interprets trends in data must comprehend mathematics and statistics; and many workers, from electricians to stockbrokers, use statistical knowledge in their work.
- Informing consumers of science and technology. Citizens are exposed to science and engineering in their everyday lives. They need to be educated about how to interpret scientific and technological information in order to make sound decisions about common activities such as parenting, consuming, and planning retirement.
- Achieving equity within the science and technology community. Current society pressures are increasing recruitment of groups that traditionally have been underrepresented in or underserved by science and technology education—females, blacks, Hispanics, Native Americans, and people with disabilities (Simpson & Anderson, 1992).

Factors Affecting Postsecondary Education

As the year 2000 approaches, factors both external to the postsecondary education system and internal to the system are having a profound effect on the purposes and roles of science, engineering, and technology education. Three of the external factors, summarized in a recent report from the Pew Higher Education Roundtable (1994), were value, budgetary support, and technology.[1]

In terms of value, students, parents, and policy makers are placing increasing pressure on colleges and universities to make college degrees more valuable for the labor market. Alarmed by increases in tuition and student debt, a perceived oversupply of college graduates, and the notion that students graduate without learning what they need to know, parents are asking institutions, "What exactly are we paying for?" They are measuring the quality of postsecondary education in terms of their children's ability to garner secure and well-paying jobs.

State policy makers are taking another look at value with regard to budgetary support. They have used reports of a positive relationship between college education and postgraduation earnings to redefine postsecondary education as a private, rather than public, good. They claim that students from well-off families should not have their college education subsidized at public expense. As a result, in many states public funding of postsecondary education has decreased, and public institutions of postsecondary education have to compete with public safety, health care, elementary and secondary education, and other services for state appropriations. This shift has affected private institutions, as well. They are now competing openly with their public counterparts for support from charitable, corporate, and other private sector sources.

Budgetary constraints are forcing more and more institutions to consider how changes in information technology make the delivery of quality education at a lower cost a possibility, a prospect that most have not yet fully explored. Differences in the way people deal with technology are also making this change possible. For instance, today's high school graduates are better acquainted and more comfortable with computer and information technologies than any generation before them. Moreover, a growing number of adult students hold full-time jobs while attending college and simply want an education, rather than a "campus experience."

Internal factors affecting science, engineering, and technical education include changes in the composition of the U.S. population. The 1990 census showed that during the 1980s the populations of Asians and Pacific Islanders living in the United States increased 99 percent, while the number of Hispanics increased by 54 percent (U.S. Bureau of the Census, 1994). In addition, the proportion of students attending college from groups that historically have been underserved by science and engineering—older students, females, racial and ethnic minorities, and people with disabilities—increased.[2] In light of such factors, educators and policy makers are reexamining how better to meet society's needs and pressures. ■

A Note on Terminology

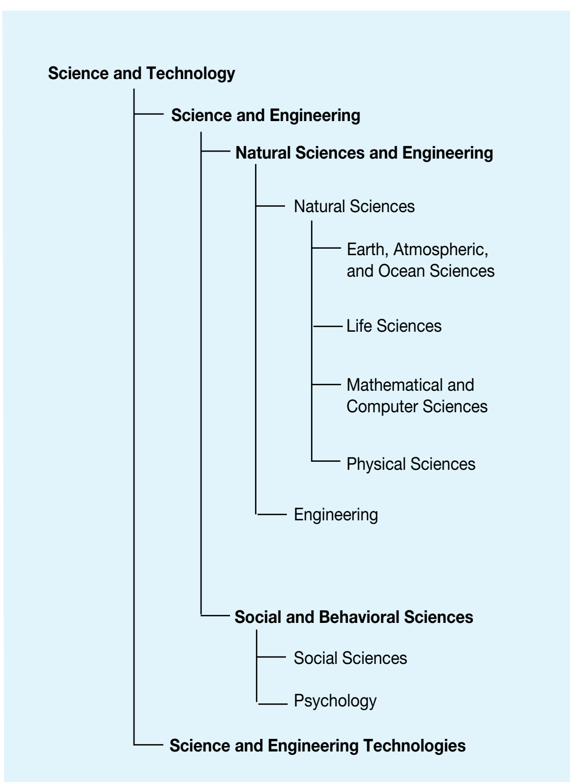
This chapter makes the following distinctions in terminology: Science and technology includes all fields of science and engineering and the development and use of technology; science and engineering encompasses all natural science, engineering, and social and behavioral science fields; natural sciences include study of earth sciences, atmospheric sciences, ocean sciences, life sciences, mathematical and computer sciences, and physical sciences; social and behavioral sciences include the social sciences and psychology. (See figure 4-1.) ■

The significance of these roles has increased because the influence of technology on society has made science and technology education an important contributor to national economic prosperity and societal well-being. (See sidebar on terminology and figure 4-1.)

This chapter considers the characteristics of students within the postsecondary systems and examines the state of science and engineering education within the context of the postsecondary environment.

FIGURE 4–1

A map of the science and technology fields used in this chapter



SOURCE: National Science Foundation. (1994a). *Science and engineering degrees: 1966-91* (NSF 94-305). Arlington, VA: NSF.

Student Characteristics

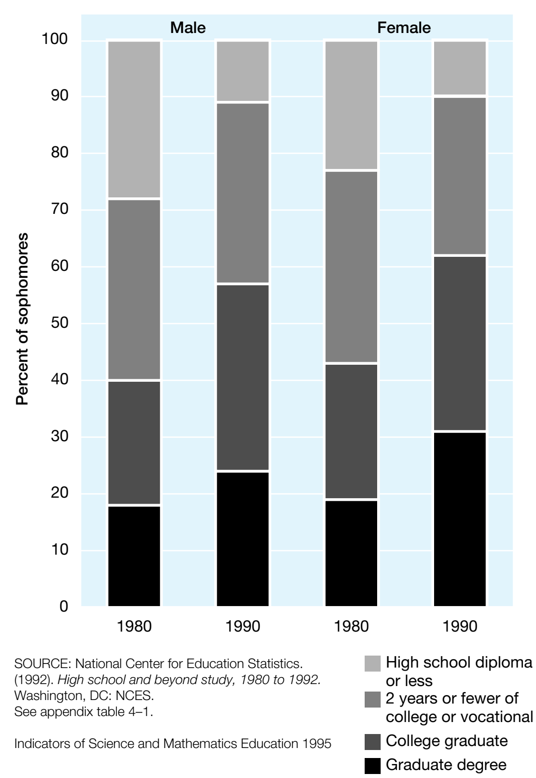
Students today aspire to higher levels of education than their recent predecessors and are enrolling in post-secondary institutions in greater numbers. The section below describes student characteristics in terms of student aspirations, enrollment patterns, and science and engineering coursetaking.

Aspirations

In general, today's high school students aspire to attend college and seek advanced degrees in much larger numbers than did their predecessors. (See sidebar on why more students are attending college on page 76.) About 90 percent of 1990 high school sophomores believed that they would attend at least some college, compared with about 70 percent of 1980 sophomores. (See figure 4-2 and appendix table 4-1.) Almost 60 percent of high school students surveyed in 1990 said they intend to seek a 4-year or graduate degree, up from about 40 percent in 1980. Of note is the growth in the percentage of female students who intend to earn a graduate degree. In 1980,

FIGURE 4–2

Percent of high school sophomores aspiring to various levels of education, by sex: 1980 and 1990



SOURCE: National Center for Education Statistics. (1992). *High school and beyond study, 1980 to 1992.* Washington, DC: NCES.
See appendix table 4–1.

Indicators of Science and Mathematics Education 1995

Why Are More Students Attending College?

One reason more students aspire to higher levels of education than in previous years may lie in students' perceptions of what it takes to get a well-paying job. The U.S. economy has shifted from a manufacturing-based economy, where higher levels of education have traditionally been unnecessary, to a service-based economy, where higher levels of education often are desirable. Between 1990 and 1992, the number of white-collar jobs in the United States increased by about 1 million, while the number of blue-collar jobs fell by about the same number (Bureau of Labor Statistics, 1993). In addition, since 1979, the salaries of individuals who have at least a bachelor's degree increased at much higher rates than those who ended their education after high school (Hecker, 1992). In the past decade, the gap in expected earnings between college and high school graduates increased by 20 percent (Pew, 1994).

This explanation is supported by a 1993 study that asked 1993 college freshmen why they decided to attend college. "Generation X" students placed more emphasis on money than did the freshmen of the baby boom generation. In 1993, 82 percent of freshmen said they decided to attend college "to get a better job," and 75 percent said "to make more money." In 1976, about 71 percent of freshmen said they wanted to get a better job, and 53 percent wanted to make more money. In both 1993 and 1976, about three-quarters of the surveyed students cited a desire to learn more about interesting things as a very important reason for attending college (Dey, Astin, & Korn, 1991; Astin, Korn, & Riggs, 1993). ■

just 19 percent of female high school students aspired to this level, compared with 31 percent in 1990. For comparison, in 1990, 24 percent of male high school sophomores expressed a desire to earn a graduate degree, up from 18 percent in 1980.

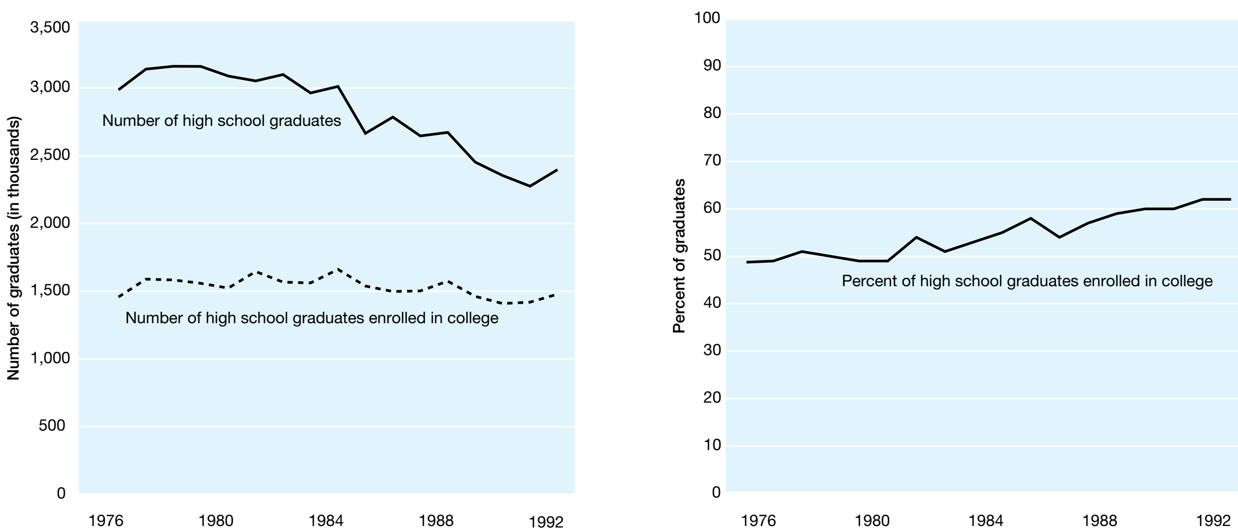
Enrollment

Over the past 20 years, the proportion of high school graduates who go directly on to college has increased from 49 to 62 percent. (See figure 4-3 and appendix table 4-2.) This rate has increased because the number enrolling in college within 12 months of their high school graduation remained steady over the period, while the number of high school graduates declined. The number of postsecondary students with limited English proficiency is growing, also, largely as a result of increases in immigration from Asia, the Pacific Islands, and Latin America (Rosenthal, 1992/1993).

Students enrolled in college in 1991 were more likely than their predecessors to be attending school part time and less likely to be 21 years old and younger. Between

FIGURE 4–3

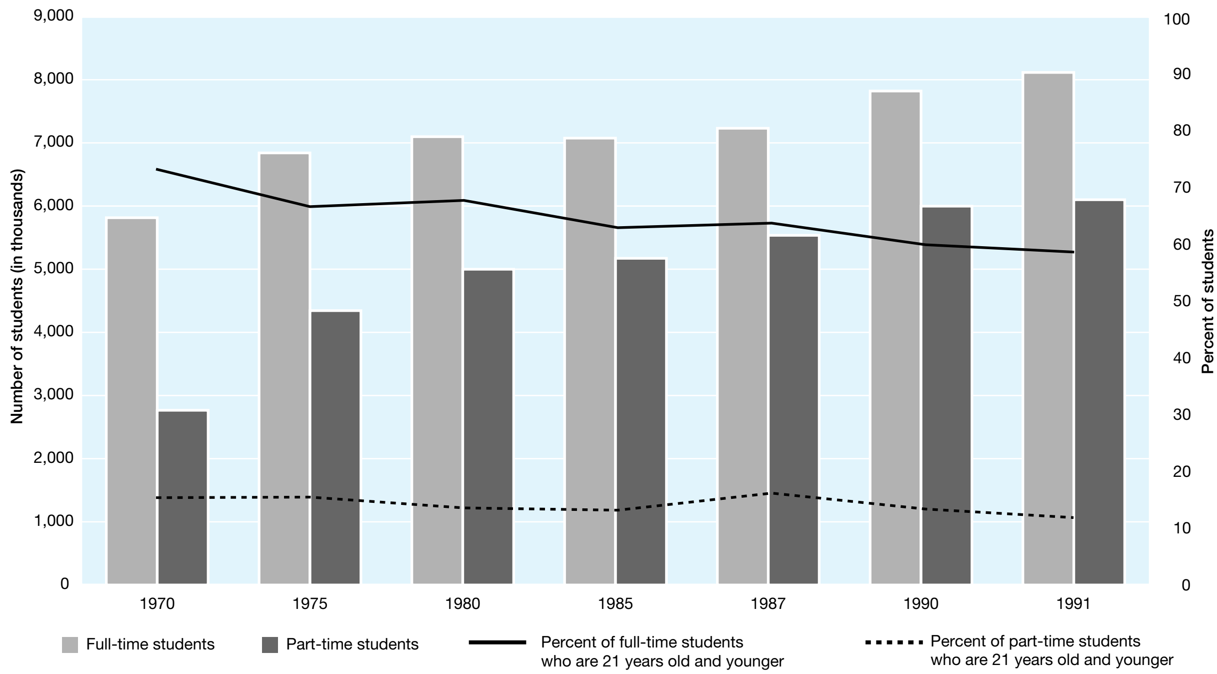
Number and percent of recent high school graduates and number who enrolled in college: 1972 to 1992



SOURCE: National Center for Education Statistics. (1994c). *Digest of educational statistics 1994* (NCES 94-115). Washington, DC: U.S. Government Printing Office.
See appendix table 4–2.

