Chapter 2
Higher Education in Science and Engineering

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HIGHLIGHTS

GLOBAL DIFFUSION OF SCIENCE AND ENGINEERING EDUCATION

- **From 1975 to 1992, higher education in science and engineering (S&E) expanded rapidly in several world regions.** By 1992, more than 1 million students successfully completed their first university degrees in natural sciences or engineering (NS&E) in selected countries in Asia, Europe, and North America. The total number of NS&E degrees awarded in Europe and North America in 1992 almost equaled the total number of NS&E degrees awarded in six Asian countries: China, India, Japan, Singapore, South Korea, and Taiwan.

- **The size of the college-age population declined in the industrialized countries of Western Europe, Asia, and North America.** This demographic trend did not result in a decline in the number of NS&E degrees awarded in Europe or Asia. However, such a decline did occur in the United States. Participation rates in university education, and in the number of NS&E degrees awarded in particular, have increased among European and Asian countries, which more than offset the declining population.

- **The United States remains one of the leading countries in the world in its creation of a system of higher education that reaches a broad cross section of citizens.** The ratio of total bachelor's degrees to the 24-year-old population reached 31 percent in the United States in 1992. Although access to higher education has greatly expanded in European countries during the past 20 years, the ratio of university degrees to their college-age populations still do not exceed 10 to 20 percent. However, compared with other countries, a relatively small percentage of U.S. college students major in NS&E fields. The ratio of NS&E degrees to the U.S. college-age population in 1992 was only 4.6 percent. For several major European and Asian countries (Germany, the United Kingdom, Japan, and South Korea), the ratios of NS&E degrees to college-age population reached 5 and 6 percent.

CHARACTERISTICS OF U.S. HIGHER EDUCATION INSTITUTIONS

- **In 1993, there were 3,611 (1,566 public and 2,045 private) institutions of higher education in the United States.** These institutions enrolled 14.7 million students in that year, more than double the number enrolled in higher education in 1967. Two-year colleges experienced the highest growth rates in student enrollments.

- **U.S. higher education institutions awarded more than 2 million degrees, one-quarter of which were in S&E fields.** The majority of these S&E degrees were earned at the bachelor's level. The largest proportions of these S&E baccalaureates continue to be awarded by research and doctorate-granting institutions. Taken together, these institutions account for more than 50 percent of the bachelor's degrees awarded in the natural sciences and 80 percent of the engineering degrees.

UNDERGRADUATE STUDENTS AND DEGREES

- **Minority students are becoming more interested in S&E majors.** By 1994, underrepresented minorities, especially women in these groups, accounted for a substantial portion of the freshmen planning to major in physical sciences (15 percent), biological fields (16 percent), social sciences (20 percent), and engineering (18 percent).

- **The number of S&E degrees awarded at the bachelor's level increased during 1989 to 1993, at a 3-percent annual growth rate, mostly because greater numbers of students are choosing to major in natural sciences and social sciences.** The number of degrees awarded in engineering, mathematics, and computer sciences has leveled off after several years of decline.

GRADUATE STUDENTS AND DEGREES

- **Graduate enrollment of women and minorities accelerated in the 1990s.** By 1993, women represented 38 percent and 15 percent, respectively, of all graduate students in natural sciences and engineering. The large increases in graduate enrollments of minority students, however, are from a low base. Minority student representation, with respect to total S&E graduate student enrollment, increased by 1 percent, from 6.3 percent in 1991 to 7.3 percent in 1993.

- **Doctoral degree production has continued to increase in S&E fields since 1985.** The number of doctoral S&E degrees awarded, which was level at about 18,000 degrees from 1975 to 1985, increased to 25,000 by 1993. However, the number of these degrees obtained by U.S. citizens increased only slightly. The ratio of doctoral degrees earned by U.S. citizens to the 29-year-old U.S. population was about 0.4 percent in 1993.

- **The European region produces more NS&E doctoral degrees than both North America and Asia.** In 1991, European countries for which data were available produced more than 25,000 NS&E doctoral degrees, which was 20 percent more than North American NS&E doctoral degree production and double Asian NS&E doctoral degree production.

- **Other countries also educate a considerable number of foreign students.** In 1993, foreign students obtained 40 percent of the NS&E doctoral degrees awarded in Japan. In France, foreign students earned one out of three doctoral degrees in all fields of science. Foreign students also earned one-half of the engineering and social science doctoral degrees, and more than one-quarter of the natural science doctoral degrees awarded in the United Kingdom.

Foreign Students in U.S. Graduate Schools

- **Foreign students have accounted for a steadily increasing proportion of doctoral degrees awarded in S&E fields.** By 1993, foreign students on temporary visas obtained 44 percent of the mathematics and computer science doctoral degrees and 50 percent of the engineering doctoral degrees. In that same year, total doctoral degrees earned by non-U.S. citizens, including both permanent residents and foreign students on temporary visas, reached 57 percent in engineering fields and 47 percent in mathematics and computer science.

- **About 30 percent of foreign students earning S&E doctoral degrees receive firm offers to remain in the United States.** Of the 8,000 foreign doctoral recipients in 1993, about 400, or 5 percent, received firm offers for academic employment; almost 500, or 6 percent, received firm offers for industrial employment; and a larger group, almost 1,500, or 18 percent, obtained a postdoctoral research appointment for 1 year.

- **Fewer foreign students are entering U.S. universities for advanced training in S&E fields.** After a decade-long steady increase, the percent of graduate enrollment of foreign students decreased by 4 percent each year in 1993 and 1994, mainly in engineering and computer science. Foreign students currently represent slightly fewer than one-third of graduate students in engineering.

Major Sources of Financial Support

- **Research assistantships are still the dominant mechanism of support for S&E graduate students.** In 1993, almost 90,000 students, representing 27 percent of all graduate S&E students, received their primary support from research assistantships. About one-half relied on Federal sources; the other half relied on nonfederal sources. These assistantships are particularly significant in the support of graduate students in fields of physical sciences, geosciences, biological sciences, and engineering. The long-term trend of a 5-percent annual growth rate in the numbers of these assistantships being offered continued until 1992. From 1992 to 1993, however, the growth rate was less than 1 percent.

- **Non-U.S. sources account for the majority of funding support for foreign students at all levels of higher education.** In 1993, two-thirds of the foreign students in the United States cited their families as their primary source of support; 7 percent of funding came from their home governments, universities, and foreign private sponsors. U.S. sources are the primary funding support for 25 percent of foreign students.

- **U.S. sources are the primary funding mechanism for almost 80 percent of all foreign S&E students at the doctoral level.** More than three-quarters of foreign S&E doctoral students receive their primary funding support in the form of either research assistantships, teaching assistantships, or university fellowships. Only 3 percent of their funding comes from Federal fellowships or traineeships.

Introduction

Chapter Background

This chapter discusses recent trends in higher education among U.S. institutions and some emerging changes in those trends. Underlying these trends and the changes are several demographic, institutional, and international factors. The changing makeup of the population and the impact of a variety of individual, organizational, and governmental decisions are creating new issues and opportunities that present challenges to higher education institutions. Changes in national and global industrial organizations provide additional challenges, and the global diffusion of scientific and engineering knowledge conditions the way higher education addresses these challenges.

Chapter Organization

This chapter begins with a global overview of the institutional and demographic conditions that are emerging in different regions of the world and their impact on first university degrees and participation rates in science and engineering degrees. Then current U.S. data on higher education are discussed and contrasted with doctoral and foreign student data from other regions of the world, particularly Asia and Europe.

Text table 2-1.
First university degrees in S&E, by region: 1992

Field	Asia	Europe	North America
All first university degrees	1,725,323	1,004,493	1,412,662
Natural sciences & engineering	523,651	299,057	242,877
Natural sciences	242,879	140,126	133,918
Engineering	280,772	158,931	108,959
Social sciences	236,018	116,353	218,026

NOTES: The requirements for first university degrees in S&E fields are not comparable across or even within the countries included in these three regions, particularly for European universities. For example, Germany submits both the university degrees (with an average duration of 7 years) and the *Fachhochschulen* degrees (polytechnics of 4.5 years average duration) as first university degrees (level 6 in UNESCO classification). Work has been underway for several years at UNESCO, EUROSTAT, and the U.S. Department of Education to refine the levels of higher education for better comparability across countries. See for example, *Mapping the World of Education: The Comparative Database System (CDS)*, (Washington, DC: U.S. Department of Education and The National Science Foundation, 1994). A new UNESCO survey will be designed and implemented by the end of this decade for better harmonization of degree data across countries.

See appendix table 2-1 for countries in each region.

Science & Engineering Indicators – 1996

Global Diffusion of Science and Engineering Education

First University Degrees[1]

One indicator of the global diffusion of science and engineering (S&E) knowledge and skills is the rapid expansion of higher education in several world regions. Data available on selected countries in Asia, Europe, and North America show dramatic growth in the number of students completing higher education in S&E fields[2] in the period between 1975 and 1992. In 1992, more than 1 million students successfully completed their first university degrees in the natural sciences or engineering (NS&E). That year, the number of NS&E degrees awarded in Europe and North America combined approximately equaled the number of similar degrees awarded in six Asian countries. (See text table 2-1.)

Among the six Asian countries studied, growth rates in the annual production of NS&E degrees from 1975 to 1992 have been highest in South Korea and Singapore (9 percent). Growth rates in Japan and India during this period were lower (2 and 3 percent, respectively). (The higher education systems in both countries grew dramatically in the 1950s.) The newly emerging economies of Asia have invested heavily in higher education, particularly in fields of NS&E, to advance their technological capacity further. China's highly developed university system, which was temporarily dismantled during the Cultural Revolution, is now producing the largest number of engineering degrees in the Asian region, more than 120,000 in 1992, with an annual growth rate of 6 percent (SRS, 1993b).

Higher education also has expanded dramatically in Europe since 1975, particularly in S&E. This expansion of higher education is an important part of, and the underpinnings for, a broader effort to revitalize Europe through the European Union. Until relatively recently, university education in Europe was lengthy, research oriented, and reserved for an extremely elite group of scholars who had successfully completed a rigorous academic high school track. In the 1960s, the accelerated pace of economic development created a demand for more skilled labor, and the expansion of the middle class caused a great demand for higher education. Governments in Europe responded to these pressures by forming the so-called nonuniversity tertiary-level institutions, such as the *Instituts Universitaires de Technologie* in France in 1966, polytechnics in the United

[1]Data in this section are primarily taken from the Science Resources Studies Division, National Science Foundation, Global Database on Human Resources for Science and Engineering.

[2]Note that, in these international comparisons, the natural sciences include the mathematical and computer, as well as the biological, agricultural, earth, atmospheric, oceanographic, and physical sciences.

Kingdom in 1969, and the *Fachhochschulen*[3] in Germany in 1971. These institutions increased the small number of students in higher education, helping to alleviate the serious shortage of trained workers (SRS, forthcoming).

Collectively, the Western European countries more than doubled their annual production of first university NS&E degrees between 1975 and 1991. (See appendix table 2-1 for countries included.) The number of natural science degrees increased from approximately 54,000 in 1975 to 108,000 in 1991. The number of engineering degrees awarded rose from 51,000 in 1975 to 106,000 in 1991. These data represent a 4.5 percent average annual rate of increase in the natural sciences and a 5.0 percent rate of increase for engineering (SRS, forthcoming).

Demographic Changes

In the 1980s, the size (in absolute numbers) of the college-age population began to decline in the industrialized countries of Western Europe, Asia, and the United States. In Western Europe, the number of 20- to 24-year-olds decreased by 3 million between 1990 and 1995. This trend is expected to continue until 2005. The population of 20- to 24-year-olds has decreased in the United Kingdom since 1985 and in Finland since 1975 (SRS, forthcoming). Japan, Singapore, South Korea, and Taiwan also have declining college-age populations. China and India, however, have increasing populations. By the end of the decade, the college-age population in China will reach 100 million and in India, 88 million (SRS, 1993b).

International Comparison of Science and Engineering Degree Trends

In the United States, the decline in the 20- to 24-year-old age group has been mirrored by a decline in NS&E degrees awarded, from 207,902 in 1986 to 173,099 in 1992. However, the declining pool of college-age students in Europe has not resulted in declining numbers of NS&E degrees. Participation rates in university education, and in NS&E degrees in particular, have increased to the extent that they more than offset the declining population. For example, Germany has continued to increase the output of S&E degrees awarded despite a declining pool of students since 1985. First university S&E degrees awarded in Germany (includes *Fachhochschulen*) increased from 59,000 in 1975 to 106,000 in 1992 (SRS, forthcoming). The rate of S&E degree production has eclipsed the overall rate of university degree production in Germany. Moreover, the reform and democratization of higher education in France, initially begun in the 1960s, have resulted in a tripling of both student enrollments and the number of new universities within a decade. Despite a declining population in France, increasing numbers of young people obtain a university education and major in NS&E fields. From 1975 to 1992, the number of NS&E degrees awarded doubled, from 17,000 to more than 35,000. During this same period, the number of young people getting a university degree in the United Kingdom tripled, particularly through the growth of new polytechnics, which were brought into the university system in 1992 (SRS, forthcoming).

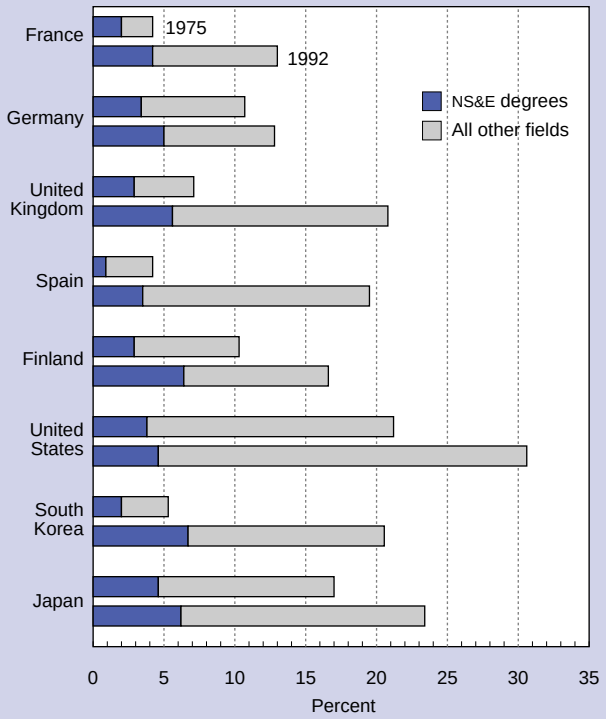
[3]*Fachhochschulen* are 4-year polytechnics that prepare students for work in various technical specialties. Graduates from these institutions generally do not pursue advanced degrees.

Access to Higher Education and Science and Engineering Degrees

The United States remains one of the leading countries in the world with a system of higher education that reaches a broad cross section of citizens. The ratio of total bachelor's degrees to the 24-year-old population reached 31 percent in the United States in 1992.[4] Only Canada and Norway have similarly high participation ratios. (See appendix table 2-1.) Although access to higher education in European countries has greatly expanded in the past 20 years, the ratios of university degrees to their college age populations still do not exceed 10 to 20 percent. (See figure 2-1.)

[4]This ratio is total degrees divided by the number of 24-year-olds. It is presented as a general indicator of the participation in higher education of the college-age population in each of the countries presented. Total degrees include those earned by older students, which makes the percentage higher than if only degrees to 24-year-olds were included.