FIGURE 4–4

Total fall education enrollment, by attendance status and percent of students who are 21 years old and younger: 1970 to 1991



SOURCE: National Center for Education Statistics. (1994c). *Digest of educational statistics 1994* (NCES 94-115). Washington, DC: U.S. Government Printing Office.
See appendix table 4–3.

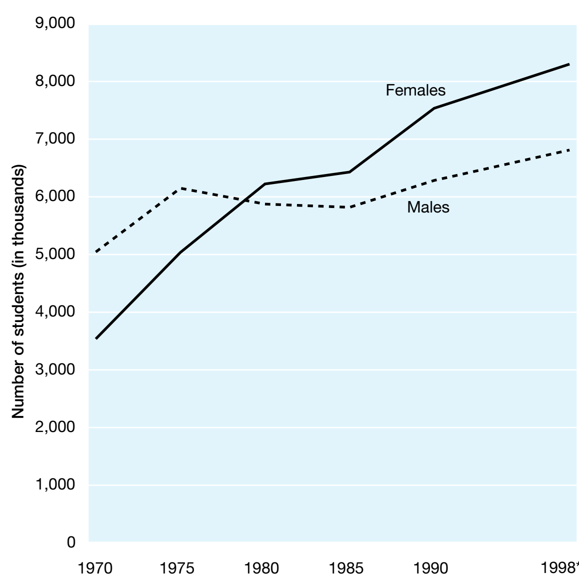
1970 and 1991, the number of postsecondary students who were enrolled part time increased from 2.8 million to 6.2 million, or from 32 percent to 43 percent of the total enrollment in postsecondary institutions. (See figure 4-4 and appendix table 4-3.) The proportion of full-time students 21 years old and younger decreased from 74 percent in 1970 to 59 percent in 1991. The proportion of part-time students 21 years old and younger decreased from 16 percent in 1970 to 13 percent in 1991.

Females

Between 1970 and 1991, there was a large shift in the makeup of postsecondary enrollment. In 1970, females accounted for only 41 percent of total postsecondary enrollment, but they made up 55 percent of enrollment by 1991. (See figure 4-5 and appendix table 4-4.) The postsecondary enrollment of males increased by nearly one-third during this 20-year period, while the number of females going to college more than doubled.

FIGURE 4–5

Total fall enrollment in postsecondary institutions, by sex: 1970 to 1998 (projected)



*1998 data are projected.
SOURCE: National Center for Education Statistics. (1994c). *Digest of educational statistics 1994* (NCES 94-115). Washington, DC: U.S. Government Printing Office.
See appendix table 4–4.

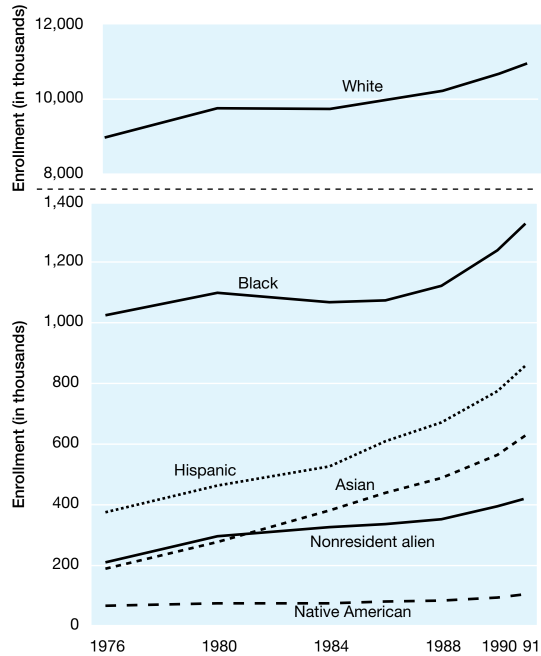
Racial and Ethnic Groups

Similarly, the ethnic and racial composition of postsecondary institutions has changed since the 1970s. (See figure 4-6 and appendix table 4-5.) In 1976,[3] whites made up 84 percent of U.S. citizens enrolled in postsecondary institutions. By 1991, that proportion had fallen to 79 percent. During the intervening 15 years, the enrollment of blacks, Hispanics, and Native Americans increased by 55 percent, while enrollment of whites increased by just 21 percent. Despite these increases in enrollment, the total number of bachelor's degrees earned by these minority groups increased only 33 percent during this period.

One reason for this disparity is that 2-year institutions enroll particularly high proportions of black, Hispanic, and Native American postsecondary students. (See appendix table 4-5.) Together, these groups accounted for 20 percent of the enrollment in 2-year institutions and 14 percent in 4-year institutions. In 1991, about 56 percent of Hispanic students, 55 percent of Native American students, and 43 percent of black students enrolled in postsecondary education were enrolled in 2-year institutions (NCES, 1994a). In comparison, 40 percent of Asian students and 38 percent of white students were enrolled in 2-year institutions.

FIGURE 4–6

Total fall enrollment in postsecondary institutions, by race or ethnic origin: 1976 to 1991



NOTES: Persons of Hispanic origin may be of any race. White enrollment uses a different scale.
SOURCES: National Center for Education Statistics. (1994c). *Digest of educational statistics 1994* (NCES 94-115). Washington, DC: U.S. Government Printing Office; National Center for Education Statistics. (1994d). *Fall enrollment in colleges and universities.* Unpublished tabulations.
See appendix table 4–5.

Indicators of Science and Mathematics Education 1995

Individuals with Disabilities

Access to postsecondary education is a key to individual financial success and independence. A 1987 study (Fairweather & Shaver, 1990) showed that students with disabilities may not be attaining access to postsecondary education in proportions equal to the general population—only 20 percent of orthopedically impaired, 24 percent of speech-impaired, 33 percent of hearing-impaired, and 40 percent of visually impaired high school graduates took at least one course in a 2- or 4-year institution within a year of graduation (Fairweather & Shaver, 1990). In 1990, about 8 percent of all undergraduate students had some form of a disability. About the same proportion of graduate students had some form of disability (NSF, 1994e). The proportion of students with disabilities in science and engineering fields is similar.

Coursetaking

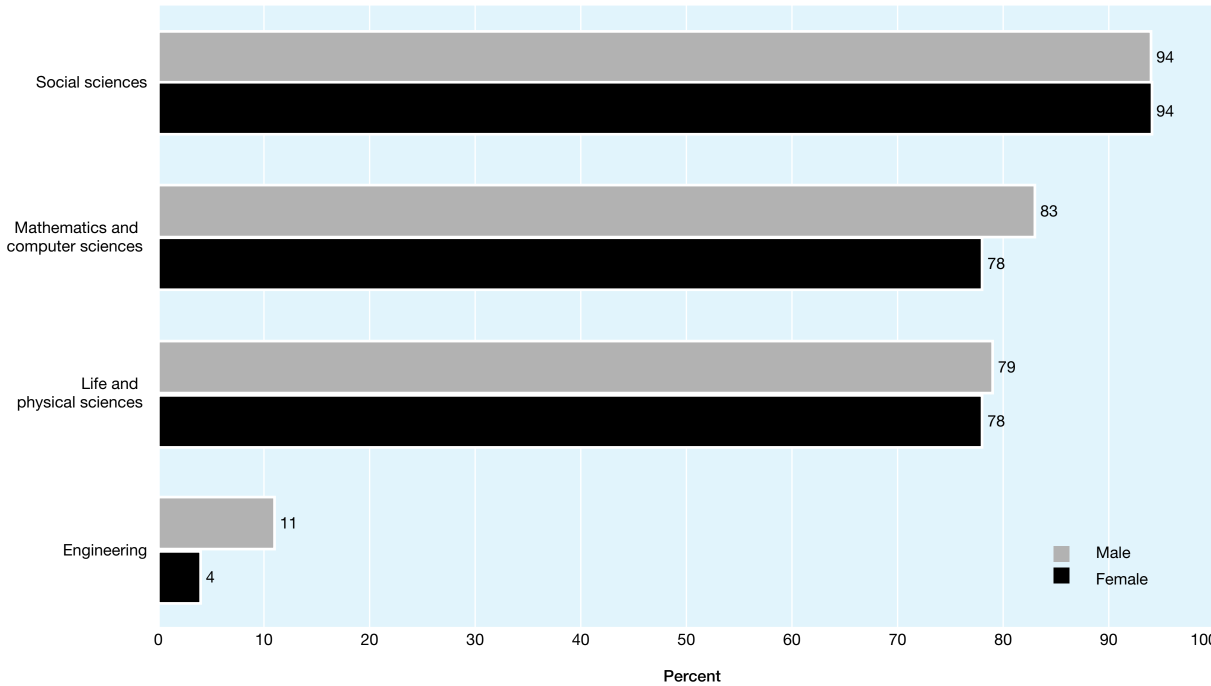
Most students, even those who are not science or engineering majors, take one or more science courses before they graduate. For example, in 1991, about 80 percent of students who earned a bachelor's degree in a field other than the life and physical sciences took one or more courses in these fields; about 17 percent of these took five or more courses. (See figure 4-7 on page 79 and appendix table 4-6.) The same pattern existed for mathematics and computer sciences courses. However, almost all nonmajors took at least one course in the social and behavioral sciences during their undergraduate careers; about half took five or more courses. Few non-science or -engineering majors took engineering courses. Males were slightly more likely to have taken at least one course in any science or engineering field than were females. (See sidebar on female achievement and figure 4-8.)

Females Outperform Males on Science and Engineering Grading Scales

Females tend to outperform males in the science and engineering classroom—and, indeed, in all fields. Overall, 59 percent of females who earned bachelor's degrees in 1991 graduated with a grade point average (GPA) of 3.0 or better on a 1.0 to 4.0 scale. (See figure 4-8 and appendix table 4-7.) Only 47 percent of males earned a 3.0 GPA. Females outperformed males in all science and engineering major fields—the largest disparities were in mathematical and computer sciences and engineering. Males' grades were most similar to females' grades in the life and physical sciences. ■

FIGURE 4–7

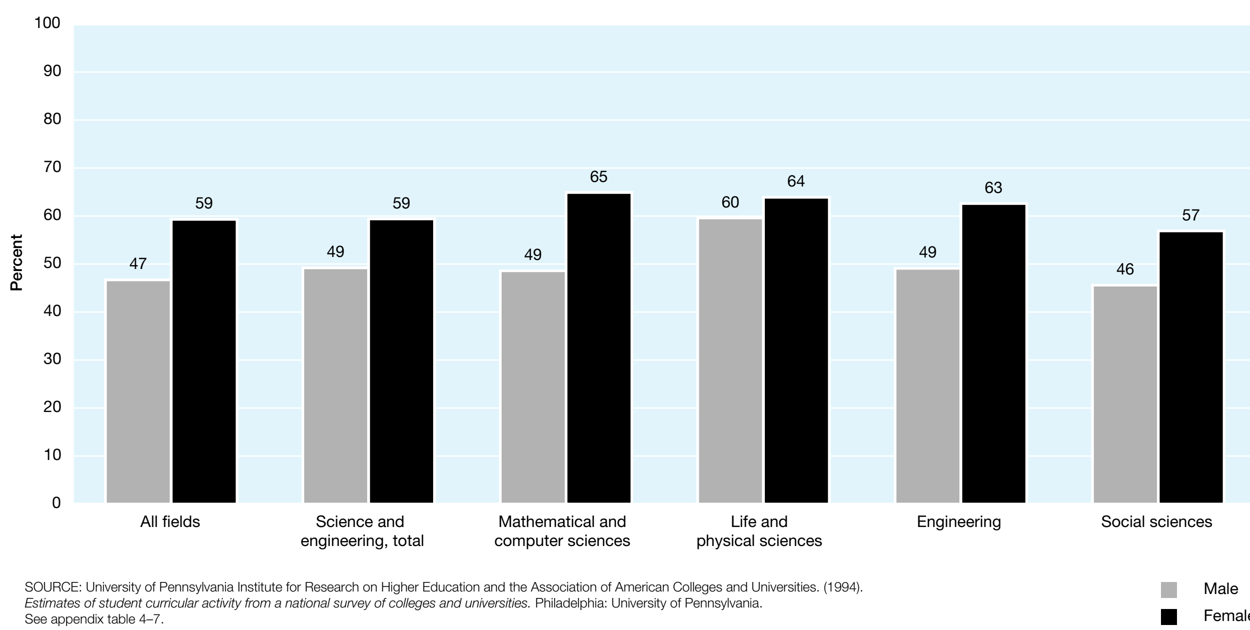
Percent of 1991 bachelor's degree recipients who took one or more courses in selected science and engineering course fields in which they did not major, by course field and sex: 1994



SOURCE: University of Pennsylvania Institute for Research on Higher Education and the Association of American Colleges and Universities. (1994). *Estimates of student curricular activity from a national survey of colleges and universities.* Philadelphia: University of Pennsylvania.
See appendix table 4–6.

FIGURE 4–8

Percent of 1991 bachelor's degree recipients who graduated with a 3.0 GPA or higher, by field and sex: 1991



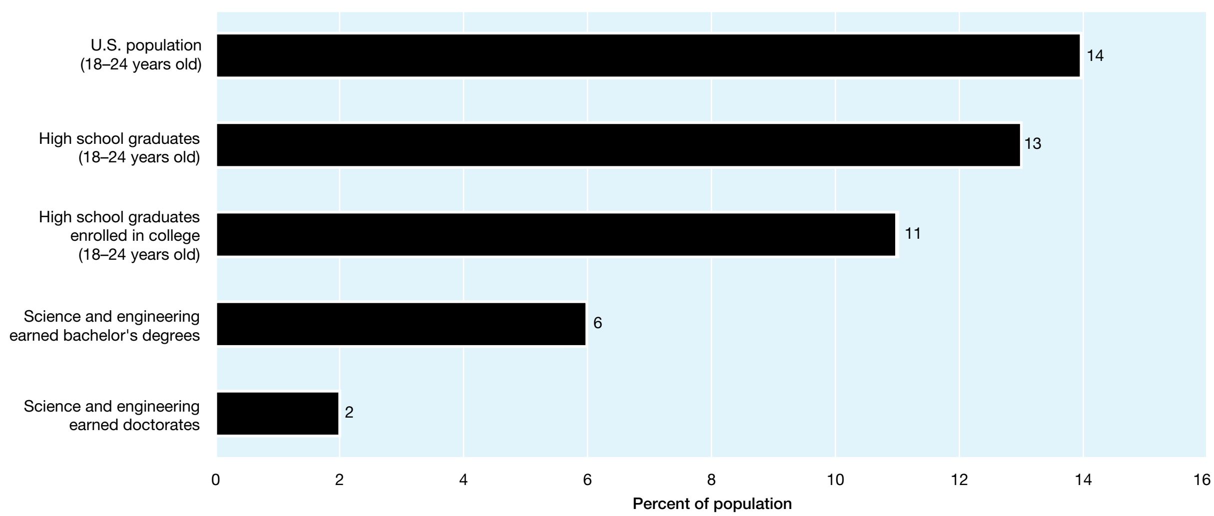
SOURCE: University of Pennsylvania Institute for Research on Higher Education and the Association of American Colleges and Universities. (1994). *Estimates of student curricular activity from a national survey of colleges and universities.* Philadelphia: University of Pennsylvania.
See appendix table 4–7.

Science and Engineering Students

Science and engineering students have many characteristics that make them unique when compared as a group with the general population of postsecondary institutions. For instance, several groups historically have been "underrepresented" in science and engineering, including females, blacks, Hispanics, Native Americans, and individuals with disabilities. (See figures 4-9 and 4-10 and appendix tables 4-8 and 4-9.) This is true particularly within the natural sciences and engineering. With attention to these unique characteristics, this section examines the preparation of students who intend to major in science and engineering fields, the flow of students into and out of science and engineering majors, coursetaking among these students, financial support, and degree production.

FIGURE 4–9

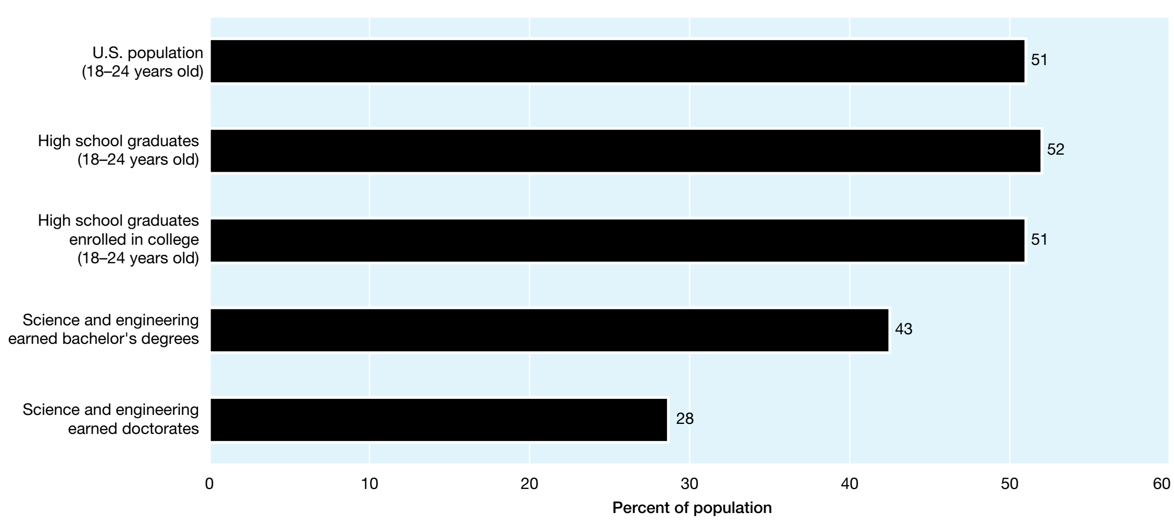
Percent of population that is black, by population group: 1990



SOURCES: National Science Foundation. (1994b). *Science and engineering degrees, by race/ethnicity of recipients: 1977-1991* (NSF 94-306). Arlington, VA: NSF; Bureau of the Census. (1992). *School enrollment– social and economic characteristics of students: October 1990* (Current Population Reports, Series P-20, No. 460). Washington, DC: U.S. Government Printing Office.
See appendix table 4–8.

FIGURE 4–10

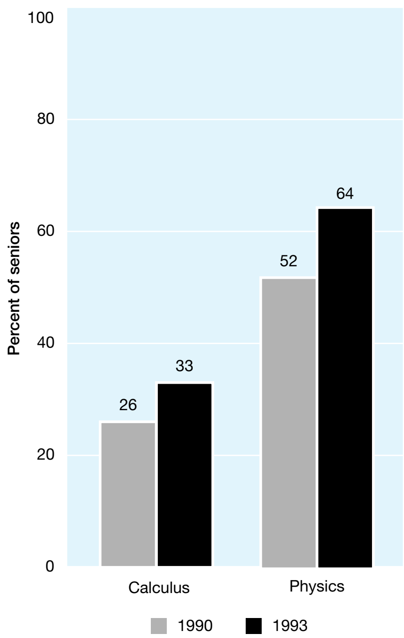
Percent of population that is female, by population group: 1990



SOURCES: National Science Foundation. (1994b). *Science and engineering degrees, by race/ethnicity of recipients: 1977-1991 (NSF 94-306).* Arlington, VA: NSF; U.S. Bureau of the Census. (1992). *School enrollment–social and economic characteristics of students: October 1990* (Current Population Reports, Series P-20, No. 460). Washington, DC: U.S. Government Printing Office.
See appendix table 4–9.

FIGURE 4–11

High school calculus and physics coursetaking of high school seniors who intend to major in natural sciences and engineering in college: 1990 and 1993



SOURCE: National Science Board. (1993). *Science and engineering indicators—1993* (NSB 93-1). Washington, DC: U.S. Government Printing Office.
See appendix table 4–10.

Preparation

Overall, high school students who plan to major in the natural sciences or engineering were better prepared in 1993 than in 1990. For example, between 1990 and 1993, the percentage of intended natural science or engineering majors who took calculus in high school increased from about one-quarter to one-third. (See figure 4-11 and appendix table 4-10.) The proportion who took physics increased by 8 percentage points over the period. Many more students who intend to major in natural sciences and engineering take advanced mathematics and science courses than students who intend some other college major. (See sidebar on preparation and figure 4-12.)

Pipeline

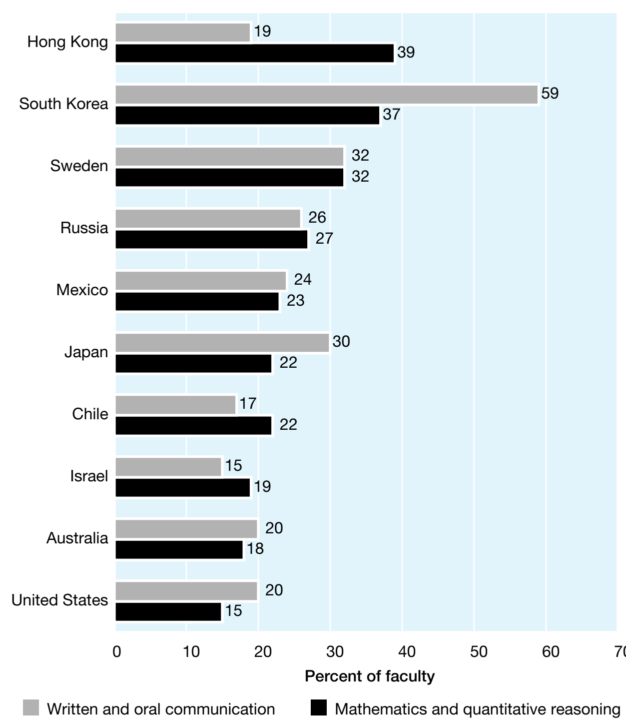
As high school sophomores, about 28 percent of males and 10 percent of females planned to study natural sciences or engineering in college (NCES, 1994a). Almost 57 percent of males and 79 percent of females, throughout high school and college, never expressed the intention to major in the natural sciences or engineering, whereas only 4 percent of males and 1 percent of females expressed consistent interest throughout high school and college in majoring in these fields. (See text table 4-1.)

Are Students Adequately Prepared for Mathematics Classes?

In an international survey performed in 1989 (Carnegie Foundation for the Advancement of Teaching, 1991), just 15 percent of U.S. faculty believed that students had adequate mathematical and quantitative skills, compared with 22 percent of Japanese faculty members, 27 percent of Russians, and 39 percent of faculty members from Hong Kong. (See figure 4-12 and appendix table 4-11.) These perceptions correspond closely with the results of the 1991 International Assessment of Educational Progress, which tested 9- and 13-year-olds on their science and mathematics abilities. The nations whose students scored the highest—Russia and South Korea—were the ones with the highest faculty perceptions of student preparation. The nation whose students scored the lowest—the United States—was the one with the lowest faculty perceptions. ■

FIGURE 4–12

Percent of faculty agreeing with statements that undergraduates in their country are adequately prepared in select skills, by type of skill and country: 1992



SOURCE: Mooney, C.J. (1994, June 22). The shared concerns of scholars. *The Chronicle of Higher Education,* XL (42), pp. A34-A38.
See appendix table 4–11.

TEXT TABLE 4-1

Percent of students identifying natural science or engineering as intended or actual field of study at various points in education system, by sex: 1980 to 1986

1980: High school sophomores (intended field)	Male	Female	1982: High school seniors (intended field)	Male	Female	1984: College sophomores (actual or intended field of study)	Male	Female	1986: College seniors (actual or intended field of study)	Male	Female
NS&E	27.8%	10.3%	NS&E	11.9%	3.1%	NS&E	6.5%	1.3%	NS&E	4.3%	0.8%
									Non-NS&E	2.2%	0.5%
						Non-NS&E	5.4%	1.8%	NS&E	0.6%	0.1%
									Non-NS&E	4.8%	1.7%
			Non-NS&E	15.9%	7.3%	NS&E	1.6%	0.6%	NS&E	0.6%	0.2%
									Non-NS&E	1.1%	0.4%
						Non-NS&E	14.3%	6.7%	NS&E	0.5%	0.1%
									Non-NS&E	13.8%	6.6%
Non-NS&E	72.2%	89.7%	NS&E	11.1%	6.9%	NS&E	3.9%	1.8%	NS&E	2.4%	0.8%
									Non-NS&E	1.5%	1.0%
						Non-NS&E	7.2%	5.1%	NS&E	0.7%	0.5%
									Non-NS&E	6.5%	4.6%
			Non-NS&E	61.1%	82.8%	NS&E	2.3%	2.8%	NS&E	0.6%	1.0%
									Non-NS&E	1.7%	1.8%
						Non-NS&E	58.8%	80.0%	NS&E	1.4%	0.7%
									Non-NS&E	57.4%	79.2%

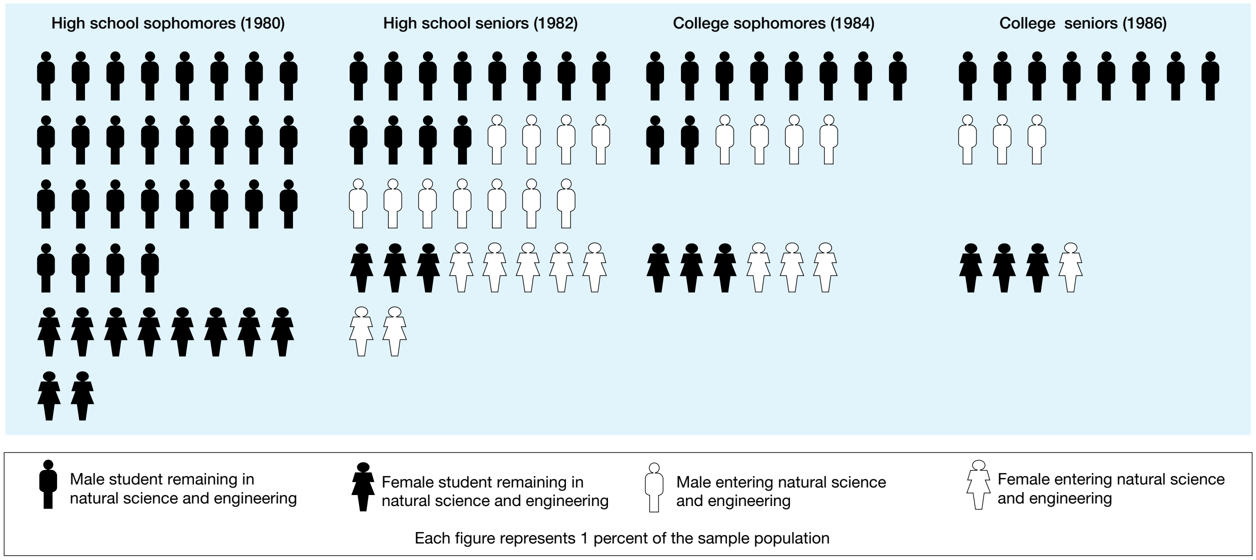
Natural science and engineering (NS&E)

Non-natural-science and -engineering discipline (Non-NS&E)

NOTES: Percent selecting natural sciences or engineering in high school is percent indicating these fields when asked to "indicate the field that seems closest to what you would most likely study in college." In college, percent selecting natural sciences or engineering are those that indicated these fields when asked, "During the last month you attended, what was your actual or intended field of study or training?" The data used in this table are drawn from the first four cycles (1980 base year, through the 1986 third follow-up) of the *High school and beyond 1980 sophomore cohort.* The sample began in 1980 with a national sample of 1,015 high schools. As a result of rounding, totals may not add to 100 percent.
SOURCE: National Center for Education Statistics. (1994a). *High school and beyond study, 1980 to 1992.* Unpublished tablulations.

FIGURE 4–13

Percent of 1980 high school sophomores identifying natural science and engineering as intended or actual field of study at various points in the educational system, by sex: 1980 to 1986



NOTES: Percent selecting natural sciences and engineering in high school is percent indicating these fields when asked to “indicate the field that seems closest to what you would most likely study in college.” In college, percent selecting natural sciences and engineering are those that indicated these fields when asked, “During the last month you attended, what was your actual or intended field of study or training?” The data used in this table are drawn from the first four cycles (1980 base year, through the 1986 third follow-up) of the *High school and beyond sophomore cohort*. The sample began in 1980 with a national sample base of 1,015 high schools.
SOURCE: National Center for Education Statistics. (1994a). *High school and beyond study, 1980 to 1992.* Unpublished tabulations.
See text table 4–1.