Figure 2-1.
Ratio of total first university degrees and NS&E degrees to the 24-year-old population, by country: 1975 and 1992



SOURCES: For 1975 data, Science Resources Studies Division (SRS), National Science Foundation, *Human Resources for Science and Technology: The Asian Region* (Washington, DC: NSF, 1993); SRS, *Human Resources for Science and Technology: The European Region* (Arlington, VA: NSF, forthcoming).

See appendix table 2-1. *Science & Engineering Indicators – 1996*

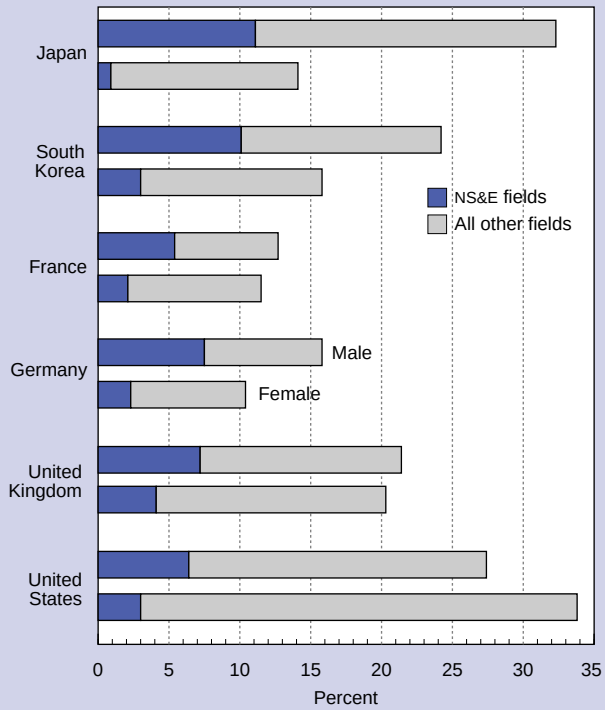
Although a high fraction of the U.S. population receives a college degree, the United States awards a relatively lower percentage of university degrees in S&E than most North American, Asian, and European countries. (See appendix table 2-2.) China's higher education system is the most focused on fields of NS&E. In 1992, more than one-half of all university degrees awarded in China were in these fields, compared with about one-third in Singapore, South Korea, and Taiwan and one-fourth of all degrees in Japan and India. Mexico had the highest percentage of university NS&E degrees in North America, approximately 33 percent.

The United States is not, therefore, among the leading countries in the world in the percentage of its college-age population with an NS&E degree. Although less than 5 percent of the U.S. college-age population earns an NS&E degree, several European and Asian countries have higher participation rates. In Finland, more than 6 percent of the college-age cohort obtains a university degree in NS&E fields, similar to the participation rates of Japan and South Korea. (See appendix table 2-1 and figure 2-1.) The large increase in participation rates in Germany in the past few years reflects the inclusion of East German universities, which have a greater focus on engineering degrees. In the United Kingdom, polytechnics, which achieved university status in 1992, have raised the participation rate in NS&E degrees to more than 5 percent. Spain's participation rate is now on a par with other European countries, after significant gains in the 1980s.

Participation rates of young people in NS&E fields differ considerably by sex. The most notable difference is in Japan, where less than 1 percent of 24-year-old females obtained a first university NS&E degree in 1992, although more than 11 percent of males obtained such a degree. In the United States, about twice as many males as females obtained an NS&E degree (6.4 percent versus 3.0 percent, respectively). In the United Kingdom, the percentages of college-age females and males receiving NS&E degrees are closer, 4.1 percent and 7.2 percent, respectively. (See figure 2-2 and appendix table 2-3.)

Women in several countries prefer natural science studies and obtain a higher share of natural science degrees at the first university degree level than do women in the United States. (See appendix table 2-4.) In 10 European countries, women obtain more than one-half of the first university degrees in the natural sciences; for 8 European countries, women obtain 20 percent or more of the engineering degrees. In the United States, women obtain 42 percent of the natural science degrees, and 16 percent of the engineering degrees. (See appendix table 2-5.)

Figure 2-2.
Ratio of total first university degrees and NS&E degrees to the 24-year-old population, by sex: 1992



See appendix table 2-3. *Science & Engineering Indicators – 1996*

The International Faculty Survey

The Carnegie Foundation for the Advancement of Teaching conducted a Survey of the International Professoriate in 1991, which indicated that across countries there is considerable diversity in the percentage of university faculty in S&E departments. Approximately 45 percent of Korean university faculty are in S&E fields, although more than 70 percent of German faculty are in these fields. (See text table 2-2.) Considerable differences exist also in the percentage of faculty within broad fields of S&E. About 20 percent of the faculty in Japan and Mexico teach in engineering programs, reflecting the high ratio of engineering degrees to total degrees (20 and 27 percent, respectively) in their higher education systems. (See appendix table 2-2.) In the United Kingdom and Germany, the highest percentages of faculty are in the natural sciences, 22 and 30 percent, respectively, reflecting the high proportion of natural science degrees to total degrees (about 17 percent) in these countries (Carnegie, 1995).

Characteristics of U.S. Higher Education Institutions

One reason for the broader U.S. access to higher education, described in the previous section, is the diverse and expansive institutional base of the U.S. higher education system. (Another is the diversity of attendance patterns. See Bachelor's Degrees in Science and Engineering in this chapter.) There were 3,611 (1,566 public and 2,045 private) institutions of higher education in the United States in 1993 (HEP, 1993). These institu-

Text table 2-2.
Distribution of faculty in selected countries, by field: 1991

Country	Total	Total S&E	S&E field: Math/physical/ biological sciences	Engineering/tech comp. science	Health sciences	Psych/social sciences	Total non-S&E
	Percent						
Japan	100	60	18	22	12	8	40
South Korea	100	45	9	18	11	6	54
Germany	100	73	30	17	15	11	27
United Kingdom	100	61	22	11	10	19	39
United States	100	61	17	8	25	11	39
Mexico	100	68	18	19	10	20	31

NOTE: Details may not add to totals because of rounding.

SOURCE: The Carnegie Foundation for the Advancement of Teaching, *The Academic Profession: An International Perspective* (Princeton: The Carnegie Foundation, 1995).

Science & Engineering Indicators – 1996

tions enrolled 14.5 million students in that year and awarded more than 2 million degrees, one-quarter of which were in S&E. (See figure 2-3 and appendix tables 2-6, 2-7, and 2-8.) The Carnegie Foundation for the Advancement of Teaching has classified those institutions into 10 categories, based on the size of their baccalaureate and graduate degree programs, the amount of research funding they receive, and—for baccalaureate colleges—their selectivity.[5] (See *Carnegie Classification of Academic Institutions* for a brief description of the categories used in this chapter.)

The number of students in U.S. institutions of higher education more than doubled between 1967 and 1993. The largest rates of growth in student enrollments were in 2-year associate of arts colleges, including community, junior, and technical colleges. (See figure 2-4 and appendix table 2-6.) Enrollment at these institutions, which grew at annual rates of 6 percent, leveled off in 1993 at 5.5 million students.

Bachelor's Degree Level

In 1993, 1,440 institutions granted 366,000 bachelor's degrees in S&E fields. The research and doctorate-granting institutions continue to award the largest proportions of baccalaureates in S&E fields. More than one-half of the bachelor-level degrees in the social and natural sciences and more than three-quarters of the engineering degrees are awarded at these institutions. (See figure 2-5.) Students earn almost 30 percent of their degrees in the social and natural sciences and about 16 percent of the engineering degrees at master's universities and colleges. Baccalaureate colleges provide a significant fraction (16 percent) of bachelor's degrees in the social and natural sciences and a small fraction (2 percent) of engineering degrees. (See appendix tables 2-7 and 2-8.)

Research I universities and baccalaureate colleges produce more undergraduates who later obtain NS&E doctorates than other types of institution. This finding holds regardless of ethnic group or gender and is largely related to the academic credentials of entering freshmen to these institutions. The most consistent determinant of an institution's ability to produce students who will complete doctorates is the quantitative ability of entering freshmen (Baker, 1994). In general, schools that are most selective in their admissions produce the highest percentage of NS&E students. However, there is also a strong and consistent relationship between female NS&E degrees and attendance at women's colleges and an increased probability of black baccalaureate degree completion at Historically Black Colleges and Universities (Baker, 1994).

Master's Degree Level

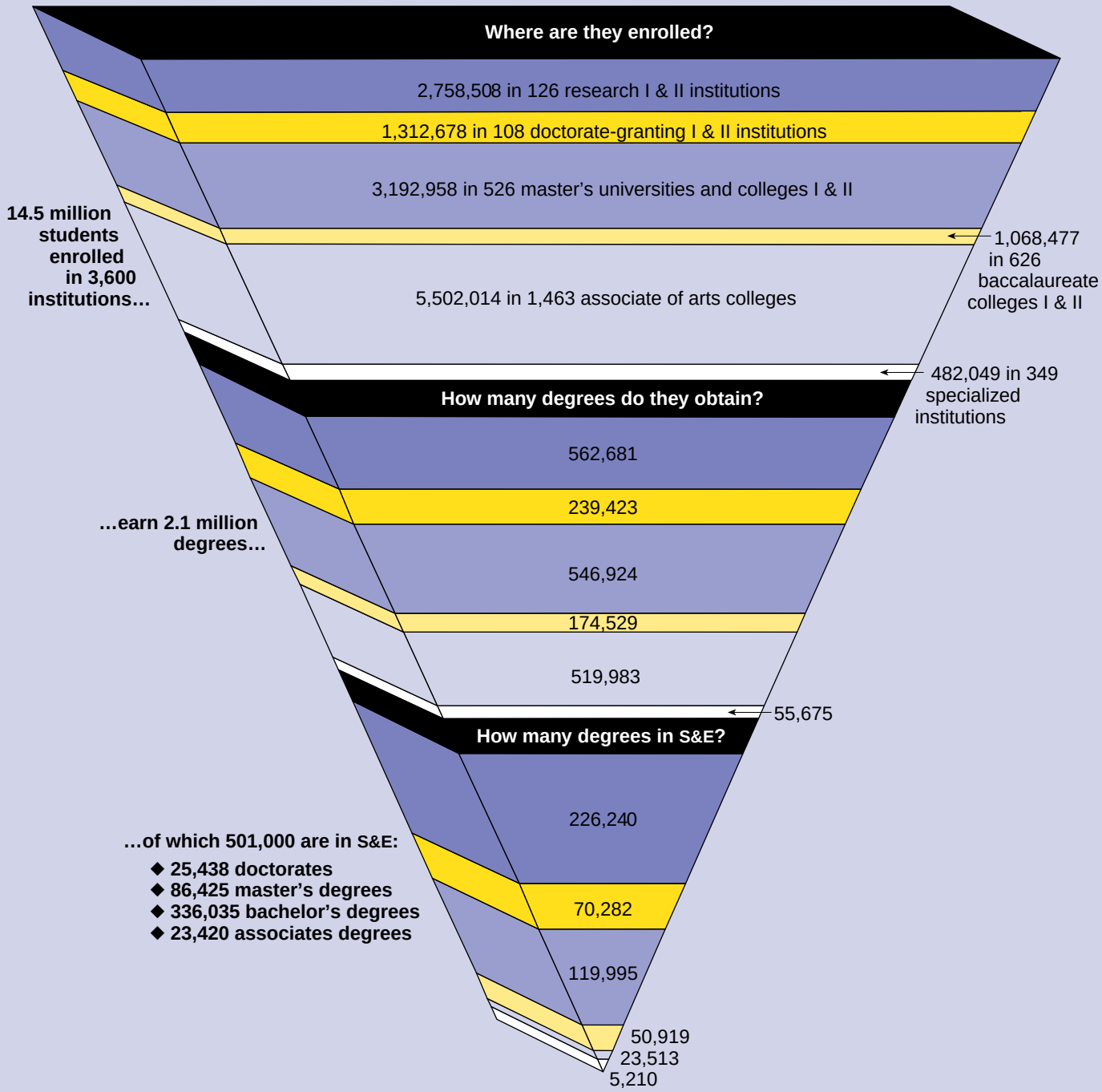
In 1993, 727 institutions granted more than 86,000 master's degrees in S&E fields. These S&E degrees were granted mainly in research and doctoral institutions. Students earn three-fourths of their natural science degrees and 85 percent of their engineering degrees at the master's level through research and doctoral level universities. (See figure 2-6 and appendix table 2-7.) Master's universities and colleges are also important in the production of S&E master's degrees, providing 30 percent of the social science degrees, 23 percent of the natural science degrees, and 11 percent of the engineering degrees.

Doctoral Degree Level

The capacity of U.S. institutions to provide doctoral degrees in S&E fields expanded in the 1960s and again in the late 1980s, as indicated by the increasing size of enrollment, faculty, staff, and budgets at research universities (President's Council of Advisors on Science and Technology, 1992). More recently, between 1988 and

[5]The Carnegie classification is not an assessment guide, nor are the distinctions between classification sublevels (e.g., research I and research II) based on institutions' educational quality. Baccalaureate colleges I exercise more selectivity regarding students than do baccalaureate colleges II, but in general the Carnegie categories are a typology, not a rank ordering.

Figure 2-3.
U.S. higher education, by students, institutions, and degrees: 1993



NOTE: This figure represents relative sizes of enrollments and degrees within Carnegie categories of institutions in 1993. It does not depict the dynamics of higher education or the movement of students among institution types prior to graduation.

See appendix tables 2-6, 2-7, and 2-8.

Science & Engineering Indicators – 1996

1993, the number of institutions of higher education that qualified as research I universities increased from 68 to 88. (See *Carnegie Classifications of Academic Institutions*.) These institutions provided more than 18,000 of the 25,000 degrees in S&E fields. This expansion was made possible by the convergence of two factors: large Federal research grants to universities and a large influx of foreign doctoral students seeking advanced training in S&E. Neither of these trends is expected to continue at the same rate of growth. (See sections on Foreign Students in U.S. Universities and Major Sources of Financial Support in this chapter for additional information on these trends.)

Carnegie Classification of Academic Institutions

Following are brief descriptions of the categories of institutions used in this chapter (Evangelauf, 1994).

Research I: These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate degree, and give high priority to research. They receive at least $40 million annually in Federal support and award at least 50 doctoral degrees.

Research II: These institutions are the same as research I, except that they receive between $15.5 million and $40 million annually in Federal support.

Doctorate-Granting I: In addition to offering a full range of baccalaureate programs, the mission of these institutions includes a commitment to graduate education through the doctoral degree. They award 40 or more doctoral degrees annually in at least five academic disciplines.

Doctorate-Granting II: These institutions are the same as doctorate-granting I, except that they award 20 or more doctoral degrees annually in at least one discipline or 10 or more doctoral degrees in three disciplines.

Master's (Comprehensive) Universities and Colleges I: These institutions offer baccalaureate programs and, with few exceptions, graduate education through the master's degree. More than half of their baccalaureate degrees are awarded in two or more occupational or professional disciplines, such as engineering or business administration. All of the institutions in this group enroll at least 2,500 students.

Master's (Comprehensive) Universities and Colleges II: These institutions are the same as master's universities and colleges I, except that all of the institutions in this group enroll between 1,500 and 2,500 students.

Baccalaureate (Liberal Arts) Colleges I: These highly selective institutions are primarily undergraduate colleges and award more than 40 percent of their baccalaureate degrees in liberal arts and science fields.

Baccalaureate (Liberal Arts) Colleges II: These institutions are primarily undergraduate colleges that award less than 40 percent of their degrees in liberal arts and science fields. They are less restrictive in admissions than baccalaureate colleges I.

Associate of Arts Colleges: These institutions offer certificate or degree programs through the associate degree level and, with few exceptions, offer no baccalaureate degrees.

Professional Schools and Other Specialized Institutions: These institutions offer degrees ranging from the bachelor's to the doctorate. At least half of the degrees awarded by these institutions are in a single specialized field. These institutions include theological seminaries, bible colleges, and other institutions offering degrees in religion; medical schools and centers; other separate health profession schools; law schools; engineering and technology schools; business and management schools; schools of art, music, and design; teachers colleges, and corporate-sponsored institutions.

Undergraduate Science and Engineering Students and Degrees

Recent Trends in College Enrollments

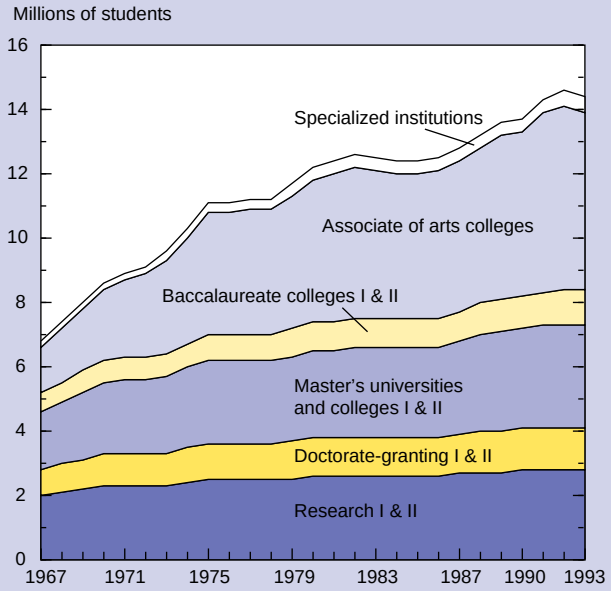
Undergraduate enrollments in higher education have grown moderately from 1978 to 1993 (1.6 percent) across the total population of students, but some minority groups have significantly increased their access to higher education. Undergraduate enrollment of Asian-American students has increased at an average annual rate of 7.8 percent from 1978 to 1993. Enrollment of Hispanics has increased at 5 percent annually, and enrollment of Native Americans has increased 3 percent over this same period. (See appendix table 2-9.) Women make up more than half of the undergraduate enrollments in higher education for every racial/ethnic group in the United States. Among black students, women comprise more than 60 percent of the undergraduate enrollments. Foreign students are the exception; women comprise less than one-half of foreign undergraduate enrollments (45 percent). Students with disabilities make up about 6 percent of all students enrolled in post-secondary institutions; 5.7 percent of all students who major in S&E fields and 6.6 percent of students who major in non-S&E fields (NCES, 1995a).

Engineering Enrollments

Most engineering programs require students to declare their major as entering freshmen, although some allow an unspecified field of engineering for the first 2 years.[6] Therefore, engineering enrollments and student composition can be used as early indications of near-term engineering degrees and participation rates of women and minorities. The total number of engineering students increased rapidly from 1979 to 1983, growing

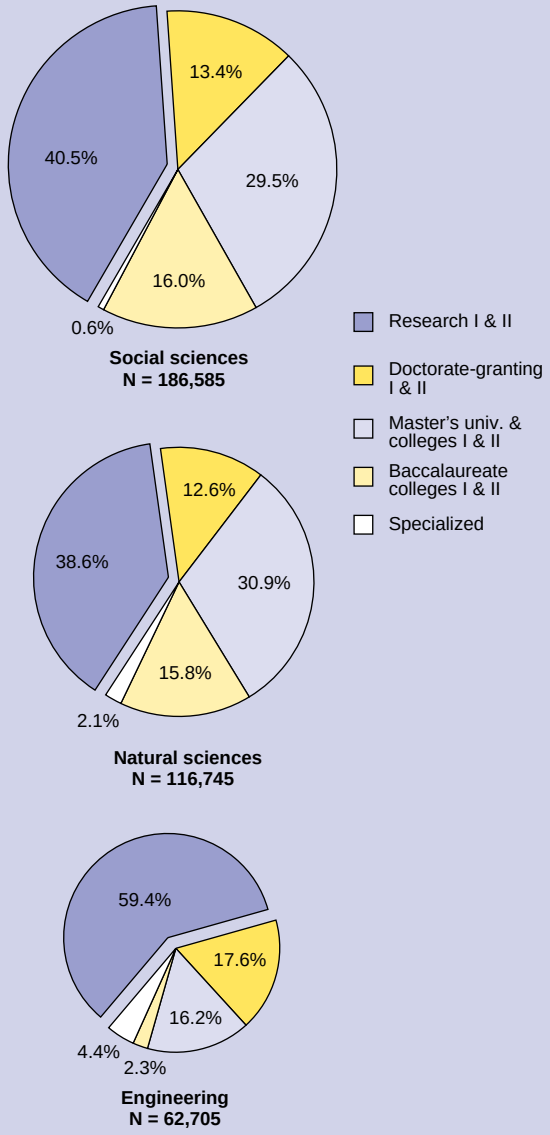
[6]Data in this section are from the Engineering Workforce Commission (EWC). The commission collects trend data on full- and part-time engineering and engineering technology enrollments in baccalaureate and 2-year programs and on enrollments of women and minorities.

Figure 2-4.
U.S. enrollment in higher education



See appendix table 2-6. *Science & Engineering Indicators – 1996*

Figure 2-5.
Bachelor's degrees awarded in S&E, by institution type: 1993



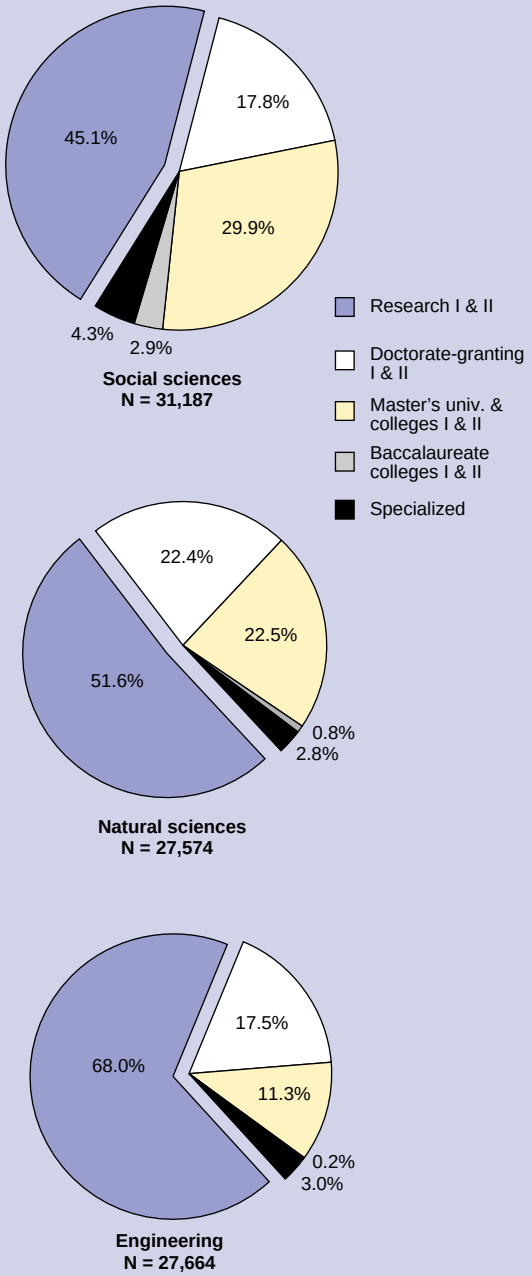
NOTES: Natural sciences include mathematics and computer sciences. Specialized includes other institutions.
See appendix table 2-7. *Science & Engineering Indicators – 1996*

from 366,000 in 1979 to more than 440,000 in 1983. The number of engineering students has declined slowly (1.6 percent annually) since then, somewhat more slowly than the decline of the college-age population (1.9 percent annually) since 1979. The number of students who studied engineering in 1994 (367,000) nearly equaled the number in 1979 (366,000). (See appendix table 2-10.)

Declining engineering enrollments are not evenly distributed among major specialties: 1994 enrollments in mechanical and aerospace engineering declined the most from the previous year, although enrollments increased in civil and environmental engineering (EWC, 1995c). In addition, the number of part-time students expanded during this period, representing approximately 11 percent of the total engineering enrollments by 1994. (See appendix table 2-11.)

During this period, student enrollment became far more diverse, with women entering engineering fields in record numbers. In 1994, females comprised almost one-fifth of the undergraduate engineering students in the United States, comparable with the leading European countries in the proportion of female engineering students: Denmark, France, Sweden, and the United Kingdom. (See appendix tables 2-5 and 2-12.) Also, underrepresented minorities made up more that 14 percent of the engineering students in 1994, up from 7 percent in 1979. Currently, blacks and Hispanics each represent almost 7 percent of the engineering enrollments, up from 4 and 3 percent, respectively in 1979. (See appendix table 2-12.) Foreign students represent only 6 percent of undergraduate engineering students, and they are declining in absolute numbers and as a percent of undergraduate engineering students. Asian-Americans comprised 10 percent of engineering students between 1979 and 1994, far higher than their representation of the college-age population (3.9 percent). (See appendix table 2-12 and figure 2-7.)

Figure 2-6.
Master's degrees awarded in S&E, by institution type: 1993



NOTES: Natural sciences include mathematics and computer sciences. Specialized includes other institutions.

See appendix table 2-7.

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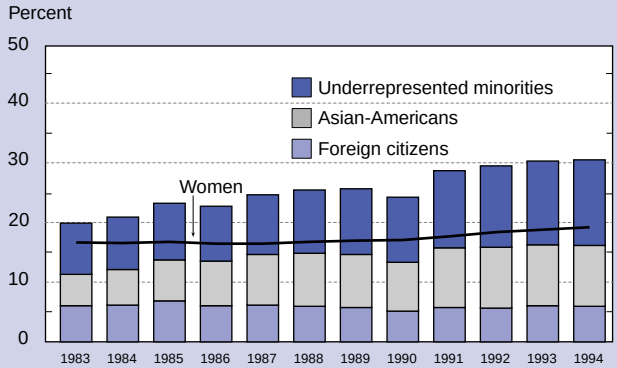
Figure 2-7.
Representation of women and minorities in undergraduate engineering enrollments



NOTE: Underrepresented minorities are blacks, Hispanics, and Native Americans.

See appendix table 2-12. *Science & Engineering Indicators – 1996*

Characteristics of American College Freshmen

Planned Majors by Sex and Race/Ethnicity

As in the past, about one-third of entering freshmen choose S&E majors.[7] In 1994, around 45 percent of Asians, 38 percent of black and Hispanic freshmen, and 31 percent of white and Native American freshmen intended to major in S&E fields. (See appendix table 2-13.) Since the late 1980s, more freshmen are choosing majors in the natural sciences, whereas the popularity of the social sciences continues to decline, especially among females. In 1994, a higher proportion of white and Asian females chose natural science majors than social science majors. Males in every group still choose engineering above all other S&E fields, but a slightly lower proportion of white students, both male and female, chose engineering in 1994 than in previous years.

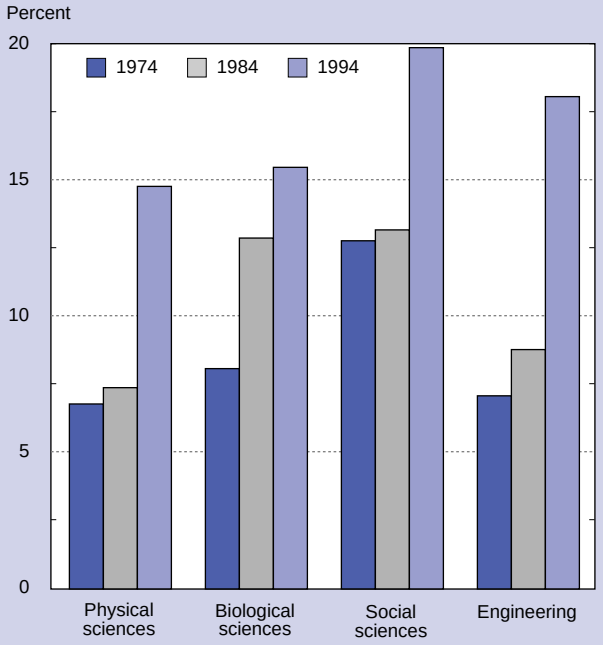
During the past 2 decades, minority representation among freshmen planning to major in selected S&E fields has greatly increased, especially for females in these groups. By 1994, underrepresented minorities made up approximately 15 percent of freshmen planning to major in the physical sciences, 16 percent planning to major in biological fields, 20 percent planning to major in the social sciences, and 18 percent planning to major in engineering. (See appendix table 2-14.) In 1974, the percentage of minorities in NS&E fields was far lower, at 7 percent. (See figure 2-8.)

Planned Majors by Disability Status

Students with disabilities are as likely to choose S&E majors as non-S&E majors. Students with hearing, speech, sight, and orthopedic disabilities and health-related problems are as equally represented in S&E

[7]These data are from Higher Education Research Institute (1994).

Figure 2-8.
Minority representation among freshmen planning to major in a science or engineering field



NOTE: Data reflect underrepresented minorities only–i.e. blacks, Hispanics, and Native Americans.

See appendix table 2-14. *Science & Engineering Indicators – 1996*

fields as non-S&E fields. Only students with learning disabilities choose non-S&E majors slightly more than they choose S&E majors. In 1994, 8.9 percent of freshmen planning to major in S&E fields had some form of disability, up from 6.1 percent in 1983. Similarly, freshmen students with disabilities entering non-S&E majors reached 9.5 percent in 1994, up from 5.9 percent in 1983. (See appendix table 2-15 and text table 2-3.)

Text table 2-3.
Choice of major for students with disabilities

Disability	Plan S&E major 1983	Plan S&E major 1994	Plan non-S&E major 1983	Plan non-S&E major 1994
	Percent			
Total	6.1	8.9	5.9	9.5
Hearing	0.6	0.8	0.8	1.0
Speech	0.2	0.3	0.2	0.3
Orthopedic	0.7	0.8	0.5	1.0
Learning disabled	0.4	1.7	0.5	2.1
Health related	0.8	1.4	0.6	1.6
Partially sighted/blind	2.4	2.4	2.4	2.2
Other	1.0	1.5	0.9	1.3

SOURCE: Higher Education Research Institute, University of California at Los Angeles. *Survey of the American Freshman: National Norms,* unpublished tabulations, 1995.

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Associate Degrees in Science and Engineering

Associate degrees in science, engineering, and engineering technology[8] are becoming increasingly important to workers in high technology industries. Engineering technology skills will be crucial in electronics, computer graphics, and mechanical engineering fields; programs focused on these industries account for more than one-half of the engineering technology programs offered at the associate level. Science technology skills will be vital in high technology industries related to agriculture, chemicals, and biotechnology; programs focused on these three fields account for nearly half of the science technology programs offered (Burton and Celebuski, 1995). The number of associate degrees in S&E fields remained relatively constant between 1983 and 1993 at around 23,000 degrees. Although the overall total in S&E degrees remained the same, individual fields varied widely. Social science degrees at the associate level increased at the rate of 2 percent annually from 4,800 in 1983 to 5,800 in 1993. Engineering and engineering technology degrees declined from 1986 to 1993 (as have bachelor-level degrees in these fields), only partially because of the declining pool of college-age students in this period. Although associate degrees in engineering and engineering technology declined 2.6 and 2.2 percent, the population of 20-year-olds declined 1.3 percent during this same time. Between 1983 and 1993, engineering technology degrees decreased from 51,000 to 41,000 (see appendix table 2-16), and science technology degrees decreased from 1,500 to 1,000.