Indicators of Science and Mathematics Education 1995

For many years, educators believed that students who eventually became science or engineering majors in college made up their minds early, in elementary or secondary school, about their career intentions. Thus, analysts assumed that, although many students dropped out of the science and engineering “pipeline” as their educational careers progressed, few new entrants replaced them along the way. However, the High School and Beyond study (NCES, 1994a) indicates that the system is more open. (See figure 4-13.) Many students drop out of science and engineering majors, some enter, and some students change their intentions several times before choosing a major.[4]

Quite a few students who major in science or engineering in college decide to do so relatively late in their undergraduate careers. The High School and Beyond study (NCES, 1994a) found that about 30 percent of students who were high school sophomores in 1980, and who ultimately became natural science or engineering majors in college, chose this direction sometime after 1984—probably after their second year of college. (See text table 4-1.) This suggests that, if policy makers’ objective is to increase the number of majors and degrees, in addition to emphasizing retention strategies, they should consider ways of attracting students who are further along in their postsecondary careers.

Overall, many more students drop out of natural sciences and engineering than enter. Of course, all college departments face attrition, as their students switch to other majors, but not all face net attrition. However, the natural sciences—and, to a lesser extent, engineering—are particularly susceptible to attrition.[5] According to the High School and Beyond study, only 40 percent of students who intended to major in natural sciences or engineering as high school sophomores were actually in a natural science or engineering major as college seniors.(See text table 4-2.)

Indeed, a 1991 study by the Higher Education Research Institute found that only about half of students who, in their first year of college, had declared or intended a major in the natural sciences followed through with their plans by the time they were in or approaching their senior year. (See figure 4-14 and appendix table 4-12.) About 62 percent of engineering students, and more than 65 percent of students who intended to major in English, the social sciences, fine arts, education, or history, followed through with their original plans.

The High School and Beyond study data indicate that the pool of students interested in natural science and engineering shrank most after the senior year in high school and before the sophomore year in college. Just over half of the net decrease in the number of students with an actual or intended major in natural sciences or engineering occurred during this period.[6] (See text table 4-2.)

TEXT TABLE 4-2

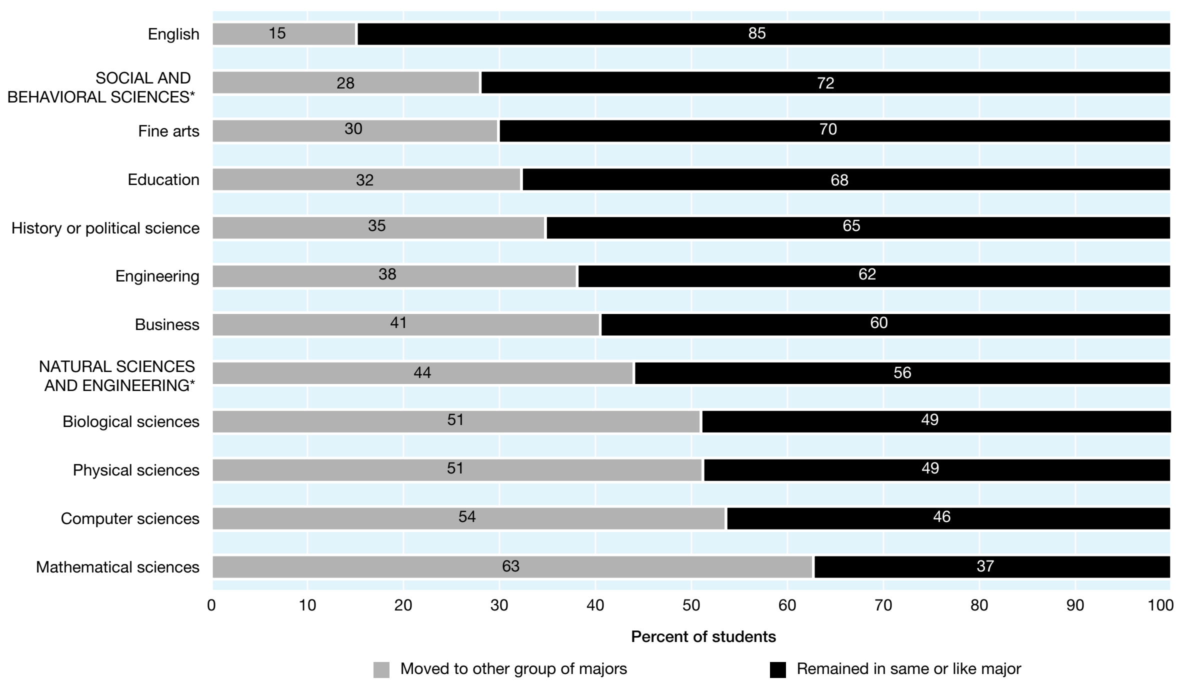
Percent of students whose actual or intended field of study is natural sciences or engineering, by education level and sex: 1980 to 1986

Sex	High school (intended field)		College (actual or intended field)	
	Sophomores (1980)	Seniors (1982)	Sophomores (1984)	Seniors (1986)
Male	27.8	23.0	14.3	11.1
Female	10.3	10.0	6.5	4.0

SOURCE: National Center for Education Statistics. (1994a). *High school and beyond study, 1980 to 1992.* Unpublished tabulations.

FIGURE 4–14

Percent of 1987 first-year undergraduate students in 4-year institutions who stayed in or switched to other (declared or intended) majors by 1991, by field of major: 1991



*The social and behavioral sciences category includes social sciences and psychology; the natural sciences and engineering category includes biological sciences, physical sciences, computer sciences, mathematical sciences, and engineering.
NOTE: Totals may not add to 100 percent as a result of rounding.
SOURCE: Seymour, E., & Hewitt, N.M. (1994). Talking about leaving: Factors contributing to high attrition rates among science, mathematics & engineering undergraduate majors. *Final report to the Alfred P. Sloan Foundation on an ethnographic inquiry at seven institutions.* Boulder, CO: University of Colorado.
See appendix table 4–12.

Indicators of Science and Mathematics Education 1995

In a study of seven institutions conducted by Seymour and Hewitt (1994), students who switched from natural sciences and engineering majors to other fields most often attributed their decision to a loss of interest in natural science and engineering coupled with increased interest in other fields, poor quality of teaching, an inflexible curriculum, fast course pace, and a sense that the career options and rewards in natural sciences and engineering were not worth the effort.

Similarly, Tinto (1988) argued that students who leave a particular college or college major before completing their studies often do so because they feel alienated from other students or faculty or because they are unable to make the transition from their old peer group to a new one. This inability to make necessary peer connections may be a particular problem for students from groups historically underrepresented in science and engineering, including blacks, Hispanics, Native Americans, and females.

Attrition among minority students in science and engineering may also be due to a variety of other social and academic obstacles. (For example, see Holden, 1992; Culotta, 1992.) Among these obstacles are financial difficulties, poor precollege preparation, low expectations from instructors, negative peer pressure, difficulty bridging the gap between their cultural identity and the world of science, and poor access to information on postsecondary educational opportunities.

Reasons for high attrition among female science and engineering students may include a lack of, or damaged sense of, self-confidence or self-esteem; stereotyping of science and engineering as "male" fields; experiences of gender bias; distaste for the competitive nature of science and engineering education; psychological alienation; an inability to get adequate academic guidance or advice; and low faculty expectations (Frazier-Kouassi et al., 1992; Seymour & Hewitt, 1994).

To encourage retention of females and students from underrepresented racial and ethnic groups, some postsecondary institutions have sponsored campus-based efforts to provide social and academic support to these groups. These were originally designed as stop-gap measures to provide students with the necessary skills to succeed in the existing undergraduate educational system; however, they are increasingly being implemented on a broader scale. Some are even working with employers and elementary and secondary school systems (National Research Council, 1992; Matyas & Malcom, 1991).

Financial Support

In the late 1980s and early 1990s, private and public 2- and 4-year institutions raised tuition and fees significantly in response to increasing costs and, for public institutions, declining or flat state appropriations levels. Between 1985 and 1993, tuition and fees in 4-year institutions increased by about 40 percent, in real 1993 dollars. (See appendix table 4-13.) The percentage increase was slightly more in public 4-year institutions and slightly less in private 4-year institutions. Public 2-year college tuition and fees increased by about 30 percent.

Between 1981 and 1993, the buying power of Federal student aid grants eroded rapidly. In 1981, the maximum Pell grant (the main Federal grant program for low-income students) covered 31 percent of the average educational expenses at a private 4-year institution. By 1993, the maximum grant covered just 16 percent of that cost. In its place have come student loans (Blanchette, 1994).

Originally conceived as a mechanism of support for middle-income students, loans have now become the major student aid program for low-income students. As a result, just under half of all bachelor's degree recipients in 1993 graduated from college in debt, compared with about one-third of graduates in 1980. The median debt of these students in constant 1990 dollars increased from about $4,000 in 1980 to about $7,000 by 1990 (U.S. Department of Education, 1993).

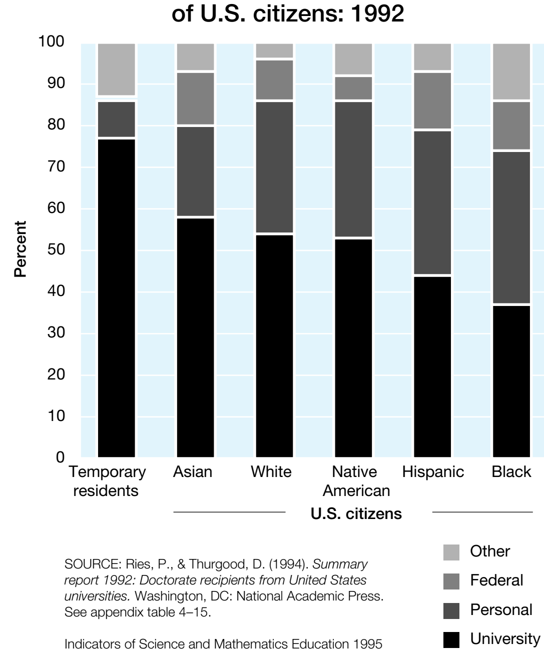
Roughly half of 1990 bachelor's degree recipients who hold postgraduation occupations in the science and technology labor market had college debt. (See appendix table 4-14.) Graduates employed as elementary and secondary teachers and engineers were most likely to have accumulated debt during their college years. Graduates working in computer science were least likely to have graduated with debt. This debt accounted for a large fraction of some graduates' median first-year income—from about 40 percent for social scientists to about 20 percent for science technicians (U.S. Department of Education, 1993).

About 24 percent of science and engineering doctoral students finance their education through personal sources such as loans. About 62 percent of science and engineering doctoral students obtain their primary financial support from university sources, mostly in the form of graduate assistantships funded by research grants awarded by the Federal Government. About 7 percent of recipients receive direct Federal support in the form of competitively selected fellowships or traineeships. (See figure 4-15 and appendix table 4-15.)

Of all U.S. citizens, 54 percent of white students and 58 percent of Asian students are supported by university sources, mostly in the form of assistantships. Only 37 per-

FIGURE 4–15

Primary source of support of science and engineering doctorate recipients, by residency status and race or ethnic origin of U.S. citizens: 1992



SOURCE: Ries, P., & Thurgood, D. (1994). *Summary report 1992: Doctorate recipients from United States universities.* Washington, DC: National Academic Press. See appendix table 4–15.

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cent of black students and 44 percent of Hispanic students are supported by university sources. (See figure 4-15 and appendix table 4-15.) A comparatively high proportion (about 77 percent) of foreign students are supported by university sources. This is due, in part, to their high concentrations in fields such as engineering, where assistantships are prevalent, and their ineligibility for Federal graduate student fellowship programs.

Blacks are more likely than other racial and ethnic groups to finance their graduate education from personal sources, such as loans, or other sources, such as nationally competitive fellowships, business or employer funds, and state governments.

Degree Production

Bachelor's degrees account for the vast majority of all science and engineering degrees awarded in any given year. (See sidebar for international comparisons and figure 4-16.) For every 14 science and engineering bachelor's degrees awarded in 1991, 1 science and engineering doctorate was awarded. (See figure 4-17 and appendix table 4-17.)

Between 1971 and 1991, the number of science and engineering degrees increased at all levels, except the associate degree level. Bachelor's degrees awarded in science and engineering increased by 15 percent, master's degrees increased by 39 percent, and doctorates increased by 23 percent. By broad field, the following trends emerged between 1971 and 1991[7] :

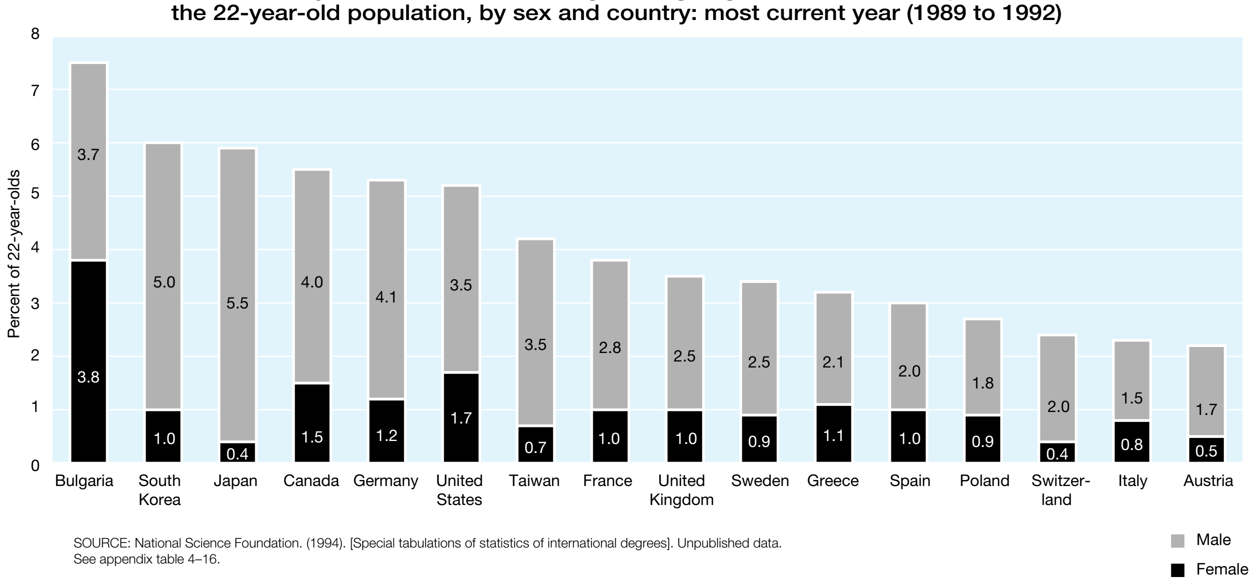
- Engineering degree production increased at the bachelor's, master's, and doctoral levels. The increases ranged from about one-third at the bachelor's level to almost one-half at the doctoral level.
- Natural science degrees increased by 11 percent at the bachelor's level, 24 percent at the master's level, and 17 percent at the doctoral level.
- Social and behavioral sciences degrees increased by 10 percent at the bachelor's level, 48 percent at the mas-

International Comparisons

A greater proportion of 22-year-olds in the United States and Canada complete college than in any of the 14 other countries from which comparable data are available. However, the proportion of individuals who earn natural science and engineering bachelor's degrees is lower in the United States and Canada than in Bulgaria, Japan, and South Korea. (See figure 4-16 and appendix table 4-16.) The proportion of males who earn natural science and engineering degrees ranges from a high of about 11 percent of male 22-year-olds in Japan to a low of about 3 percent in Italy. In the United States, about 7 percent of the male college-age population earns bachelor's degrees in these fields. The countries with the highest proportion of females who earn natural science and engineering degrees are Bulgaria, the United States, and Canada. In Bulgaria, the proportion of females earning degrees in these fields is more than double that of the United States or Canada. ■

FIGURE 4–16

First university natural science and engineering degrees awarded as a percent of the 22-year-old population, by sex and country: most current year (1989 to 1992)



SOURCE: National Science Foundation. (1994). [Special tabulations of statistics of international degrees]. Unpublished data. See appendix table 4–16.