To counter these declining trends, the Advanced Technology Education (ATE) Program was begun in 1992 to improve technical education at the associate level in the United States.[9] ATE supports projects in curriculum and laboratory development, improved teacher preparation, and enhanced partnerships with local businesses and industry. Sponsored projects are linked with the feeder high schools to improve preparation in science and mathematics and with 4-year colleges and universities to facilitate transfer students. Although fewer engineering technology degrees have been awarded, the 1995 Higher Education Survey (Burton and Celebuski, 1995) reports increasing enrollments in these programs—and even more growth in science technology programs. Further initial results of this ATE program are reflected in the EWC 1994 survey, which showed an increase in associate-level degrees in engineering technology for the first time since 1990.[10] Associate-

[8]Engineering technology and science technology are not within the taxonomy of fields included under S&E in the Standard Classification of Instructional Programs.

[9]The Scientific and Advanced Technology Act of 1992 called for the National Science Foundation to establish a national program to improve the education for technicians in advanced technology fields.

[10]The EWC survey of engineering uses a narrower definition of engineering technology and covers slightly fewer colleges than the NCES survey data used in this report. Therefore, engineering degree data contained in this chapter's appendix tables are not comparable with the degree data found in the EWC (1995a) full report: *Engineering and Technology Degrees, 1994*.

level degrees in S&E are more prominent in some European and Asian countries. (See *Technical Education in Germany, France, Japan, and South Korea*.)

Associate Degrees by Race/Ethnicity

Minority students are more represented in S&E fields at the associate level than in other levels of higher education, mainly in the social sciences and computer science.[11] Underrepresented minorities obtained 25 percent of social science degrees and 22 percent of computer science degrees awarded at the associate level in 1993. These minority groups obtained 14 percent of the associate-level degrees in engineering and engineering technology. (See appendix table 2-17.) Although the total number of engineering degrees awarded fell from 1986 to 1993, the number of associate-level degrees in engineering awarded to blacks increased by 3.9 percent annually, and the number awarded to Hispanics increased by 2.5 percent annually.

Bachelor's Degrees in Science and Engineering

The number of overall S&E degrees at the bachelor's level peaked in 1986, declined until 1989, and subsequently increased, at a 3-percent annual growth rate.[12] Natural sciences and social sciences account for this increase; the number of degrees in engineering and mathematics and computer sciences is leveling off after several years of decline. (See figure 2-9 and appendix table 2-18.) The patterns in each broad field are examined separately below.

The number of natural science degrees, which declined steadily during the 12-year period between 1977 and 1989, increased sharply from 1989 to 1993. During this period, both male and female students increasingly chose to major in natural science fields. Recent increases can be accounted for mainly by the high rate of growth in natural science degrees to women, almost 5 percent annually. (See figure 2-10.) Among subfields of the natural sciences, the largest growth has come in biological, physical, and earth, atmospheric, and oceanographic sciences. (See appendix table 2-18.)

The number of degrees in mathematics and computer sciences grew rapidly from 1975 to 1986, at 8 percent annually, followed by a steady decline until 1991. Since then, the numbers have leveled off. The pattern is the same for both males and females. Computer science degrees have undergone the sharpest decline.

The number of social and behavioral science degrees declined from 1975 to 1985, mainly because fewer male students chose these fields during that 10-year period. Since 1986, both male and female students have increasingly majored in the social and behavioral sciences; female growth rates have been slightly higher.

The number of degrees in engineering peaked in 1986, and subsequently declined until 1991. In 1993, engineering degrees increased slightly, mainly from the growth in chemical, civil, and mechanical engineering fields. Electrical engineering, the largest field, continued to decline in absolute numbers and in proportion to all engineering degrees. In contrast, civil and chemical engineering, fields which are popular with women, have grown since 1989. (See appendix table 2-18.) Women received nearly 17 percent of overall bachelor's degrees in engineering in 1994 (EWC, 1995b) and almost one-third of the undergraduate degrees in chemical engineering. Overall, the number of engineering bachelor's degrees obtained by women has declined since 1987 at the same rate of decline as the female college-age population, 1.5 percent.

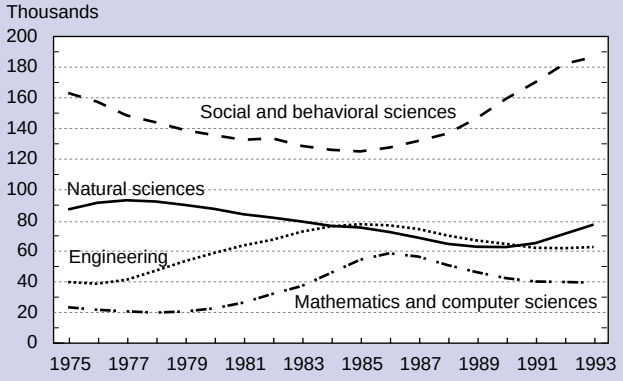
Bachelor's Degrees by Race/Ethnicity

Blacks and Hispanics recently have earned degrees in greater numbers in S&E fields. Although the total number of engineering degrees has decreased annually since 1986, until leveling off in 1993, the number of engineering degrees awarded to blacks has increased 5.7 percent annually since 1989. (See appendix table 2-19.) The number of engineering degrees awarded to Hispanic students increased 5.6 percent annually over the same time. Blacks and Hispanics account for a portion of the increases in the number of degrees awarded in the natural sciences and the social sciences. Although the proportion of S&E degrees awarded to blacks and Hispanics is still small, the growth rates are high. Natural science degrees awarded to blacks increased 8 percent annually, and the number of social science degrees awarded increased 12 percent annually, from 1989 to 1993. Degrees obtained by Native American students increased in the natural sciences and the social sciences, but not in engineering. Engineering degrees obtained by foreign

[11]Overall trends are available for 1975 to 1993; degrees by race/ethnicity are available from 1983 to 1993.

[12]Data in this section are from the National Center for Education Statistics, Earned Degrees and Completion Surveys.

Figure 2-9.
Bachelor's degrees awarded in science and engineering



See appendix table 2-18. *Science & Engineering Indicators – 1996*

Technical Education in Germany, France, Japan, and South Korea

The trend in Europe is toward more technical education, which was first introduced in the 1970s for labor market requirements. Even students who qualify for admission to universities, based on their successful completion of the academic track of upper secondary school, are attracted to technology institutes because of good job-placement rates. In Asia, South Korea's educational policy provides equal quotas for junior-college-level education in S&E fields as for bachelor's level. Japan, similar to the United States, has a small number of associate-level degrees in S&E fields in comparison with university degrees in these fields.

Germany. Training aimed at providing a highly skilled labor force is available within Germany's higher education system through a great variety of institutions, including polytechnics, called *Fachhochschulen*, vocational academies, and technical trade schools. They have different levels of entrance requirements, duration of study, and alliance with industry.

Fachhochschulen, established in the early 1970s to address the serious shortage of skilled workers (Von Friedeburg, 1990), prepare students in programs that teach a variety of technical specialties. The average duration of these programs is 4.5 years. They have become increasingly attractive to students with the *Abitur** because of the relatively favorable employment prospects.† German industrial firms consider this training to be more practical and focused on their needs (Tessaring, 1992). The *Fachhochschulen* are an important source of training for engineers, accounting for two-thirds of the engineering degrees awarded in Germany in 1992. Germany would like to divert more of its engineering students from universities to *Fachhochschulen*. The German government is establishing new *Fachhochschulen* in former East Germany to create a more highly skilled labor force and to foster economic growth in that region. (As of 1992, only 15 percent of the engineering degrees in the former East Germany were earned in *Fachhochschulen*.)

In addition, Germany has 2- and 3-year higher education programs‡ in vocational academies (*Berufsakademien*) which integrate practical training in industry with theoretical education in a local university. Graduates are placed within the enterprises where they were trained. Although attractive because of job placements, they are limited to around 6,000 students a year, and the degrees are not always recognized outside the state where they were earned. More significant and numerous are the trade and technical schools (TTS), open to students who have not completed the academic track of upper secondary school. Students with certificates from vocational high schools and apprenticeships, which together compose more than half the German high school student population, can receive further training in a variety of TTS. German industry heavily supports one variety: 3-year institutes, called *Fachschulen*. These institutes retrain their current workers in industry-specific skills. In 1987, there were 85,000 university graduates, 52,000 *Fachhochschulen* graduates, and 41,000 *Fachschulen* graduates (Tessaring, 1992). In 1990, West German postsecondary institutions awarded 18,700 associate-level degrees in engineering. Adjusting for the size of the German college-age population, which is one-third that of the United States, indicates a figure somewhat more than the 43,000 engineering and engineering technology associate-level degrees awarded in the United States.

France. The reform and democratization of higher education in France, which began in the 1960s and resulted in the tripling of student enrollments and the number of new universities over a 10-year period, have begun a new period of expansion in the 1990s. Technical education, especially 2- and 3-year programs, has expanded even more rapidly than university programs.

In 17 years, the number of degrees awarded at *Sections de Technicien Supérieur (STS)*, 2- and 3-year courses conducted in high schools following the *baccalauréat*, has increased fivefold, from 11,526 in 1975 to 62,171 in 1992. These institutes absorb the increasing number of students who complete the technology courses of study in high school, such as construction mechanics, electronics, and microprocessing.# These high school technology tracks, initially designed to prepare students for immediate employment, are increasingly becoming a first stage toward students' higher education in technology institutes.

Other 2-year technology institutes for high-level technical workers, the *Instituts Universitaires de Technologie (IUT)*, have about one-third the enrollment of the STS. They are connected to existing universities, but administered separately. The IUT awarded more than twice as many degrees in 1992 as in 1975, from 14,746 in 1975 to 31,204 in 1992. In 1992, 93,000 students successfully completed technical training within these two types of institute§ (Charlot and Pottier, 1992). IUT diplomas are creditable toward university studies.

South Korea. Like many countries in Asia, South Korea aspires to promote coherent and self-sustained development through education. It emphasizes S&E education through special scholarships, exemption from military service, and rewarding employment. The government's decision to double admissions quotas in higher education in 1980 was an attempt to keep up with industry's demand for engineers, computer scientists, and other specialists. New local area colleges had to be added to existing universities to ease the strain on laboratories and computer facilities. A fivefold increase in S&E degrees at the bachelor level occurred over the 15-year period, from 1975 to 1990 (SRS, 1993b). The number of associate degrees awarded in S&E fields grew even faster during this same period; the number of associate degrees in engineering grew at an average annual rate of 19.4 percent in South Korean junior colleges from 1977 to 1992. Thirty percent of all degrees awarded at the junior college level are in engineering fields. By 1992, the number of associate degrees in engineering equaled the number of bachelor degrees in these fields, around 32,000 (Govt. of the Republic of Korea, 1993).

Japan. Colleges of technology and junior colleges in Japan provide engineering technology degrees comparable with U.S. associate degrees. The number of Japanese degrees at this level is, however, relatively small, amounting to less than one-quarter of Japan's university degrees in engineering (Govt. of Japan, 1993). In 1994, Japan produced around 20,700 degrees at the associate level and 90,000 engineering degrees at the bachelor's level. Programs of study in engineering technology offered at Japanese junior colleges include information processing, laboratory technician training, and electronics. Graduates in Japanese technical colleges are trained in more narrowly specialized technical areas in engineering (production, construction, industrial chemistry, information, electronics, and mechanical engineering) than are junior college graduates. The percentage of these graduates going directly into the labor force has been decreasing during the past decade. About three-quarters of the 1994 graduates went directly into the skilled labor force. A greater percentage of graduates from colleges of technology are continuing with advanced training. An increasing number of junior college graduates in engineering are unemployed, about 13 percent (Govt. of Japan, 1995).

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*Secondary school completion examination. Scores on this exam determine admission into particular university departments.

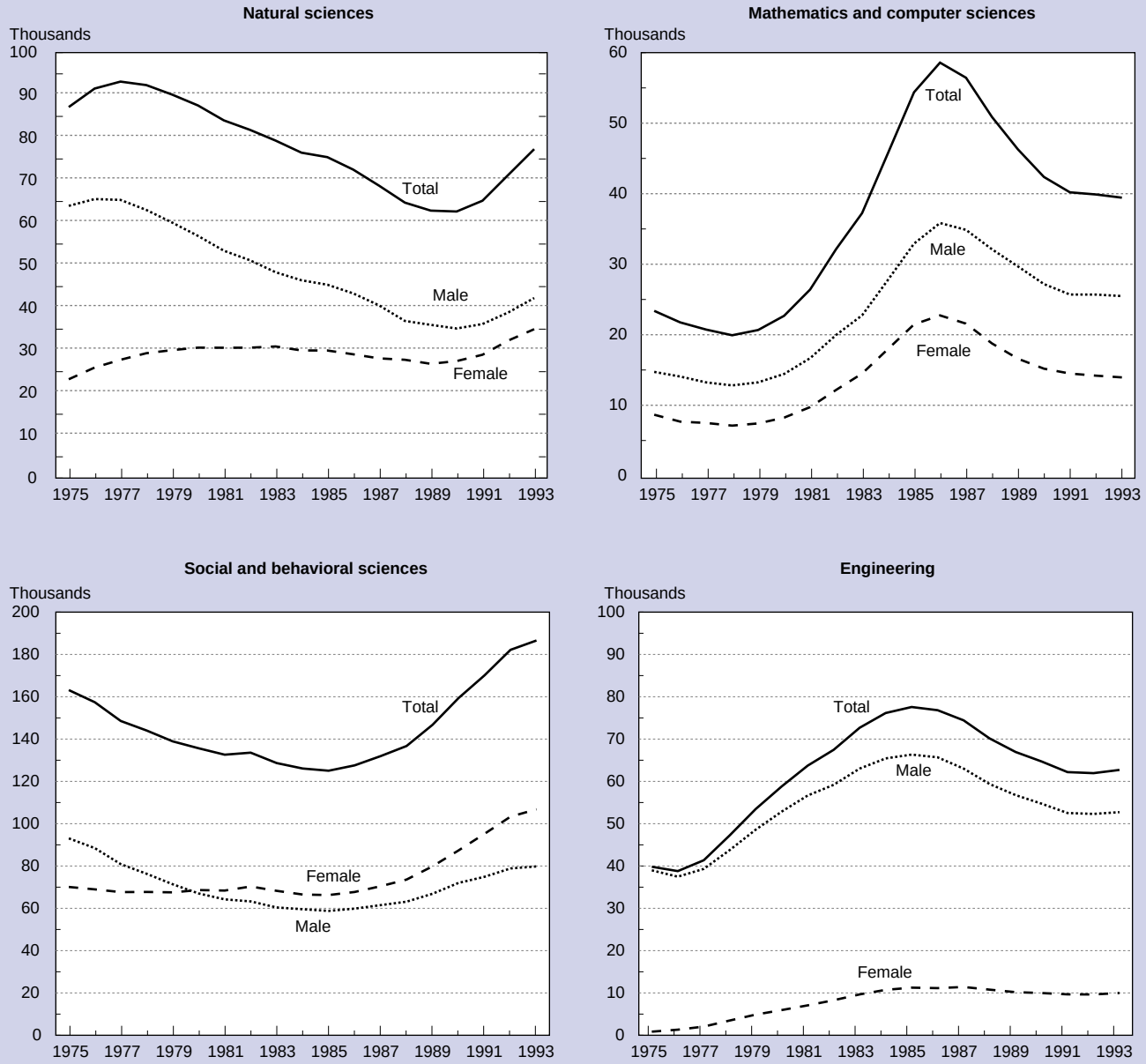
†Also in response to the labor market over the past 20 years, students have shifted their preferred field of study in higher education toward engineering and sciences and away from languages, arts, and sports.

‡Students with the *Abitur* have a shorter program.

#Students who complete the general course of study in high school generally enter the university, preparatory classes for the grandes écoles, and the *Instituts Universitaires de Technologie.*

§These statistics are not broken down by field or specialization and thus do not allow comparison across countries in associate degrees in engineering.

Figure 2-10.
Bachelor's degrees awarded in science and engineering, by sex



See appendix table 2-18.

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students declined more than 3 percent annually from 1981 to 1993.

Despite these recent gains, participation by some minorities in the U.S. higher education system remains low. (See text table 2-4.) Although 4.4 percent of the white college-age population obtains an NS&E degree, only 1.8 percent of the black college-age population and 1.7 percent of the Hispanic population obtain a degree in these fields.[13] (See *U.S. Higher Education Faculty* for participation rates of women and minorities among S&E faculty.)

In contrast to these low participation rates, 10.6 percent of the Asian-American college-age population obtains an NS&E degree, similar to the high participation rates for males in Japan and South Korea. (See appendix table 2-3.) In fact, Asian-Americans are the only group that receives a higher proportion of NS&E degrees than their percentage of the population. Although Asian-Americans comprise just 3.9 percent of the population, they earn 8.9 percent of the NS&E degrees at the bachelor's level. The desire of Asian-American students and foreign students to study electrical and computer engi-

[13]The Hispanic population, the fastest growing in the United States, includes many recent immigrants without high school education who could not be immediately recruited into the U.S. higher education system. In 1993, only 60 percent of the Hispanic 18- to 24-year-old population had graduated from high school (U.S. Bureau of the Census, 1993).

U.S. Higher Education Faculty

Only one-third of U.S. higher education faculty are in S&E departments, while two-thirds are in non-S&E fields. Minority faculty in S&E departments comprise less than five percent of total U.S. faculty. (See text table 2-5 and appendix table 2-20.)

Women comprise approximately 20 percent of all U.S. higher education faculty, mainly at the assistant professor level. (See text table 2-6 and appendix table 2-21.) They primarily teach in social and behavioral science fields. (See appendix table 2-20.)

Among S&E fields, the largest percentage of foreign-born faculty teach in engineering departments. Thirty percent of the U.S. higher education engineering faculty are foreign born. More than half of these faculty members have become naturalized U.S. citizens. Less than 15 percent are non-U.S. citizens; a large majority of these individuals have become permanent residents of the United States. The remainder are foreign citizens on temporary visas. (See text table 2-7 and appendix table 2-22.) In contrast, 15 percent of the U.S. higher education faculty teaching in natural science fields are foreign born, and less than 12 percent of social science faculty are foreign born.

Text table 2-5.
U.S. higher education faculty, by field and race/ethnicity: 1993

			S&E field				
	Total	S&E	Natural sciences	Math/ comp. sciences	Social sciences	Engineering	Non-S&E
	Percent						
Total	100.0	33.1	11.0	8.5	9.8	3.9	67.3
White	87.5	28.8	9.8	7.3	8.6	3.1	58.7
Asian	4.8	2.2	0.6	0.6	0.3	0.6	2.6
Black	4.8	1.3	0.3	0.3	0.6	0.1	3.5
Hispanic	2.8	0.8	0.2	0.2	0.3	0.1	2.0
Native American	0.5	0.2	0.0	0.1	0.0	0.0	0.4

NOTE: Details may not add to totals because of rounding.

See appendix table 2-20.

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Text table 2-6.
Distribution of U.S. higher education faculty in science and engineering fields, by rank and sex: 1993

	All ranks	Full professor	Associate professor	Assistant professor	Instructor	Lecturer	Other
	Percent						
Total	100.0	37.4	24.0	21.2	9.8	1.4	6.2
Male	80.1	33.7	19.4	15.2	6.7	0.9	4.2
Female	19.9	3.7	4.6	6.0	3.1	0.5	2.0

NOTE: Includes full-time faculty.

See appendix table 2-21.

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Text table 2-7.
U.S. higher education faculty, by field and citizenship status: 1993

		U.S. citizen		Non-U.S. citizen	
Field	Total	Native	Naturalized	Permanent resident	Temporary resident
	Percent				
Natural sciences	100	85	8	6	1
Math/comp. sciences	100	85	7	6	2
Social sciences	100	89	5	5	1
Engineering	100	70	16	12	2

See appendix table 2-22.

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Text table 2-4.
Participation rates of 24-year-olds in first university degrees in science and engineering, by race/ethnicity: 1993

	All first univ. degrees	Degree fields: Natural sciences	Degree fields: Social sciences	Degree fields: Engineering	Total number	24-year-olds: With first univ. degrees	24-year-olds: With NS&E degrees	24-year-olds: With soc. sci. degrees
	Number					Percent		
Total	1,179,278	116,742	186,585	62,705	3,752,400	31.4	4.8	5.0
Male	537,536	67,799	79,792	52,724	1,908,400	28.2	6.3	4.2
Female	641,742	48,946	106,793	9,981	1,844,000	34.8	3.2	6.0
White	931,603	87,401	164,917	44,853	3,028,200	30.8	4.4	5.4
Asian	50,587	9,524	8,573	6,407	149,800	33.8	10.6	5.7
Black	76,667	6,972	14,872	2,577	537,000	14.3	1.8	2.8
Hispanic	57,845	5,034	10,447	2,961	471,400	12.3	1.7	2.2
Native American	5,574	504	1,139	176	37,600	14.8	1.8	3.0

NS&E = natural science and engineering
See appendix table 2-1 for international comparisons of participation rates.
See appendix table 2-19.

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neering has kept these fields predominant among engineering programs.

Attendance Patterns by Major Fields

A wide use of attendance patterns (full-time, part-time, intermittent, and transfer students) contributes to the broad nature of U.S. access to higher education.[14] (See International Comparison of Science and Engineering Degree Trends and Participation Rates in Higher Education and Science and Engineering Degrees in this chapter and appendix table 2-1.) In 1991, approximately 52 percent of the more than 1 million baccalaureate recipients in liberal arts and sciences were so-called traditional students. That is, just more than half of the students were granted degrees from the school where they matriculated as freshmen and had spent uninterrupted years of full-time study. The remaining students did some or all of the following: transferred among institutions, attended part-time, or were intermittent (i.e., they spent at least one term away from their home campus). The attendance patterns of the students varied by area of study. Among the sciences, about 66 percent of students in life and physical sciences, 60 percent of students in social sciences, and 58 percent of students in engineering were classified traditional. Only 48 percent of students in mathematics and computer science were classified traditional. The areas of mathematics and computer science also had the largest share of part-time students: 24 percent (Institute for Research on Higher Education, 1994).

[14]These data are taken from the newly developed Curriculum Assessment Service National Database, referred to as the Transcript Study. The project is a collaborative effort of the Institute for Research on Higher Education at the University of Pennsylvania and the Association of American Colleges and Universities. The final report to the National Science Foundation, *Curriculum Assessment Service Database*, is available from the University of Pennsylvania.

Graduate Science and Engineering Students and Degrees

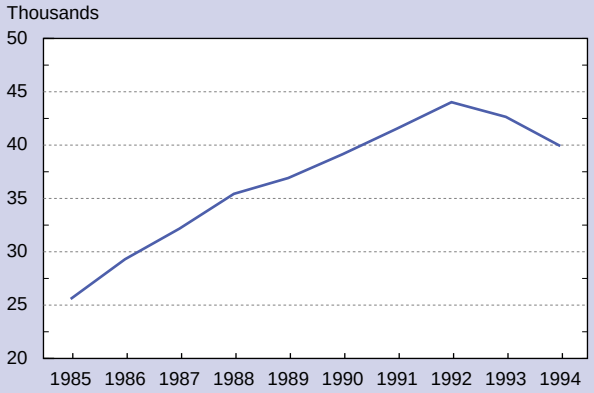
Trends in Graduate Enrollment

After a decade-long steady increase, fewer foreign students are entering U.S. universities for advanced training in S&E fields.[15] Graduate enrollments in S&E programs grew only modestly in 1993, mainly as a result of the decline in the number of foreign students. (See appendix table 2-23.) Many countries are developing the capacity to provide higher education in S&E at the graduate and undergraduate level. The number of foreign graduate students in engineering programs grew steadily from 28,800 in 1985 to a peak of 41,454 in 1992. In 1993, foreign students decreased their total graduate S&E enrollments by 4 percent from the previous year, mainly as a result of the decline in engineering and computer science. The Engineering Workforce Commission 1995 survey data show that graduate engineering enrollments of foreign students continued at the same rate of decrease in the fall of 1994. Foreign students currently represent slightly less than one-third of graduate engineering students (EWC, 1995b). (See figure 2-11 and appendix tables 2-23 and 2-24.)

The long-term modest increases in graduate enrollment of women and minorities from 1977 accelerated in the 1990s. In fields of natural sciences, the steadily increasing enrollment of women in graduate programs quickened during the late 1980s. By 1993, women represented 38 percent of all graduate students in these fields of science. Women comprised 15 percent of the graduate engineering students in 1993, up from 11 percent in

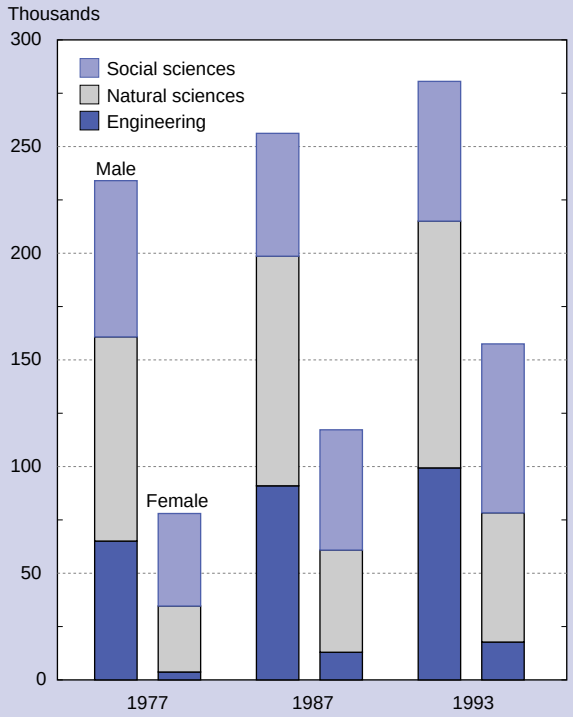
[15]Data presented here are from the SRS/NSF Survey of Graduate Students and Postdoctorates in Science and Engineering (1995e) and from the Engineering Workforce Commission (EWC, 1995b).

Figure 2-11.
Foreign student enrollment in graduate engineering programs



See appendix table 2-24. *Science & Engineering Indicators – 1996*

Figure 2-12.
Graduate enrollment in science and engineering programs, by sex



NOTE: The natural sciences include mathematics and computer sciences.

See appendix table 2-25.

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1983. (See figure 2-12 and appendix table 2-25.) The number of underrepresented minorities enrolled in graduate S&E programs increased at a much faster average annual rate between 1991 and 1993 than it had in the previous decade (11 percent and 4 percent, respectively). However, these large increases are relative to a very low base. The proportion of minority S&E students versus all graduate S&E students increased by only 1 percentage point between 1991 and 1993, from 6.3 percent to 7.3 percent.

Master's Degrees in Science and Engineering

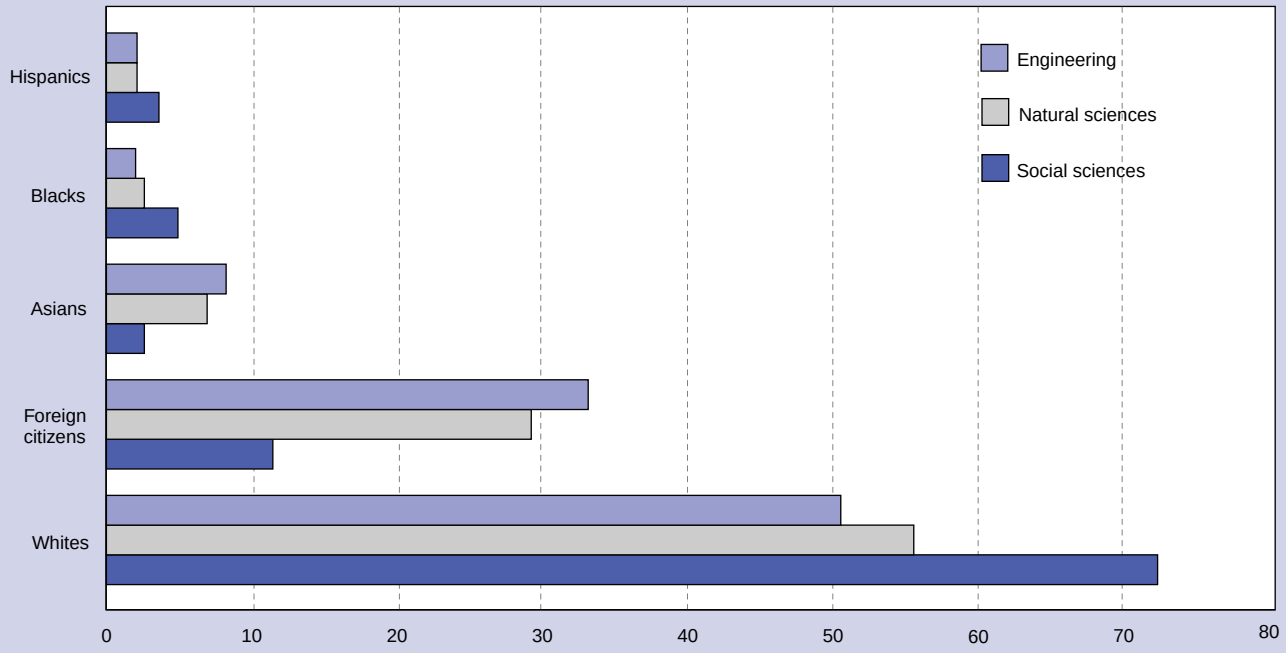
In 1993, almost one-quarter of all master's degrees were obtained in S&E fields.[16] Since 1975, the annual rate of growth for degrees in S&E has been slightly higher than for non-S&E degrees (2.3 percent and 1.3 percent, respectively). However, natural sciences are the exception. Fewer students are majoring in the natural sciences at the master's level. The slight annual decline in graduate enrollments and master's degrees in natural sciences continued over the period between 1978 and 1991, with degrees in these fields declining from 15,500 in 1978 to 12,700 in 1991. The number of master's degrees in natural sciences showed a slight upturn of 4 percent from 1992 to 1993. In contrast, the number of master's degrees in computer science and engineering increased significantly, primarily as a result of the interest and aptitude of Asian-American and foreign students in these fields. The number of degrees in computer science increased at 9 percent annually from 1979 to 1993; engineering increased 4 percent annually over this same time. Within engineering, students have especially pursued advanced training in civil, electrical, and mechanical engineering fields. (See appendix table 2-26.)