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ter's level, and 19 percent at the doctoral level. (See appendix tables 4-18, 4-19, and 4-20.)

Even though the absolute number of science and engineering degrees awarded rose substantially between 1971 and 1991, science and engineering bachelor's degrees decreased as a proportion of total baccalaureates; they accounted for 35 percent of all baccalaureates awarded in 1971, but only 31 percent in 1991. (See figure 4-18.)

The proportion of science and engineering master's degrees stayed about the same—almost one-quarter of all master's degrees. On the other hand, science and engineering doctorates increased as a percentage of all doctoral awards; science and engineering doctorates accounted for 61 percent of all doctoral degrees awarded in 1971 and about 64 percent in 1991.

Sex. Although females earned the majority of bachelor's degrees awarded in all academic fields in 1991, they earned only about 44 percent of science and engineering bachelor's degrees (NSF, 1994a). Females earned 56 percent of social and behavioral sciences bachelor's degrees, 41 percent of the bachelor's degrees awarded in the natural sciences, and just 16 percent of engineering bachelor's degrees.(See appendix table 4-18.)

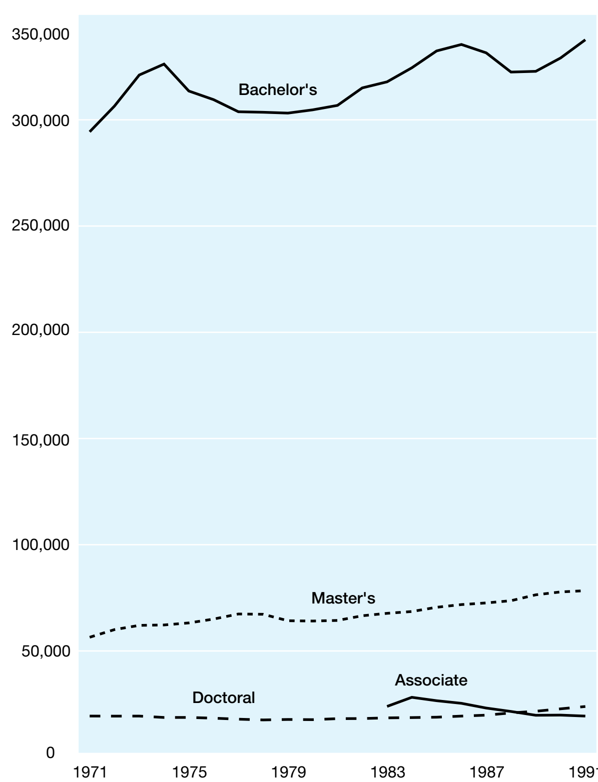
Females also earned the majority of master's degrees awarded in all fields; however, they earned just 36 percent of science and engineering master's degrees (NSF, 1994a). Females earned 54 percent of the master's degrees awarded in the social and behavioral sciences, 36 percent of natural sciences master's degrees, and 14 percent of engineering master's degrees.(See appendix table 4-19.)

Although females earned 37 percent of all doctorates, they earned just 28 percent of doctorates in science and engineering (NSF, 1994a). Females earned 48 percent of doctorates in the social and behavioral sciences, 26 percent of doctorates within the natural sciences, and 9 percent of engineering doctorates. (See appendix table 4-20.)

The gap between the number of science and engineering degrees awarded to females versus males at all degree levels has narrowed over the past 20 years—mostly because the proportion of males who earned degrees in these fields

FIGURE 4–17

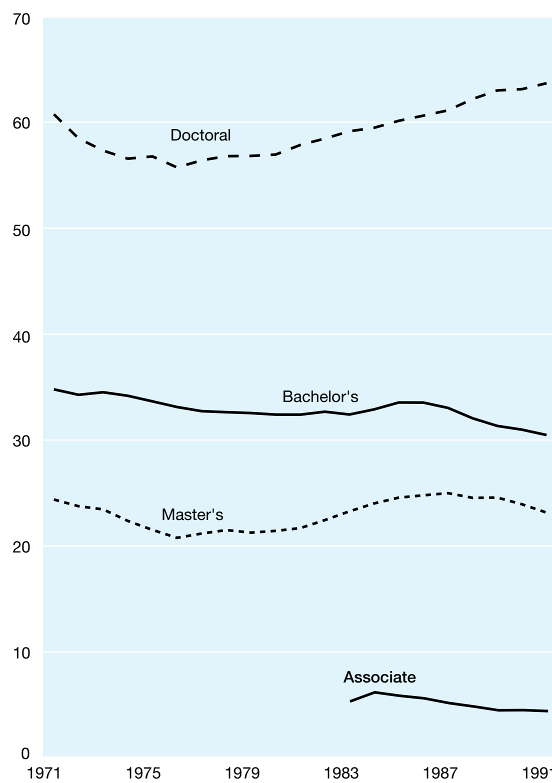
Science and engineering degrees awarded, by degree level: 1971 to 1991



NOTE: Associate degree data available beginning in 1983.
SOURCE: National Science Foundation. (1994a). *Science and engineering degrees: 1966-91* (NSF 94-305). Arlington, VA: NSF.
See appendix table 4–17.

FIGURE 4–18

Science and engineering degrees awarded as a percent of degrees awarded in all fields, by degree level: 1971 to 1991



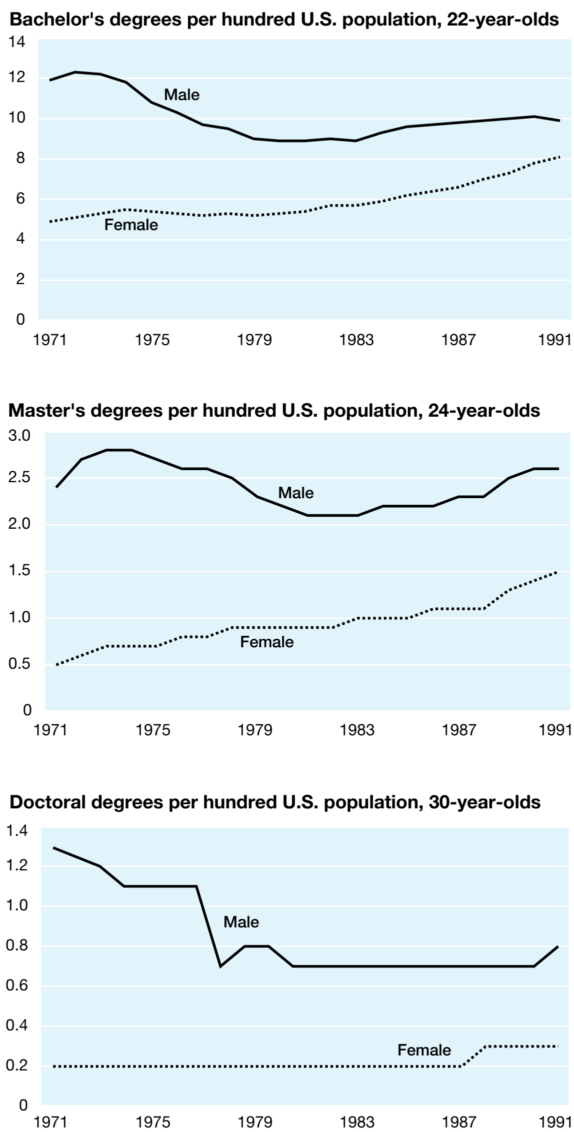
NOTE: Associate degree data available beginning in 1983.
SOURCE: National Science Foundation. (1994a). *Science and engineering degrees: 1966-91* (NSF 94-305). Arlington, VA: NSF.
See appendix table 4–17.

declined, while the proportion of females increased. (See figure 4-19 and appendix table 4-21.)

The gap between the proportion of males and females who earned science and engineering degrees narrowed most at the bachelor's degree level. In 1971, 12 males versus 5 females per hundred 22-year-olds received a bachelor's degree in science and engineering. By 1991, 10 males versus 8 females per hundred 22-year-olds received a bachelor's degree in science and engineering.

FIGURE 4–19

Science and engineering degrees awarded per hundred U.S. population, by degree level and sex: 1971 to 1991



SOURCE: National Science Foundation. (1994a). *Science and engineering degrees: 1966-91* (NSF 94-305). Arlington, VA: NSF.
See appendix table 4–21.

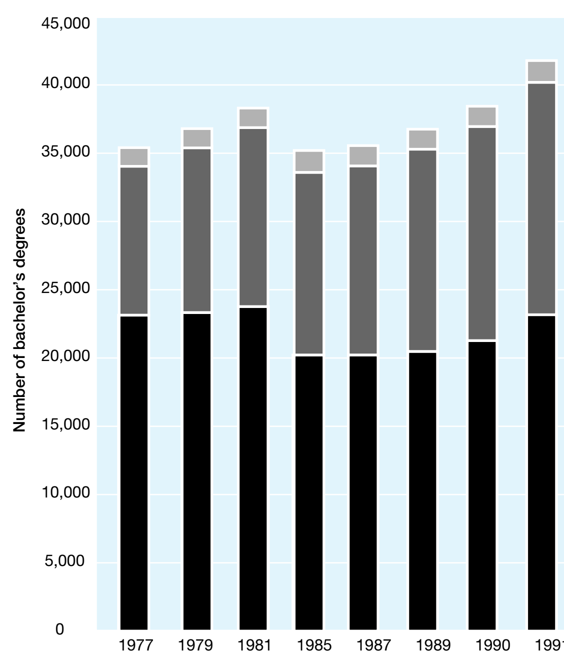
At the doctoral level, a large decline in the number of males enrolled in science and engineering—rather than an increase in the number of females enrolled in science and engineering—narrowed the gap. In fact, the proportion of the females who earned science and engineering doctorates remained flat for most of the period between 1971 and 1991.

Race and ethnic origin. Blacks and Hispanics remain underrepresented in science and engineering.[8] In 1991, although blacks made up about 14 percent of the college-age population, they earned just over 6 percent of the science and engineering bachelor's degrees conferred to U.S. citizens. (See figure 4-20 and appendix table 4-22.) After a decline in the 1980s, the number of science and engineering bachelor's degrees awarded to blacks in 1991 returned to 1977 levels. Blacks received a total of just 36 more science and engineering bachelor's degrees in 1991 than in 1977. (See appendix table 4-22.)

Similarly, Hispanics made up 11 percent of the college-age population, but earned not quite 5 percent of science and engineering degrees; however, their representation has increased markedly. (See sidebar on concentration of engineering degrees and figures 4-21 and 4-

FIGURE 4–20

Number of science and engineering bachelor's degrees awarded to students in underrepresented racial and ethnic groups: 1977 to 1991



NOTE: Persons of Hispanic origin may be of any race.
SOURCE: National Science Foundation. (1994b). *Science and engineering degrees, by race/ethnicity of recipients: 1977-91* (NSF 94-306). Arlington, VA: NSF.
See appendix table 4–22.