Women account for part of the high growth in computer science and engineering degrees. Master's degrees awarded to women majoring in computer science and engineering grew at a faster rate (7 and 12 percent, annually) than the overall growth in these fields during this period. Women obtain 15 percent of overall engineering degrees at the master's level, but representation differs across fields of engineering. The largest numbers of women are in civil and electrical engineering. Women received more than 18 percent of the master's degrees in chemical and civil engineering, but only 10 to 12 percent in electrical and mechanical engineering, the two largest engineering fields. (See appendix table 2-26.)

The growth in S&E master's degrees is attributed not only to more women studying computer science and engineering, but also to the increasing number of Asian-American and foreign students majoring in these fields. Asian-American students and foreign students had similar high rates of growth in these fields: around 12 percent annually in computer science and 6 to 7 percent annually in engineering from 1977 to 1993. Underrepresented minorities also had high rates of growth in computer science and in engineering (5 percent) during this same time, but from a very small base. (See figure 2-13.) The participation rate of underrepresented minori-

[16]Data for S&E master's degrees are from the National Center for Education Statistics annual survey of earned degrees; the data have been adapted to the National Science Foundation field classifications.

Figure 2-13.
Percent of master's degrees in S&E fields, by race/ethnicity/citizenship: 1993



NOTE: The natural sciences include mathematics and computer science.

See appendix table 2-27.

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ties in master's level S&E programs has changed little since 1977. (See appendix table 2-27.) The recent progress made at the bachelor's degree level in increasing participation of underrepresented minorities in S&E degrees has not as yet made an impact on advanced degree levels. (See figure 2-13.)

Although their graduate S&E enrollment in U.S. institutions is beginning to decline, the number of foreign students who earned S&E degrees at the master's level showed continual increases through 1993. This trend is in contrast to declining trends of engineering degrees earned by foreign students on the bachelor's level. (See Bachelor's Degrees by Race/Ethnicity in this chapter and appendix table 2-19.) In 1993, foreign students obtained 35 percent of the master's degrees in computer science and 33 percent of those in engineering, up from 11 and 22 percent of these respective fields in 1977. (See appendix table 2-27.)

Doctoral Programs in the United States

In the United States, there has been a review of doctoral programs in S&E by the Committee on Science, Engineering, and Public Policy (COSEPUP). The 1995 COSEPUP report *Reshaping the Graduate Education of Scientists and Engineers* recommended broadening the education of doctoral students to meet students' career needs better. The report indicated that the current focus of U.S. doctoral programs on research training in a narrow discipline was appropriate when demand for research was rising. Research and development (R&D) spending increased rapidly from the late 1970s to the latter part of the 1980s, and consequently doctoral R&D employment increased by almost 5 percent annually. However, only one-third of future doctoral recipients in S&E will enter the academic tenure system; two-thirds will have nonacademic employment. (See chapter 3, Science and Engineering Workforce.) The report concluded that doctoral course offerings needed to be expanded to reflect the diversity and complexity of employment options. Future work will require the application of advanced understanding of S&E to societal needs. As a result, doctoral students will need more education than training—education in the broad fundamentals of their fields, familiarity with several subfields, the ability to communicate complex ideas to nonspecialists, and the ability to work well in teams (COSEPUP, 1995).

Doctoral degree production in the United States has continued to increase in S&E fields since the late 1980s, especially from more foreign students seeking advanced training in computer science and engineering programs.[17] The number of doctoral S&E degrees, which was level at about 18,000 degrees from 1975 to 1985, increased to more than 25,000 by 1993. However, the number of these degrees obtained by U.S. citizens

[17]Data on S&E doctorates granted in the United States are from the NSF's Survey of Earned Doctorates (SRS, 1994a).

increased only slightly. In 1993, only about 0.4 percent of the 29-year-old population in the United States obtained a doctoral degree in an S&E field. This percentage has remained nearly constant in the past 20 years.

The share of doctoral degrees obtained by women has increased in some fields of S&E, but the low participation rates of minority groups have not improved in any S&E field. Women accounted for a large part of the growth in natural science degrees. The number of doctoral degrees obtained by women in these fields increased 6 percent annually from 1975 to 1993. By 1993, women's share of the doctoral degrees in natural sciences increased to 31 percent. The proportion of degrees obtained by women reached 38 percent in biological sciences in 1993, but remained at 9 percent in engineering. (See appendix table 2-28.)

There has been little progress in the number of S&E degrees earned by blacks, even though the number of 29-year-olds continues to grow. Hispanics were awarded three times the number of S&E doctoral degrees from 1977 to 1993, similar to the rate of increase in the size of their 29-year-old cohort. However, together, underrepresented minority groups earned only 4 percent of natural science, 2 percent of engineering and computer science, and 7 percent of social science doctoral degrees. (See appendix table 2-29.)

Foreign students accounted for a steadily increasing proportion of doctoral degrees in S&E from 1985 to 1992, especially in mathematics, computer science, and engineering. By 1993, foreign students on temporary visas obtained 44 percent of mathematics and computer science doctoral degrees and 50 percent of engineering doctoral degrees. (See appendix table 2-29.) If non-U.S. citizens with permanent residence in the United States are added to foreign students on temporary visas, the percentage of doctoral degrees in engineering earned by non-U.S. citizens would be 57 percent; the percentage in mathematics and computer science would be 47 percent. However, the proportion of S&E doctoral degrees to foreign students declined slightly in 1993. Declining foreign enrollments in U.S. graduate engineering programs suggests further decreases in the percentage of S&E degrees to foreign students in the next several years (EWC, 1995c).

Worldwide Doctoral Reforms and Comparison of Degrees

Interest in doctoral education is increasing worldwide, with a re-examination of its aims and structure. Reforms in doctoral programs in the United States, Europe, and Asia are aimed at similar concerns: strengthening and expanding doctoral education, as well as making doctoral training relevant to a wider range of occupations than just academic careers, and educating highly qualified professionals who can solve problems raised by broader social and economic issues. The following section will present the expansion of S&E doctoral programs and changes in their structure in major countries of Asia and Europe and in the United States.

Asian Doctoral Programs

The scale of graduate education in Japan has been small by international standards. Japanese industries have traditionally offered little wage incentive for doctoral degrees in relation to bachelor's degrees and have provided needed in-house training for advanced research. Although industrial laboratories for such research were excellent, university research facilities were generally out of date. Doctoral reforms of 1989 called for the expansion and strengthening of graduate schools and establishment of a new type of university for graduate study. Among the new schools are the Graduate University for Advanced Study, the Nara Institute of Science and Technology (NAIST), a national graduate school for advanced studies in information and biological sciences, and the Japan Advanced Institute of Science and Technology in Hokuriku (JAIST). NAIST and JAIST provide doctoral training in emerging science and technology fields, rather than in traditional disciplinary areas. Japan's University Council recommended doubling the number of graduate students (including foreign students) to train an adequate number of researchers. The reforms stressed that the aim of doctoral programs is no longer limited to training only future academic researchers. Doctoral programs are to train people with high level abilities capable of working in various sectors of society (Yamamoto, 1995).

During the 1980s, basic research in Japanese universities was underfunded.[18] As research conditions became very inadequate in universities, students became more attracted to work in private industry. Japanese companies provide superior research facilities in which employees can receive research training and prepare a so-called thesis doctorate *Ronbun Hakase*. These researchers submit the thesis to their prior university, which awards the doctoral degree. One advantage of this type of training is its relevance to industrial problems. By 1992, 45 percent of the engineering doctoral degrees were earned by employees in industry conducting their doctoral research in an area of interest to their Japanese firm. In that same year, 35 percent of the doctoral degrees in the natural sciences were earned by employees within Japanese industries (Govt. of Japan, 1995).

The Ministry of Education, *Monbusho*, is increasing support to universities to improve facilities and greatly accelerate doctoral programs in NS&E fields. The annual growth for natural science and engineering doctoral degrees, respectively, has been 6 and 13 percent from 1990 to 1993. The number of degrees earned by doctoral students in universities in these combined fields exceeded 2,500 in 1992.[19] *Monbusho* provides research funds to all national universities based on the number of faculty (113 billion yen in 1991, equivalent to about $503 million), plus individual research grants based on compet-

[18]The General University Fund rose very slowly (Yamamoto, 1995).

[19]Total doctoral degrees in these fields, including those earned within universities and industries, were approximately 4,200 in 1992.

itive applications (59 billion yen in 1991, approximately $274 million). *Monbusho* also provides funding for university centers of excellence (4 billion yen in 1991, equivalent to about $18 million). In addition, the Japan Society for the Promotion of Science has increased its competitive program for fellowships to about 800 young Japanese researchers (doctoral students).

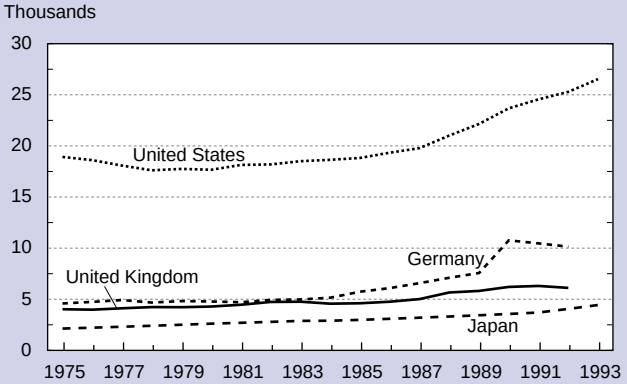
Developing Asian countries, given their conviction that economic development is dependent on science and technology knowledge and its connection to production, are also increasing their capacity to educate scientists and engineers at the doctoral level. In 1992, Chinese students obtained more than 1,200 doctoral degrees in NS&E fields within Chinese universities, nearly approaching the number obtained by Chinese foreign students within U.S. universities (1,500). (See Foreign Students in U.S. Universities, Foreign Students in European Universities, and Foreign Students in Japanese Universities in this chapter.) South Korea is also interested in improving graduate education. The recently established Pohang University of Science and Technology (POSTECH) is one of the foremost S&E institutions of higher learning in Korea, with several engineering centers of excellence. POSTECH, funded by private industry, is seeking to establish first-class systems engineering education so that the graduates would have more capacity for innovative product design. Korean universities awarded more than 1,000 NS&E doctoral degrees in 1992 (SRS, 1993b).

European Doctoral Programs

Major European countries have reformed their doctoral programs to augment, improve, and accelerate their training of scientists and engineers. Anticipating the need for highly trained personnel for emerging industries, German universities have accelerated the formation of scientists and engineers. S&E doctoral degrees in the former West Germany grew faster than overall doctoral degrees between 1975 and 1992. The number of natural science degrees increased 5.1 percent annually; engineering increased 4.8 percent annually, and overall degrees increased 3.4 percent annually during this 17-year period (SRS, forthcoming). The number of NS&E degrees at the doctoral level accelerated in the second half of the 1980s. (See figure 2-14.) The large increase between 1989 and 1990 reflects the inclusion of doctoral degrees from the former East Germany. (See appendix table 2-30.)

The number of doctoral degrees in Germany reached a plateau in the 1990s, as the Ministry of Education restructured doctoral programs in the former East Germany, as well as throughout the country. Degree data for the former East Germany show a large drop-off in S&E doctoral degrees between 1990 and 1992. The number of natural science degrees declined by nearly 50 percent, from almost 900 in 1990 to fewer than 500 in 1992. The number of engineering doctoral degrees awarded declined by almost two-thirds, from 1,100 in 1990 to 400 in 1992 (Govt. of Germany, 1994).

Figure 2-14.
Trends in doctoral degrees in S&E



See appendix table 2-30. *Science & Engineering Indicators – 1996*

Germany is also concerned about the ability of doctoral education throughout the entire country to provide the highly trained personnel needed for universities and emerging industries. In traditional programs, German doctoral candidates have no formal admission procedure or organized program of course requirements. The doctoral research is supervised by the professor who accepts the candidate. German doctoral programs require long-term commitments, an average of 10 years, and have low completion rates. In response to these concerns, Germany began an experiment in 1989 with a new structure for doctoral training called the *Graduiertenkollegs.* Students at these institutions have considerably more interaction with faculty and participate in interdisciplinary study and research groups. The primary goals of *Graduiertenkollegs* are (1) to increase the number of trained doctorates; (2) to improve the quality of research training by providing a more suitable environment; (3) to prepare students for nonacademic employment; and (4) to encourage innovative interdisciplinary work (Nerad, 1994). About 10 percent of the doctoral students participate in this experimental program.

Likewise, France undertook a reform of doctoral studies in 1988 in an effort to double the number and improve the quality of S&E doctoral degrees within 8 years. The recent establishment of the Technological University of Compiegne has helped to increase the number of engineering doctoral programs (Govt. of France, 1994a). The number of S&E doctoral degrees increased from 6,000 in 1989 to 8,200 in 1992, nearly a 27-percent increase. These gains, particularly in mechanical, process, and civil engineering, have been supported through increased government funding of research assistantships for doctoral students. In addition, collaboration between industry and university helped fund doctoral students and provide dissertation research opportunities in innovative areas of interest to private industry.

Women in France earn higher percentages of doctoral degrees in most NS&E fields than women in other European countries or in the United States. (See text table 2-8.)

Pressures for reform of the doctoral program in the United Kingdom began in the early 1980s with a report on graduate education of the Advisory Board for the Research Council. This report criticized the lengthy time to degree, overly ambitious thesis topics, and poor completion rates, particularly in the social sciences. In 1990, the then Science and Engineering Research Council[20] report on graduate engineering education (the Parnaby Report) criticized the doctoral engineering program as being too narrow and academic. The council called for greater industry involvement in the training of engineers (Burgess et al., 1995).

British doctoral programs have traditionally been based entirely on research; course work was not a part of the program. Doctoral candidates completed the program under the guidance of a supervisor. U.K. universities are changing somewhat from this traditional apprenticeship model. Aspects of the U.S. system of doctoral training, such as the teaching of research skills through course work and the emphasis on academic collaboration during the training process, have been integrated. For U.K. doctoral students, formal interaction with supervisors has become much greater, and natural science students often join a research team. Students are also encouraged to complete the master's program of course work before entering a doctoral program.

Responding to the criticism cited by the Parnaby Report regarding the narrow nature of academic training, the Research Councils are experimenting with private industry's involvement in doctoral training. Under the Cooperative Awards in Science and Engineering scheme, industrial companies collaborate with academic departments on specific projects and provide financial support. The U.K. White Paper on Science and Technology of 1993, *Realizing Our Potential*, emphasized the critical links between universities and industrial R&D and encouraged training partnerships between these organizations (Govt. of United Kingdom, 1993a).

In the United Kingdom, the number of doctoral degrees in fields of S&E did not grow as fast as overall doctoral degrees from 1975 to 1992. Doctoral degrees in all fields grew at a rate of 2.7 percent annually. The number of natural science degrees grew 2.3 percent annually, from 2,000 degrees in 1975 to 3,000 degrees in 1992. The number of engineering degrees grew 1.3 percent annually, from 1,000 degrees in 1975 to 1,300 degrees in 1992. Women represented 27 percent of the natural science doctoral degrees and 11 percent of the engineering doctoral degrees. (See appendix table 2-30.)

International Comparison of Doctoral Degrees

Collectively, the European countries produce considerably higher numbers of doctoral degrees in NS&E fields than the North American region. In 1992, European countries, for which data were available, produced more than 25,000 NS&E degrees at the doctoral level, nearly 30 percent higher than the North American doctoral degrees in these fields and more than twice as many as Asian countries. (See text table 2-9.)

Although the scale of S&E doctoral programs in Asian countries is small in comparison with Europe and the United States, the growth rate in these programs, 6 percent annually, is higher than U.S. or European doctoral programs. Japan is significantly increasing its production of doctoral degrees in NS&E, in part by attracting Asian

[20]Research Councils in the United Kingdom have been reorganized to six councils.

Text table 2-8.
Percentage of S&E doctoral degrees earned by women in selected countries, by field: 1992

Field	France	Germany	United Kingdom	United States
	Percent			
Physics	18.7	7.1	12.7	12.1
Chemistry	33.8	21.0	24.5	26.2
Math	20.0	18.0	17.9	19.4
Computer science	19.8	8.3	13.4	15.8
Social science	37.9	19.0	31.3	37.1
Electrical engineering	15.4	2.2	5.9	7.9
Mechanical engineering	19.5	3.9	10.3	6.7
Civil engineering	–	4.8	5.7	3.9

– Included in the percentage for mechanical engineering.

SOURCES: Government of France, Ministère de L'Enseignement Superieur et de la Recherche, *Rapport sur les Etudes Doctorales (1994)*; Government of the Federal Republic of Germany, Statistisches Bundesamt Wiesbaden, *Prufungen an Hochschulen (1994)*; Government of United Kingdom, *Universities Statistical Record*, unpublished tabulations,1993; Science Resources Studies Division, National Science Foundation, S*elected Data on Science and Engineering Doctorate Awards: 1993*, NSF 94-318 (Arlington, VA: NSF, 1994).

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Text table 2-9.
Doctoral degrees in S&E, by region: 1992

Field	Asia	Europe	North America
All doctoral degrees	25,590	47,128	42,701
Natural sciences & engineering	11,223	25,089	19,449
Natural sciences	6,593	18,796	13,344
Engineering	4,630	6,293	6,105
Social sciences	544	4,195	7,423

See appendix table 2-31 for countries in each region.
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foreign students to Japan's doctoral programs through generous support. Also, improving the laboratory facilities of Japanese universities and building up centers of excellence have had a positive effect on the growth rate.

International Comparisons of Foreign Students

Foreign Students in U.S. Universities

The United States is one of several nations that has trained future researchers and educators in S&E for other countries around the world. Foreign students comprise only 3 percent of total enrollments in U.S. higher education, but they are concentrated in fields of S&E, particularly in advanced degrees. Foreign students accounted for the large growth in master's and doctoral degrees in S&E fields over the past 15 years. Nearly half of the approximately 400,000 foreign students enrolled in 1991–92 were studying S&E fields. (See text table 2-10.)

For some of the Asian countries, however, the percentage studying S&E fields is even higher. Two-thirds of the students from China and India enrolled in U.S. universities major in S&E, mainly at advanced levels. (See text table 2-11.) Japan is the exception. The majority of Japanese students come at the undergraduate level and study either business management or social sciences. Few Japanese study natural science or engineering fields in the United States.

The participation rate for foreign students in S&E degrees in U.S. universities rises by level of degree. Thus, although foreign students obtain only a small fraction of S&E bachelor's degrees, they obtain 25 percent of the master's degrees and 47 percent of the doctorates. These percentages differ by fields of science. (See figure 2-15 and appendix tables 2-19, 2-27, and 2-29.)

The number of S&E master's degrees obtained by foreign students from U.S. universities more than doubled in the past 16 years, from approximately 8,000 in 1977 to 20,000 in 1993. (See figure 2-16.) The majority of these master's degrees are in engineering fields. (See appendix table 2-27.) For U.S. citizens and permanent residents, the number of master's degrees in S&E fields showed minimal change over this time, growing from 56,000 in 1977 to 61,000 in 1993.

In this same period, S&E doctoral degrees obtained by foreign students from U.S. universities tripled, from 2,600 degrees in 1977 to more than 8,000 degrees in 1993. (See figure 2-17 and appendix table 2-29.) In con-

Text table 2-10.
Foreign students enrolled in U.S. universities from several regions, by major field and region: 1991–92[1]

			S&E field				Non-S&E field	
	Total, all fields	Total, S&E	Natural science	Math/comp. science	Social science	Engineering	Bus/mgt.	Other
	Number							
Total	395,828	193,311	46,783	36,980	34,002	75,547	80,279	122,238
Asia	245,809	126,665	30,625	26,460	18,865	50,715	49,490	69,654
Europe	53,708	20,625	5,640	3,169	6,230	5,586	11,977	21,106
Latin America	43,200	17,669	4,752	2,462	3,888	6,566	9,245	16,286
Middle East	31,210	17,665	2,590	3,246	2,434	9,394	5,493	8,052
Africa	21,901	10,688	3,176	1,643	2,584	3,285	4,074	7,140
	Percent							
Total	100.0	48.8	11.8	9.3	8.6	19.1	20.3	30.9
Asia	100.0	51.5	12.5	10.8	7.7	20.7	20.2	28.3
Europe	100.0	38.4	10.5	5.9	11.6	10.4	22.3	39.3
Latin America	100.0	40.9	11.0	5.7	9.0	15.2	21.4	37.7
Middle East	100.0	56.6	8.3	10.4	7.8	30.1	17.6	25.8
Africa	100.0	48.8	14.5	7.5	11.8	15.0	18.6	32.6

NOTE: Applies to foreign students in all levels of U.S. higher education.
[1]Omitted regions are North America and Oceania, about 5% of total.

SOURCES: Institute of International Education (IIE), *Profiles 1991–92, Detailed Analyses of the Foreign Student Population* (New York: IIE, 1993); IIE, *Open Doors, 1992–93: Report on International Education Exchange* (New York, 1993).

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Text table 2-11.
Asian students in U.S. universities, by level and field: 1991–92

Country	Students	Undergraduate	Graduate	Natural sciences	Engineering
		Percent			
China	42,941	13.7	83.2	44.1	20.9
Japan	40,700	70.0	18.2	7.0	3.7
Taiwan	35,552	26.6	68.3	23.7	22.4
India	32,534	18.8	79.0	28.3	38.8
South Korea	25,719	31.7	60.8	20.2	15.8

SOURCE: Institute of International Education (IIE), *Profiles 1991–92, Detailed Analyses of the Foreign Student Population*, (New York: IIE, 1993).

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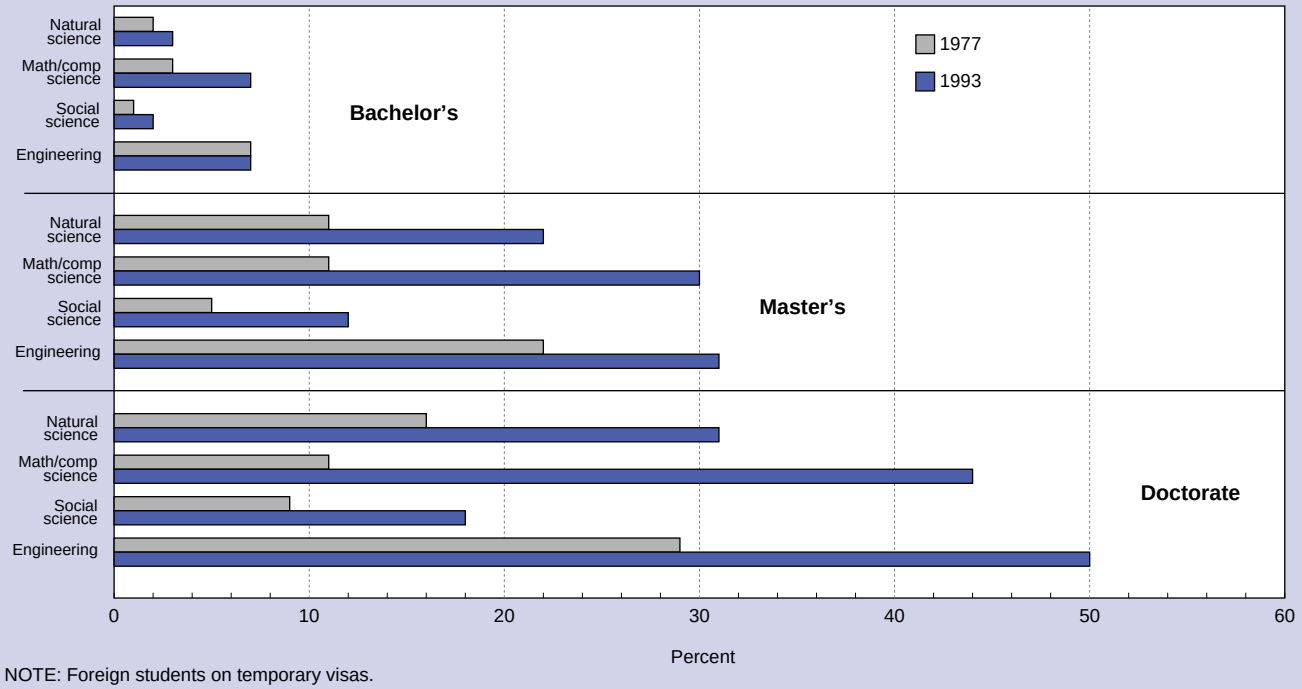
Figure 2-15.
Percent of science and engineering degrees awarded to foreign students: 1977 and 1993



NOTE: Foreign students on temporary visas.

See appendix tables 2-19, 2-27, and 2-29.

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trast, the number of S&E doctoral degrees awarded to U.S. citizens and permanent residents remained almost stable, growing at only 0.2 percent annually, from 15,000 in 1977 to 16,000 in 1993.

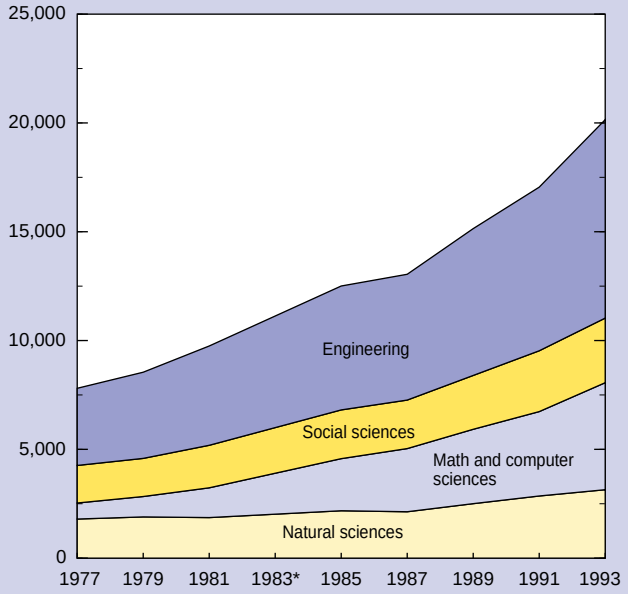
S&E doctoral degrees obtained by Asian foreign students more than tripled in the past decade, from 1,600 in 1983 to almost 5,600 degrees in 1993. (See figure 2-18 and appendix table 2-32.) The approximately 2,000 engineering degrees obtained by Asian foreign students represented 36 percent of the total doctoral degrees awarded in U.S. universities in 1993. The 2,800 doctoral degrees in natural sciences, mathematics, and computer sciences obtained by Asian foreign students represented more than one-quarter of all doctoral degrees awarded in these fields from U.S. universities in that year.

Foreign Students in European Universities

Currently, three European countries educate a considerable number of foreign students: France, Germany, and the United Kingdom, in order of the number of foreign students enrolled (UNESCO, 1994). Foreign students represented between 5 and 7 percent of the total enrollments in higher education in these three countries in 1990–91. (See text table 2-12.)

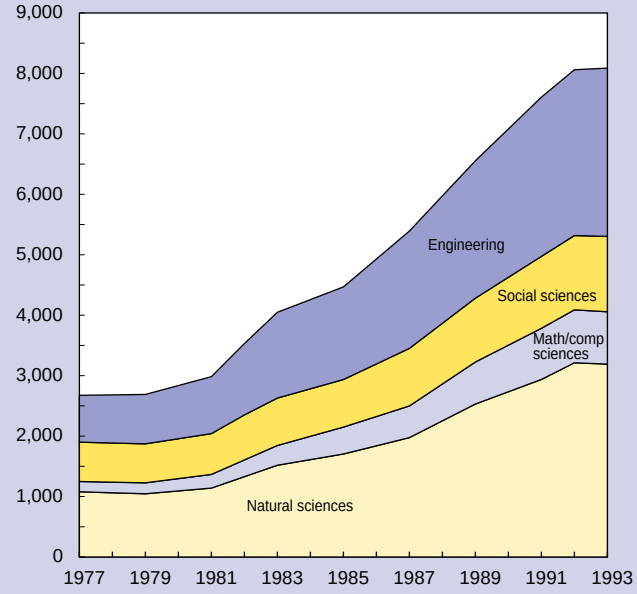
Traditionally, the regions from which these European countries received their foreign students reflected their colonial history; France received the majority of foreign students from Africa; the United Kingdom from the Commonwealth countries in Asia; and Germany from Eastern Europe and the Middle East. Today, however, France, Germany, and the United Kingdom receive a

Figure 2-16.
Master's degrees received in S&E by foreign students in U.S. universities



NOTE: Data for 1983 interpolated linearly from 1981 and 1985 data.
See appendix table 2-27. *Science & Engineering Indicators – 1996*

Figure 2-17.
Doctoral degrees in S&E obtained by foreign students in U.S. universities

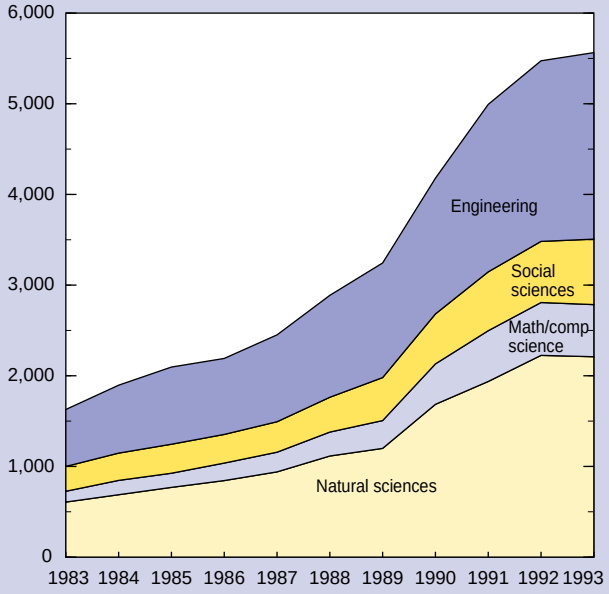


See appendix table 2-29. *Science & Engineering Indicators – 1996*

great percentage of their foreign students from the countries of the European Union. (See text table 2-13.)

Foreign students in Germany receive about 12 percent of all engineering doctoral degrees and about 7 percent of the natural science doctoral degrees. These percentages have remained relatively stable over the past decade (Govt. of Germany, 1994). (See figure 2-19 and appendix table 2-33.)

Figure 2-18.
Doctoral degrees in S&E fields obtained by Asian students in U.S. universities



See appendix table 2-32. *Science & Engineering Indicators – 1996*

Foreign students earn one out of three doctoral degrees in France in all fields of science, with variations among fields. In 1992, they earned less than 20 percent of the medical degrees, but 44 percent of the mathematics and 41 percent of mechanical, process, and civil engineering doctoral degrees. About half the foreign doctoral recipients in the natural sciences and engineering stay to work in France. The return rate of foreign doctoral recipients to their home country differs by field; in 1992, only 44 percent with mathematics degrees returned, but 80 percent of those with degrees in earth, atmospheric, and oceanographic sciences returned (Govt. of France, 1994a).