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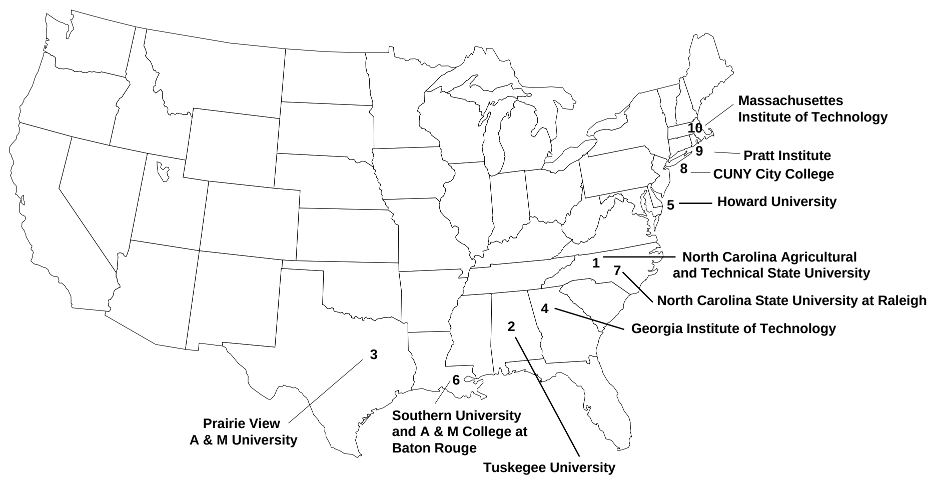
A Few Schools Award Most Engineering Degrees to Minorities

In 1993, blacks and Hispanics each earned about 4 percent of engineering bachelor's degrees (NSF, 1994e). Roughly one-third of these degrees earned by blacks were granted by just 10 colleges and universities. (See figure 4-21 and appendix table 4-23.) Five of these institutions are historically black colleges and universities, and two offer a doctorate in engineering. Similarly, in 1993, just 10 postsecondary institutions conferred 41 percent of the engineering bachelor's degrees awarded to Hispanics. Nine of these institutions are located in states or territories with large Hispanic populations. (See figure 4-22 and appendix table 4-23.) ■

FIGURE 4-21

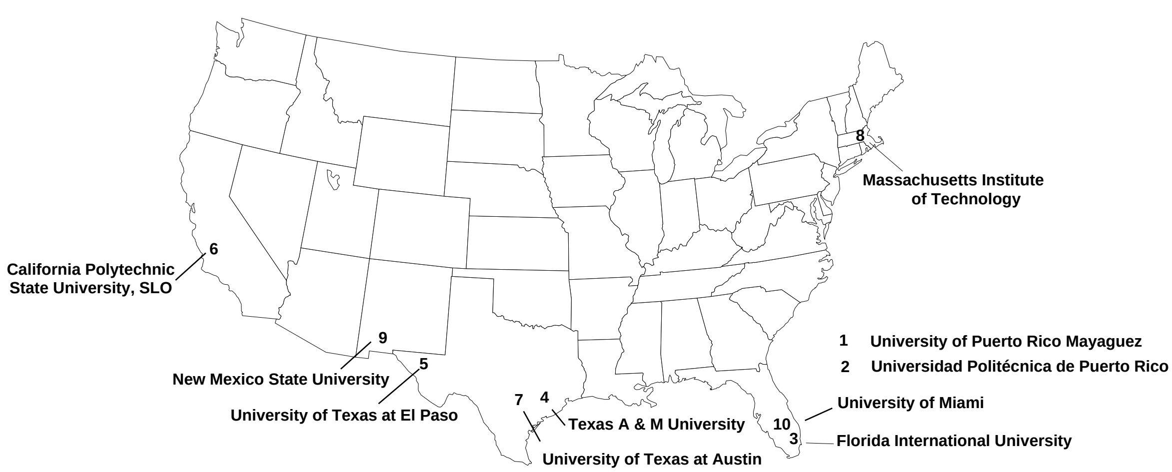
Ten colleges and universities that award the highest number of bachelor's degrees in engineering to blacks: 1993



SOURCE: National Center for Education Statistics. Integrated Postsecondary Education Data System. Special tabulations by Science Resources Studies Division, National Science Foundation. See appendix table 4–23.

FIGURE 4-22

Ten colleges and universities that award the highest number of bachelor's degrees in engineering to Hispanics: 1993



SOURCE: National Center for Education Statistics. Integrated Postsecondary Education Data System. Special tabulations by Science Resources Studies Division, National Science Foundation. See appendix table 4–23.

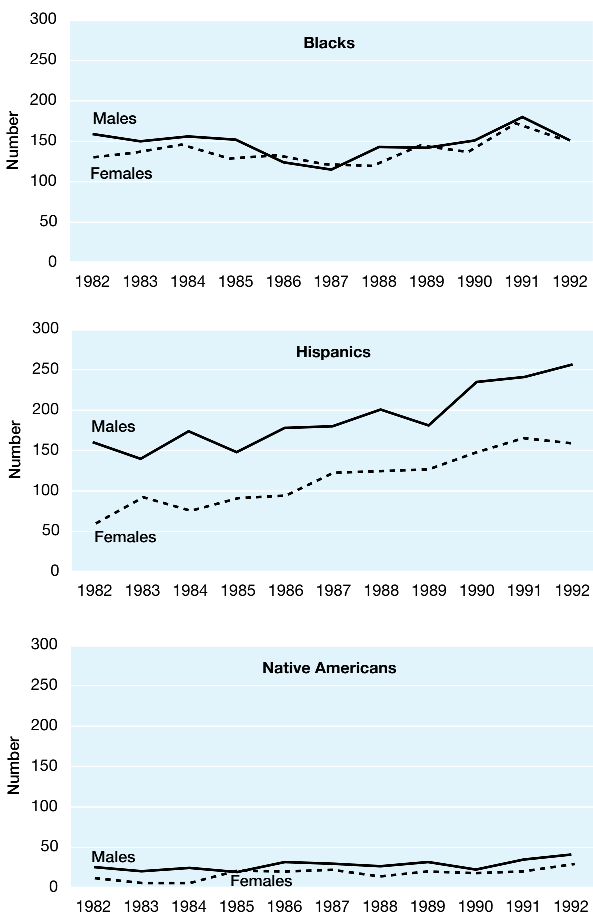
22.) Hispanics earned 55 percent more bachelor's degrees in science and engineering in 1991 than in 1977.

Over this same period of time, the number of science and engineering bachelor's degrees awarded to groups not underrepresented in science and engineering remained relatively constant overall. Although the number of science and engineering bachelor's degrees awarded to Asians more than tripled, the number of degrees awarded to whites decreased by 6 percent. (See appendix table 4-22.)

Blacks and Hispanics are even more underrepresented at the master's degree level than at the bachelor's and still more underrepresented at the doctoral level. In 1992, blacks earned just 2 percent of the science and engineering doctorates awarded to U.S. citizens, and Hispanics earned about 3 percent. (See appendix table 4-24.)

FIGURE 4–23

Science and engineering doctorates awarded to blacks, Hispanics, and Native Americans, by sex: 1982 to 1992



NOTE: Numbers refer to U.S. citizens only.
SOURCE: National Science Foundation (1993b). *Selected data on science and engineering doctorate awards: 1992* (NSF 93-315). Washington, DC: NSF.
See appendix table 4–25.

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Black females earned about the same number of science and engineering doctorates as black males in 1992—the number of black females earning doctorates increased slightly and the number of black males earning doctorates decreased slightly between 1982 and 1992. (See figure 4-23 and appendix table 4-25.) Although Hispanic females were earning increasingly more engineering doctorates, the total number of doctorates they earned still lagged behind the total number of doctorates Hispanic males earned. (See sidebar on diversity and figure 4-24.)

Foreign Students

Between 1972 and 1992, the number of science and engineering doctorates awarded to foreign students by U.S. postsecondary institutions more than doubled, although the number awarded to U.S. citizens declined slightly. (See figures 4-25 and 4-26 and appendix table 4-26.) In 1972, foreign students earned 20 percent of science and engineering doctorates; by 1992, they earned 38 percent.

The science and engineering field with the highest proportion of foreign graduates is engineering. Foreign

Are Postsecondary Institutions Doing Enough About Diversity?

Despite a large postsecondary educational infrastructure and perhaps 20 years of effort to diversify the science and engineering workforce, few institutions are producing large enough numbers of black and Hispanic doctorates to achieve true diversity. In 1992, universities awarded only 5 percent of science and engineering doctorates to blacks and Hispanics, collectively (NSF, 1993b). That year, although 366 postsecondary institutions awarded one or more science and engineering doctorates, nearly two-thirds of these institutions awarded no doctorates to blacks, and fewer than half of these institutions awarded even one science and engineering doctorate to a Hispanic. (See figure 4-24.)

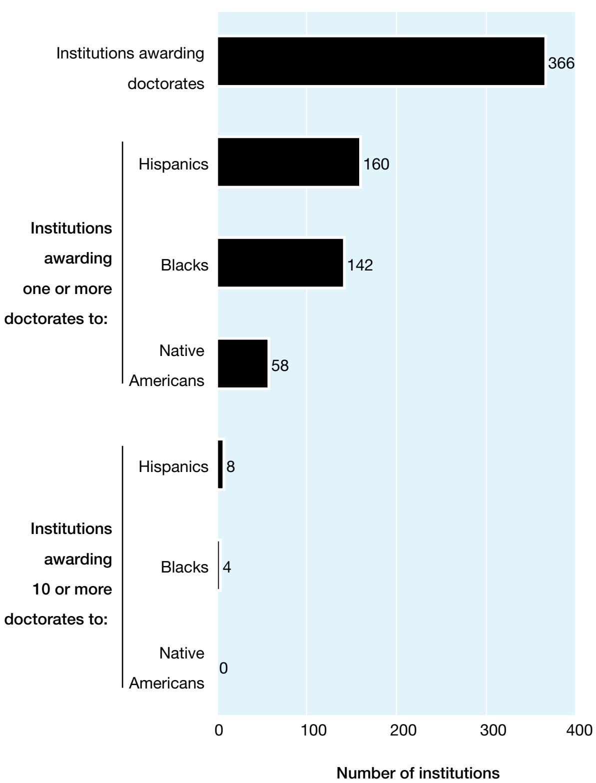
Diversifying the science and engineering workforce may be possible only if postsecondary institutions increase access to science and engineering study. Blacks and Hispanics come from backgrounds historically overrepresented at the lower socioeconomic strata, at lower household income levels, and among families living in poverty. Students from low-income family backgrounds of all races and ethnic origins complete college at lower rates than those from higher income families. For example, 25 percent of blacks who graduated from high school in 1980 and who are from families in the top socioeconomic quartile have since obtained bachelor's degrees. Only 8 percent of blacks from the bottom quartile have completed college. ■

students earned about 61 percent of all engineering doctorates in 1992. In the natural sciences, foreign students earned 41 percent of the doctorates, and in the social and behavioral sciences, they earned 28 percent. In non-science and -engineering fields, foreign students earned only 17 percent of the doctorates. The majority of foreign students studying science and engineering in the United States are from Asia.

The opportunities at home for many foreign science and engineering doctoral recipients have increased during the past 20 years as the economies of many countries, particularly those in Asia, have expanded. As a result, more of these students are returning home than in previous years. In 1970, about 54 percent of the foreign science and engineering doctorate recipients planned to stay in the United States after graduation, mostly to work in academia or industry. In 1992, about 44 percent planned to stay in the United States (NSF, 1993c).

FIGURE 4–24

Number of institutions awarding science and engineering doctorates, by race or ethnic origin of recipient: 1992



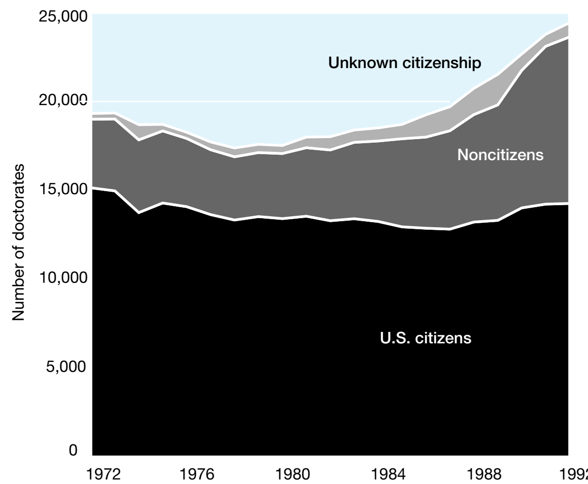
NOTE: Persons of Hispanic origin may be of any race.
SOURCE: National Science Foundation (1994d). [Special tabulations from the National Science Foundation survey of earned doctorates]. Unpublished data.

Technical Students

Individuals with technical[9] training play an important role in the ability of the United States to maintain and advance its economic position in the world (Collins, Gentry, & Crawley, 1993). The most common types of

FIGURE 4–25

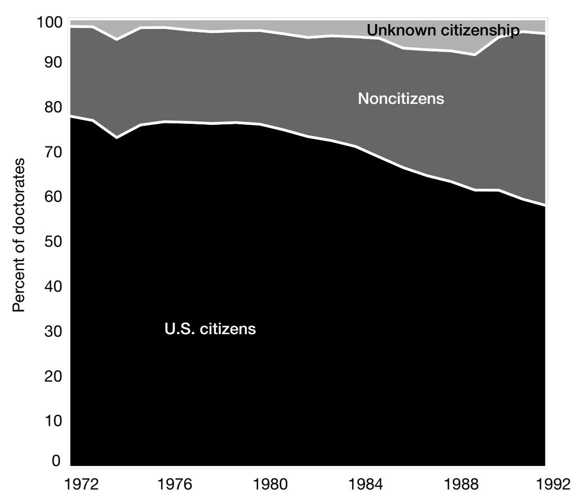
Science and engineering doctorates awarded, by citizenship of recipient: 1972 to 1992



SOURCES: National Science Foundation. (1993a). *Science and engineering doctorates: 1960-91* (NSF 93-301). Washington, DC: NSF; National Science Foundation. (1993b). *Selected data on science and engineering doctorate awards: 1992* (NSF 93-315). Washington, DC: NSF.
See appendix table 4–26.

FIGURE 4–26

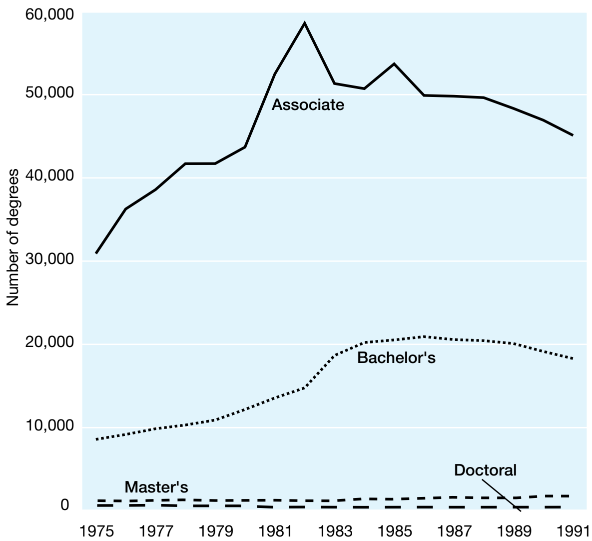
Proportional distribution of science and engineering doctorates awarded, by citizenship of recipient: 1972 to 1992



SOURCES: National Science Foundation. (1993a). *Science and engineering doctorates: 1960-91* (NSF 93-301). Washington, DC: NSF; National Science Foundation. (1993b). *Selected data on science and engineering doctorate awards: 1992* (NSF 93-315). Washington, DC: NSF.
See appendix table 4–26.

FIGURE 4–27

Total number of engineering technology degrees awarded, by degree level: 1975 to 1991



SOURCE: National Science Foundation. (1994a). *Science and engineering degrees: 1966-91* (NSF 94-305). Arlington, VA: NSF.
See appendix table 4–27.

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technical degree awarded are in engineering technologies. (See figure 4-27 and appendix table 4-27.) Other types of technical degree include science technologies, communications technologies, and health technologies. During the past 15 years, the number of students who earned technical degrees and certificates increased at all degree levels (NSF, 1994a).

In 1991, most students who studied engineering technologies received associate degrees, as opposed to any other type of degree. Between 1975 and 1991, the number of engineering technology associate degrees increased by 46 percent, although the 1991 level is a drop from its peak level in 1982. Bachelor's and master's degrees in this field have doubled and tripled, respectively. (See sidebar on technicians.)

Technicians Are Not Just Junior Scientists

In a 1993 study of science technicians, Barley and Bechky found that, while technicians often work with scientists and engineers, they are not junior scientists and engineers, nor do they perform routine tasks. Instead, their work emphasizes skilled technical applications, which require a significant understanding of the fundamental science and engineering underpinning of their trade. Because scientists and engineers, on one hand, and technicians, on the other, employ complementary sets of skills, the division of labor between the two occupational groups is more collaborative than hierarchical (Barley & Bechky, 1993). ■

The Carnegie Classification

The Carnegie Classification, developed by the Carnegie Foundation for the Advancement of Teaching (1991), groups the 3,600 postsecondary institutions into 11 categories, based largely on their academic missions. The classification includes all colleges and universities in the United States that are degree-granting and accredited by an agency recognized by the U.S. Secretary of Education. Used as a key resource for academe, it aids in assessing the changing state of postsecondary education and as a way for campus officials at the respective colleges and universities to define a niche in relation to other postsecondary institutions.

Colleges and universities are divided into the following categories: research universities, doctoral universities, master's (comprehensive) universities and colleges, baccalaureate (liberal arts) colleges, associate of arts colleges, professional schools and specialized institutions, and other specific groupings. Institutions are classified according to the highest level of degree they award, the number of degrees conferred by the discipline, and, in some cases, the amount of Federal research support they receive and the selectivity of their admissions. ■

Postsecondary Learning Environment

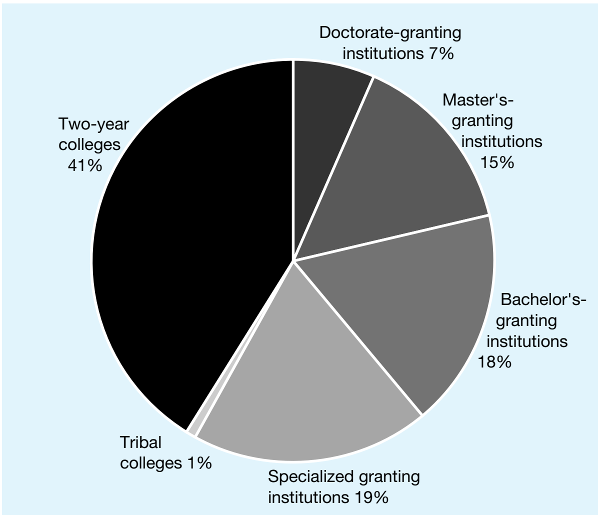
In 1994, there were 3,600 postsecondary institutions in the United States. (See sidebar for definition of Carnegie Classification.) This was a net increase of about 200 institutions since 1987.[10] (See appendix table 4-28.) The greatest increase was among 2-year colleges, with a net increase of more than 100 institutions. In 1994, 2-year institutions accounted for a full 40 percent of all postsecondary institutions; this was the largest single institutional category.[11] (See figure 4-28.) Doctoral-granting institutions, which make up only 7 percent of the postsecondary schools, award the largest share of bachelor's, master's, and doctoral science and engineering degrees (NSB, 1993).[12]

Faculty

The representation of blacks and Hispanics is lower within the natural sciences and engineering fields than in either the social and behavioral sciences or non-science and -engineering fields. (See figure 4-29 and appendix table 4-29.) For example, blacks make up about 5 percent of all postsecondary faculty, but only about 3 percent of natural sciences faculty and less than 3 percent of faculty in engineering. Females are most underrepresented in

FIGURE 4–28

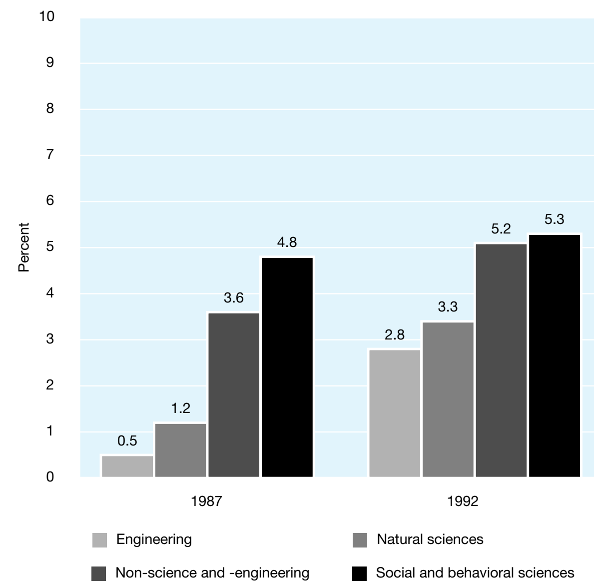
Institutions of higher education, by institutional type: 1994



NOTE: Percents have been rounded to the nearest whole number.
SOURCE: Carnegie Foundation for the Advancement of Teaching. (1991, May/June). Research-intensive vs. teaching-intensive institutions. *Change,* 23-26.
See appendix table 4–28.

FIGURE 4–29

Percent of full-time faculty who are black, by field: Fall 1987 and Fall 1992



SOURCE: National Center for Education Statistics (1994b). [Special tabulations from the 1993 national study of postsecondary faculty]. Unpublished data.
See appendix table 4-29.

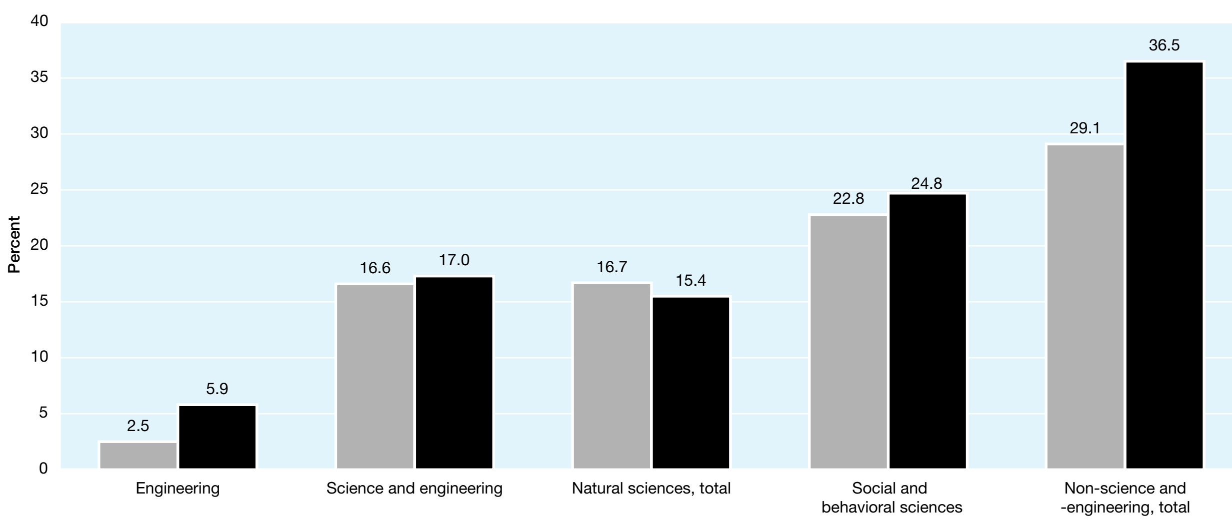
engineering. Although they make up about one-third of all postsecondary faculty, they account for about 15 percent of faculty in the natural sciences and only about 6 percent of engineering faculty. (See figure 4-30 and appendix table 4-30.)

One difficulty that postsecondary institutions have in diversifying their workforce is the small pool of job applicants who are female, members of racial and ethnic minority groups, or disabled. For example, blacks and Hispanics collectively account for a small percentage of all science and engineering doctoral recipients. (See the section on degree production on page 86.)

The difficulty raised by underrepresentation does not end with successful recruitment of a satisfactory candidate. Instead, the burden is transferred to the shoulders of the new recruit. Many young faculty members from

FIGURE 4–30

Percent of full-time instructional faculty who are female, by field: Fall 1987 and Fall 1992



SOURCE: National Center for Education Statistics. (1994b). [Special tabulations from the 1993 national study of postsecondary faculty]. Unpublished data.
See appendix table 4–30.

underrepresented groups frequently find themselves overwhelmed with committee assignments, extracurricular activities, and other responsibilities reflecting their position as role models. In addition, limited expectations and alienation experienced during college years sometimes reemerges, persists, or grows worse at the faculty level (Barinaga, 1992, and Etzkowitz et al., 1994). Many experts believe that these problems will exist until a critical mass of faculty from underrepresented groups is achieved (Culotta, 1993).

Teaching and Research

The struggle to prioritize time and resources between teaching and research continues in postsecondary institutions today. In a 1992 study, about two-thirds of U.S. faculty in all fields favored teaching over research, compared with less than half of British faculty, about one-third of German faculty, and about one-quarter of Japan's faculty. (See figure 4-31.)

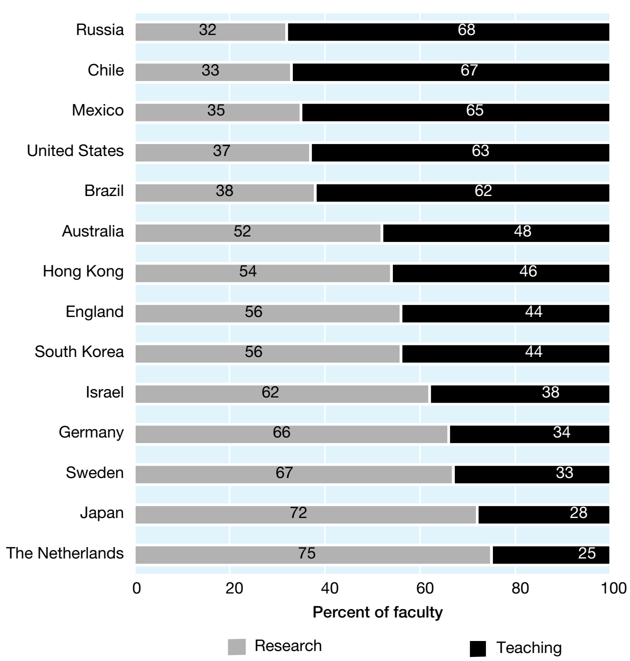
Most postsecondary faculty in the United States, in all fields, cited teaching as their principal job activity. The proportions of faculty who indicated teaching as their primary responsibility varied among the science fields by only about 10 percentage points—from about 63 percent in the natural sciences to about 73 percent in the social and behavioral sciences. (See appendix table 4-31.) However, within natural sciences, the proportions of faculty engaged primarily in teaching varied widely, from about 45 percent of life science faculty, to about 84 percent of mathematics. About 24 percent of faculty in the natural sciences cited research as their principal activity, compared with 16 percent in engineering and only 10 percent social and behavioral sciences.

In doctorate-granting institutions, faculty in science and engineering typically teach between one and two courses per semester. In master's- and bachelor's-degree-granting institutions, faculty in these fields teach between two and three courses on average. In 2-year institutions, faculty teach between three and four courses. (See appendix table 4-32.)

Academic research as a primary institutional mission is most commonly found among doctorate-granting institutions, which account for only 7 percent of postsecondary institutions. In 2-year institutions and bachelor's-granting institutions, which account for nearly 60 percent of the 3,600 postsecondary institutions in the United States, faculty interests and the reward and tenure system frequently reflect their greater teaching missions.

FIGURE 4–31

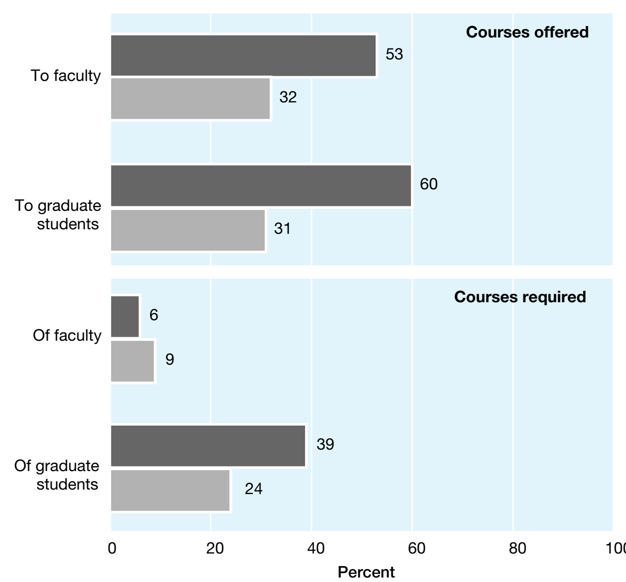
Percent of all faculty whose interest lies primarily in teaching versus research, by country of faculty residence: 1992



NOTE: Includes faculty of all disciplines and departments.
SOURCE: Mooney, C.J. (1994, June 22). The shared concerns of scholars. *The Chronicle of Higher Education,* XL (42), pp. A34-A38.

FIGURE 4–32

Percent of engineering departments (electrical, mechanical, and civil only) requiring or offering courses in communications to faculty and graduate students, by size of department: 1992



SOURCE: Burton, L., & Celebuski, C.A. (1994). *Higher education surveys: Undergraduate education in electrical, mechanical and civil engineering* (HES Survey No. 16). Washington, DC: National Science Foundation.
See appendix table 4–33.

> **PROJECT KALEIDOSCOPE PROVIDES NEW PERSPECTIVES**
>
> Project Kaleidoscope (1991), which began in 1989, is a collaborative effort to analyze and reform the current structure of undergraduate science and mathematics. Supported by the National Science Foundation and various grants, the project is a consortium of presidents, deans, and faculty in mathematics and the natural sciences from liberal arts colleges and other predominately undergraduate institutions. The consortium recommends revitalizing introductory undergraduate science and mathematics courses, supporting faculty in their role as teachers and scholars within the community of learners, and providing adequate science facilities and equipment. ■

PART-TIME INSTRUCTORS

Some teaching at postsecondary institutions is performed by graduate students and part-time instructors. About 1 in 10 mathematics courses at bachelor's-degree-granting institutions is taught by a graduate student; about 4 in 10 of these courses at 2-year institutions are taught by part-time faculty. Many of these instructors have little or no formal preparation for the classroom; moreover, many graduate teaching assistants are not native English speakers. (See section on foreign students on page 90.)

However, postsecondary institutions are taking steps to enhance teaching by part-time instructors and teaching assistants. Today, 17 states require public colleges and universities to certify that their teaching assistants are competent in English (Chronicle of Higher Education, 1994). Also, some engineering departments are requiring that their faculty and/or graduate students take courses in communications. These courses may cover teaching techniques, academic or career advising, English language skills, and American customs and behavior. About 33 percent of mechanical, electrical, and civil engineering departments require their graduate students to take communications-related classes. (See figure 4-32 and appendix table 4-33.) Large departments, those employing more than 20 faculty members, are more likely than small departments to offer and require these courses.

INSTRUCTIONAL PRACTICES

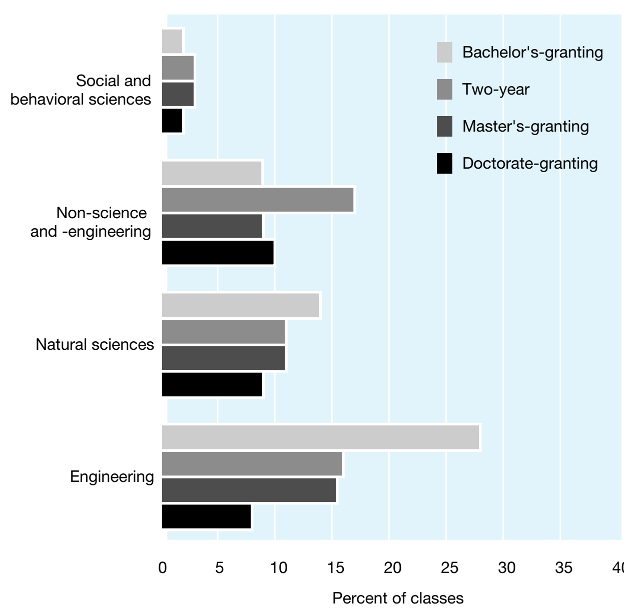
Effective science and engineering education requires that postsecondary institutions enable students to make connections between in-class learning and real-world situations—whether in the laboratory or in the field. Some postsecondary institutions are beginning to put this type of hands-on approach into practice. For instance, at the University of Houston—Downtown, through Project Kaleidoscope (see sidebar on Project Kaleidoscope), students have analyzed blood chemistry and height–weight data in order to establish the equations needed to determine the level of drug delivery for cancer patients undergoing chemotherapy.

However, overall, only a small percentage of science and engineering classes make use of a laboratory or problem-solving format; instead, they rely mostly on lectures. By field, the laboratory or problem-solving format is most likely to be used in engineering and least likely to be used in the social and behavioral sciences. The format's use varies significantly by institution type across fields. For example, although only about 9 percent of all science and engineering classes at bachelor's-granting institutions used laboratories and problem-solving sessions, 28 percent of engineering classes at these institutions used the format. (See figure 4-33 and appendix table 4-34.) In contrast, only about 8 percent of the engineering classes at doctorate-granting institutions used this format.

Still, many undergraduate mathematics majors have opportunities to perform discovery-based activities, including research projects and senior projects or theses. (See figure 4-34 and appendix table 4-35.) Doctorate-granting institutions are more likely than other types of institutions to allow undergraduate mathematics majors

FIGURE 4–33

Percent of classes that use a laboratory or problem-solving format, by type of institution and field of faculty: Fall 1992



SOURCE: National Center for Education Statistics. (1994b). [Special tabulations from the 1993 national study of postsecondary faculty]. Unpublished data.
See appendix table 4–34.

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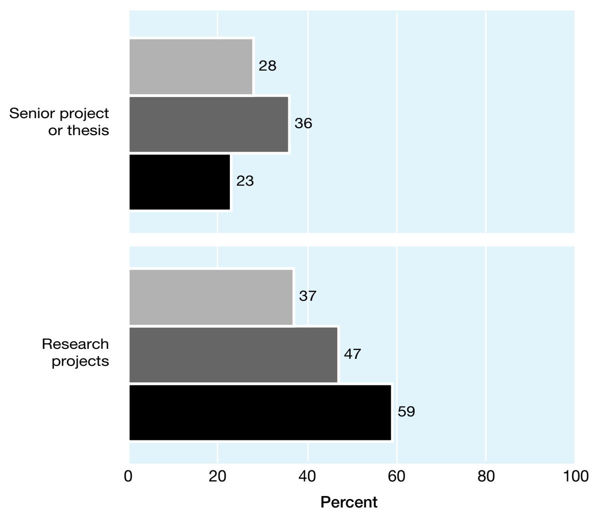
FIGURE 4–34

Percent of mathematics departments offering research opportunities to undergraduate mathematics majors, by type of project and institution: 1990



SOURCE: Albers, D.J., Loftsgaarden, D.O., Rung, D.C., & Watkins, A.E. (1992). *Statistical abstract of undergraduate programs in the mathematical sciences and computer science in the United States: 1990-91 CBMS survey* (MAA Notes No. 23). Washington, DC: Mathematical Association of America.
See appendix table 4–35.

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opportunities to engage in research. Master's-granting institutions are more likely to offer senior projects or theses than are other institutions. Bachelor's-granting institutions are more likely than other institutions to require calculus sections to perform writing activities, group projects, and computer assignments. (See appendix table 4-36 and the sidebar on calculus reform.)

Of course, laboratory or practical problem-solving experience is not, in itself, a guarantee that students will be challenged by and engaged in their science and engineering studies. The scientific research society, Sigma Xi (1990), reports that laboratory experiences—particularly at the introductory levels—lack imagination and are routine and dull. Many laboratory investigations make doing science seem like following a recipe in a cookbook: Students learn that if they repeat the steps outlined in the laboratory manual, they get the proper outcome. Instead, the laboratory format should instill understanding through discovery.

Similarly, Rigden and Tobias (1991) found that classroom atmosphere tends to dampen the spirit of intellectual adventure. They say that interactive, cooperative learning experiences take a distant back seat to passive instructional formats. Introductory classes tend to feature the professor working through a series of problems that students are expected to record in their notebooks and mimic on homework problems. This approach, along with the rapid pace of the courses, large class sizes, and a lack of exchange among students and with faculty, never allows students to see science and engineering as a process of discovery (Simpson & Anderson, 1992).

Resources

Much of the storehouse of research equipment and instrumentation owned by colleges and universities is not used for undergraduate instruction. Of all of the equipment and instrumentation valued at between $10,000 and $1 million owned by doctorate-granting institutions in 1989, just under two-thirds was used only in research. (See figure 4-35 and appendix table 4-37.) Just 8 percent

Reform in Calculus Classes

In 1986, a national calculus reform effort was born at a conference at Tulane University. The conference emphasized three main ideas:

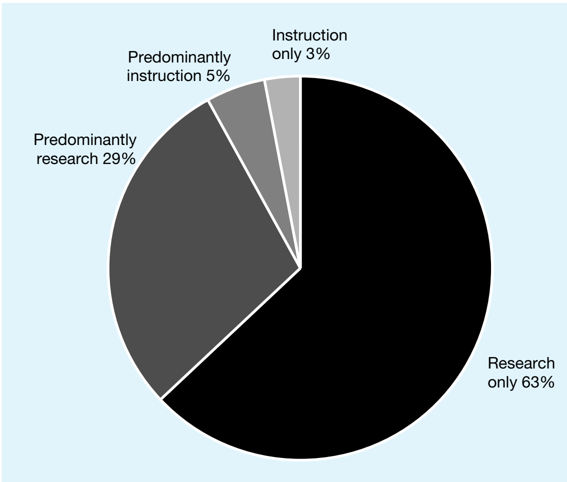
- Courses should promote conceptual understanding and the application of calculus to open-ended problems rather than focus on rote implementation of symbolic algorithms.
- Calculus should be geared to the needs of average students—students for whom some command of calculus is necessary for further learning in their majors.
- Students should be engaged in doing calculus as active learners.

To accomplish these goals, conference participants recommended a change in instructional techniques and the active use of technology—particularly computer technology—in learning (Leitzel & Tucker, 1994). Based on these ideas, in 1988, the National Science Foundation began funding calculus reform efforts across the Nation—efforts that have begun to make an impact. In 1992, just 11 percent of all postsecondary institutions reported that they were engaged in major reform of their calculus courses (Leitzel & Tucker, 1994). By 1994, however, that proportion had doubled.

Yet, as of 1990, few calculus courses embodied the activities advanced by the calculus reform movement. Of all calculus course sections offered in 4-year institutions, about 10 percent had some writing component, about 8 percent of sections used computer-based projects, and just 3 percent used group projects. ■

FIGURE 4–35

Percent of college and university equipment and instrumentation at doctorate-granting institutions used for instruction or research: 1988 to 1989



NOTE: Includes only movable instrumentation and equipment originally costing $10,000 to $999,999 owned by research-performing colleges and universities for use in the natural sciences and engineering, from 1988 to 1989.
SOURCE: National Science Foundation. (1991). *Characteristics of science/engineering equipment in academic settings: 1989-90* (NSF 91-315). Washington, DC: NSF.
See appendix table 4–37.

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of the equipment and instrumentation (such as computers, spectrometers, microscopes, and bioanalytical instruments) were used either solely or predominantly for instruction.[13]

Conclusion

Science, engineering, and technical education remains vital in the United States. An analysis of median earnings of full-time workers with at least a bachelor's degree shows that society places high value on those in natural science and engineering occupations. In 1990, engineers earned 26 percent more than the median income of those holding bachelor's or higher degrees in any field, physical scientists made 8 percent more, and computer scientists earned 5 percent more than the median income. However, those with degrees in education and the social sciences made 32 and 23 percent less, respectively, than the median (U.S. Department of Education, 1994).The ranking of median income by occupation was virtually the same in 1970.

Only one of the occupations that the Bureau of Labor Statistics projected to grow fastest in absolute numerical terms between 1992 and 2000 clearly required postsecondary science or technical educations: systems analysis. About half of the top 25 fastest growing occupations—which are expected to account for half of the total employment growth in the United States over the period—are in retail, clerical, and maintenance areas, requiring little or no advanced preparation in science and technology. However, occupations requiring training in natural sciences and engineering are expected to experience favorable growth between 1992 and 2000. Of course, projections must be interpreted with caution, because they are based on models that assume previous trends will continue.

Reviews and studies on the skills requirements of current and future jobs reveal little overall change in the skills required for particular occupations and no dramatic shifts in demand for skilled labor for the workforce of 2000 (Levin, 1993). However, some experts believe that, in order to remain competitive, employers will need workers with a greater depth and breadth of skills who can rethink and reorganize the way that goods and services are produced (Levin, 1993; Commission on the Skills of the American Workforce, 1990).

U.S. postsecondary science, engineering, and technical education should be able to fulfill future demands for skilled workers. Despite some problems, the condition of postsecondary science, engineering, and technical education in the United States is strong and is continuing to adapt to meet new pressures and needs. High school graduates have higher aspirations, and are better prepared, for postgraduate study. Total enrollment and the diversity of enrollment, in terms of sex, race, and ethnic origin, have increased, although somewhat slowly for blacks.

Very high proportions of students are taking at least one college course in mathematical or computer sciences, physical or life sciences, and social and behavioral sciences. Mathematics college course enrollments have increased, although a substantial part of that increase is due to increases in remedial math enrollments.

Ongoing reforms are changing the way science and engineering are taught and learned at the undergraduate level; however, very few college science and engineering courses are taught in a laboratory or problem-solving format, and seldom do mathematics courses require, for example, writing assignments, group projects, or computer assignments. Policy makers and educators continue to look for ways to reduce the high levels of student attrition from majors in the natural sciences and engineering.

Although the numbers of bachelor's, master's, and doctorate degrees earned by females and underrepresented racial and ethnic groups have increased, these groups remain underrepresented in science and engineering, particularly within the natural sciences and engineering, at the graduate level and among science and engineering faculty. Of particular concern are degree trends for blacks. The number of undergraduate- and graduate-level science and engineering degrees earned by blacks have remained relatively flat over the past 10 years. Moreover, the number of science and engineering doctorates earned by black males has actually declined.

More systematic research is needed on the quality of education received by students in college and universities, how curricula are being reformed, and ways of reducing student attrition. Research is particularly needed on the proper education of students who will become elementary and secondary schoolteachers of science and mathematics. In addition, research ought to consider more fully the contributions that science, engineering, and technical education make to the economy and national well-being. ■

Endnotes

[1] The report was based on the findings from 30 roundtable sessions that brought together senior officers from hundreds of colleges and universities across the United States.

[2] Because these students provide diverse perspectives that can potentially benefit science and technology fields, science and engineering education must change to accommodate new learning styles and fulfill new needs (Wineke & Certain, 1990).

[3] This is the first year for which complete enrollment data by race and ethnicity exist.

[4] The extent to which this finding applies to various subpopulations—including those who have historically been underrepresented in science and engineering—is unknown because of sample size.

[5] The problem of student retention in science and engineering is not confined to the undergraduate level. At the graduate level, as many as half of science and engineering graduate students fail to complete their studies (U.S. Department of Education, 1988).

[6] Some of this decrease can be attributed to students who graduate from high school and do not to pursue postsecondary education of any kind.

[7] For more information on trends in science and engineering degrees, see NSB (1993).

[8] People with disabilities are also considered to be underrepresented in science and engineering, although no data on degrees by disability status exist.

[9] Technicians apply science- and engineering-based techniques using complex technologies in order to transform materials into useful products. Technicians may also be called upon to modify or repair equipment that is used in the production of goods and services.

[10] The Carnegie Foundation for the Advancement of Teaching last classified U.S. postsecondary institutions in 1987.

[11] Two-year institutions provide educational access for local residents to job-related courses, adult education, technically based programs, and preparation for study at 4-year institutions. Tuition is generally lower at 2-year institutions than at 4-year colleges, and campuses are community-based, allowing students to pursue postsecondary education more easily while holding full- or part-time jobs.

[12] One reason may be that these institutions draw students from a wider geographic area than other schools and combine an educational mission with a strong mission in fundamental research and discovery.

[13] The proportion of this fraction that was available for undergraduate, rather than graduate, instruction is unknown.

Chapter 4 References

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