Half of U.K. doctoral degrees in engineering and the social sciences are obtained by foreign students. More than one-quarter of the U.K. doctoral degrees in natural sciences are earned by foreign students. (See figure 2-19.)

Foreign Students in Japanese Universities

The recruitment of top foreign students and more salaried appointments for foreign researchers is part of Japan's efforts to improve its graduate schools and develop centers of excellence for basic research. The Ministry of Education, *Monbusho,* is financing support in order to attract more foreign researchers and provide postdoctoral fellowships for young foreign researchers. Scholarships are offered in master's and doctoral pro-

Text table 2-12.
Foreign student enrollments in higher education in the United States and selected European countries

Country	Year	Enrollments in higher education	Foreign students	Percent
United States	1986	12,670,121	349,610	2.8
	1991	14,527,881	419,585	2.9
France	1986	1,289,942	126,762	9.8
	1991	1,840,307	136,963	7.4
Germany	1985	1,550,211	79,354	5.1
	1990	1,933,602	107,075	5.5
United Kingdom	1985	1,032,491	53,694	5.2
	1990	1,258,188	80,183	6.4

SOURCE: UNESCO, *Statistical Yearbook* (Paris, 1994).

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Text table 2-13.
Foreign student enrollments in higher education in selected European countries, by region of origin

Country	Year	Total	Africa	North America	South America	Asia	Europe
				Number			
France	1986	126,762	72,270	5,830	4,188	21,762	21,427
	1992	138,477	74,941	5,636	4,356	20,521	31,957
Germany	1985	79,354	4,614	5,272	2,578	33,041	32,303
	1991	116,474	7,916	5,505	3,385	50,132	47,175
United Kingdom	1985	53,694	10,248	6,121	823	25,800	9,814
	1991	88,141	9,325	7,578	1,471	33,091	34,120
				Percent			
France	1986	100.0	57.0	4.6	3.3	17.2	16.9
	1992	100.0	54.1	4.1	3.1	14.8	23.1
Germany	1985	100.0	5.8	6.6	3.2	41.6	40.7
	1991	100.0	6.8	4.7	2.9	43.0	40.5
United Kingdom	1985	100.0	19.1	11.4	1.5	48.1	18.3
	1991	100.0	10.6	8.6	1.7	37.5	38.7

NOTE: Details may not add to totals because of rounding.

SOURCE: UNESCO, *Statistical Yearbook* (Paris, 1994).

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grams at the University of Tokyo. Asian foreign students, mainly from China and South Korea, have sustained the Japanese doctoral degree programs within the universities. The government's plan is to accept 100,000 foreign students for enrollment at universities by the year 2000. The recruiting area includes all the Indian Institutes of Technology, Chinese universities in Beijing and Shanghai, and universities in Pakistan, Bangladesh, Thailand, Indonesia, and Sri Lanka. Doctoral programs are often in English, and the generous scholarships, available primarily to foreign students, are considered an investment. It is assumed that these graduates will serve as a bridge between the businesses of their countries and those of Japan (Nishino, 1992). The *Monbusho* scholarships for doctoral programs provide additional support for 5 years after the doctorate so that foreign students will be able to visit their major professor. In 1993, foreign students obtained almost 40 percent of the doctoral degrees awarded in NS&E

Figure 2-19.
International comparisons of doctoral degrees in natural sciences and engineering obtained by foreign students

[1]Data for Japan combine natural sciences and engineering.

See appendix table 2-33.

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fields within Japanese universities[21] (Govt. of Japan, 1994). (See figure 2-19.)

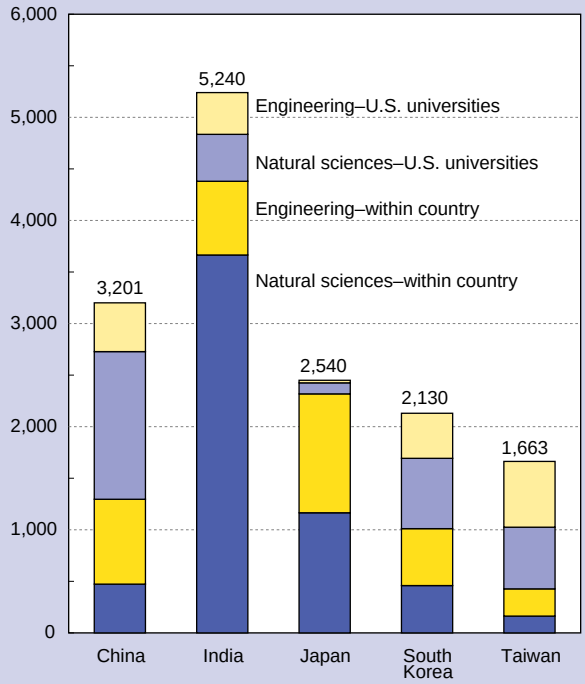
Who Benefits from Educating Foreign Students in Science and Engineering?

In 1992, Chinese foreign students earned more than 1,900 NS&E doctoral degrees in U.S. universities (SRS, 1994a). This represents more S&E doctorates being earned in U.S. universities by Chinese students than in Chinese universities. (See figure 2-20 and text table 2-14.)

Some of the benefits to the United States are in the intellectual capital that these students bring to U.S. university departments of S&E. Foreign doctoral students who work their way through graduate school with research assistantships contribute to U.S. research performed by universities. Those who remain for postdoctoral training in the United States contribute to the U.S. basic research infrastructure.

The country of the foreign doctoral student benefits as well. Young scholars receiving doctoral training in the United States can make contributions to science infrastructure in their own countries, in research and teaching. The actual contribution they can make depends on the economic opportunities and science policies of the countries. South Korea apparently has the greatest capacity to absorb high-level S&E personnel trained in the United States. Korean foreign students have the lowest rate for staying in the United States after completion of their doctoral degree.

Figure 2-20.
Doctorates obtained in natural sciences and engineering by Asians within country and in the United States: 1992



See text table 2-14.

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[21]These data exclude doctoral awards for research in Japanese industries.

Text table 2-14.
Doctoral degrees in natural sciences and engineering awarded to Asian foreign students in U.S. universities and within country, for selected Asian countries: 1992

Country	Within country		U.S. universities	
	Natural sciences	Engineering	Natural sciences	Engineering
China	473	823	1,432	473
India	3,665	715	455	405
Japan	1,165	1,153	107	25
South Korea	459	552	682	437
Taiwan	163	264	598	638

SOURCES: For within country degrees, see chapter 2 references. For degrees to Asian foreign students in U.S. universities, see Science Resources Studies Division, National Science Foundation. *Selected Data on Science and Engineering Doctorate Awards: 1993*. NSF 94-318 (Arlington, VA: NSF, 1994).
See figure 2-20.

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Stay Rates of Foreign Doctoral Recipients in the United States

The Survey of Earned Doctorates (SED) annually elicits from foreign students both their plans to locate in the United States, as well as any firm offers they have received to do so.[22] These trend data on intent to stay are supplemented by a new study on the percentage of foreign doctoral recipients working and receiving wages in the United States several years after completing their degrees.

Foreign students' plans to locate in the United States after earning a doctoral degree in an S&E field differ widely by field as well as by their country of origin. Among Asian countries, a high proportion of Chinese and Indian foreign students who received doctoral degrees in S&E fields from 1988 to 1992 (around three-quarters) planned to locate in the United States. Also, a high proportion of foreign students from the United Kingdom and the East European countries planned to locate in the United States in this period. (See text table 2-15.)

The SED survey shows that a smaller percentage of those planning to stay in the United States have received firm offers to do so. Of the 8,000 foreign students earning S&E doctoral degrees in U.S. universities in 1993, about 30 percent of them received firm offers to remain in the United States after completing their program. These firm offers were from three sources:

- About 400, or 5 percent, received firm offers for academic employment;
- Almost 500, or 6 percent, received firm offers for industrial employment; and
- A larger group, almost 1,500, or 18 percent, obtained a postdoctoral research appointment for 1 year. (See text table 2-16.)

The overall percentage of foreign students receiving firm offers to remain in the United States has been stable (between 30 and 35) in the past several years. But firm offers to stay in the United States show large variation among individual countries. About 50 percent of Chinese

Text table 2-15.
S&E doctoral degrees earned by foreign students, and their plans to stay in the United States: 1988–92

Region/country	Doctoral degrees	Plan to stay in U.S.[1]
	Number	Percent
Asia	18,599	NA
China	5,648	75.7
Taiwan	5,007	43.7
South Korea	4,567	33.4
India	3,377	72.4
Europe	4,083	NA
Greece	693	47.8
United Kingdom	589	59.9
Germany	542	42.4
Italy	341	37.3
France	312	33.2
Other Western European	902	40.5
Scandinavian countries	302	34.7
East European countries	402	60.3
North America	1,826	NA
Canada	1,270	42.6
Mexico	556	33.1

NA = not available

NOTE: Foreign students on temporary visas only.
[1]Intention to locate in the United States is provided in the annual *Survey of Earned Doctorates*. A smaller percentage has a firm offer to stay in the United States, mainly for a 1-year postdoctoral appointment. See appendix table 2-34 for "firm plans" to stay, by field and country, various years.

SOURCE: Science Resources Studies Division, National Science Foundation, *Survey of Earned Doctorates*, unpublished tabulations,1995.

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[22]Data in this section are derived from the NSF's Survey of Earned Doctorates (SRS, 1994a).

Text table 2-16.
Foreign doctoral recipients with definite plans to remain in the United States, by field: 1993

	S&E	Natural sciences	Social sciences	Engi-neering
Total, recipients	8,087	4,057	1,247	2,783
Total, plans in United States	2,464	1,518	252	694
Postdoctoral research	1,463	1,127	55	281
University employment	416	188	139	89
Industrial employment	481	165	15	301
Other	104	38	43	23
Total, plans in United States	30.5	37.4	20.2	24.9
Postdoctoral research	18.1	27.8	4.4	10.1
University employment	5.1	4.6	11.2	3.2
Industrial employment	5.9	4.1	1.2	0.8

NOTE: Details may not add to totals because of rounding.

SOURCE: Science Resources Studies Division, National Science Foundation. *Selected Data on Science and Engineering Doctorate Awards: 1993.* NSF 94-318 (Arlington, VA: NSF,1994).

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and Indian doctoral recipients from U.S. universities have firm offers for postdoctoral training or employment in a university or industry. In contrast, less than 20 percent of South Korean foreign doctoral recipients have firm plans to remain in the United States. These percentages of S&E foreign doctoral recipients remaining in the United States are somewhat higher in the natural sciences and somewhat lower in engineering. For example, only 15 percent of foreign students from South Korea who obtain a doctoral engineering degree from a U.S. university have firm plans to remain in the United States. (See appendix table 2-34.)

A recent study of foreign doctoral recipients working and earning wages in the United States (Finn et al., 1995) shows that about 42 percent of the foreign students who earned doctorates in 1984 were working in the United States in 1992. The percentages are higher in the physical sciences and engineering, and lower in the life sciences and social sciences. Of the foreign students who received their S&E degree in 1987–88, about 41 percent were working in the United States in 1992. For these more recent graduates, a smaller percentage of engineering doctoral recipients were still working in the United States in 1992 compared with the earlier study. (See figure 2-21 and appendix table 2-35.)

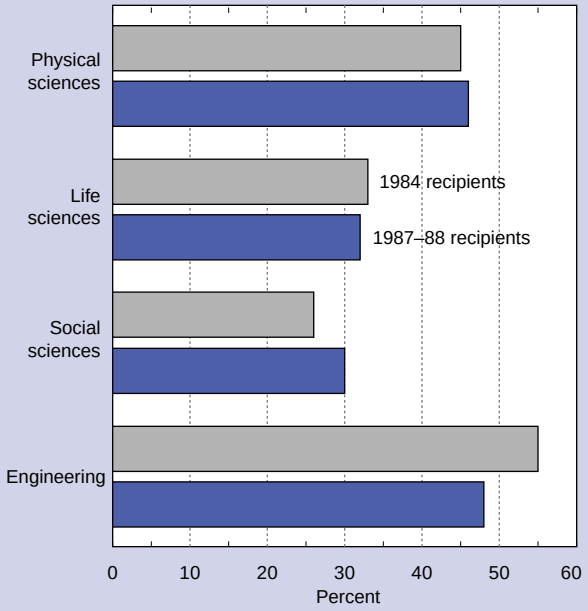
Analysis of foreign students employed in the United States by country of origin confirms the SED survey data. A large percentage of the 1987–88 foreign doctoral recipients from India and China were still working in the United States in 1992: more than three-quarters of those from India and two-thirds of those from China. In contrast, only 20 percent of South Koreans who completed engineering doctorates from U.S. universities in 1987–88 were working in the United States in 1992. (See appendix table 2-36.)

Not every foreign student who receives a firm offer to stay in the United States does so. Factors that influence foreign doctoral recipients to return home are offers from their home country to set up a first-rate laboratory in their field of specialty, the chance to expand science in their own country, and family considerations.[23] The availability of housing, the quality of schools for their children, the political environment, and free press also influence their decisions. What facilitates the decision to return home and set up a national laboratory is the opportunity to continue research collaboration with their major professor. It is important that these foreign students do not feel cut off from first-rate science. A visit once a year with their major collaborator for research and advice is helpful while they are building the facilities for the particular research directions in which their country can make a unique contribution.

As emerging countries expand their capacity to educate at the doctoral level, it is expected that fewer foreign students will come to the United States to be educated, as was indicated in the 1993–94 graduate S&E enrollment data. Previously, increasing national capacity showed a direct relationship to sending students abroad. (See figure 2-22 and appendix table 2-37). However, there is now growing capacity to educate *in situ* (SRS, 1993b; forthcoming), and the major support mechanism for foreign doctoral students

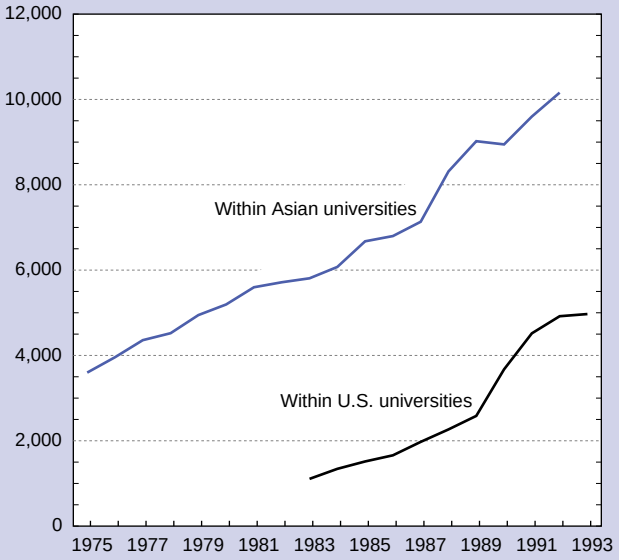
[23]Unpublished interviews are from National Science Foundation, International Cooperative Research Program, 1978–88.

Figure 2-21.
Percentage of foreign doctoral recipients from various years working in the United States in 1992



See appendix table 2-35. *Science & Engineering Indicators – 1996*

Figure 2-22.
S&E doctoral degrees earned by Asian students within Asian universities and from U.S. universities



NOTE: Includes 6 countries: China, India, Japan, Singapore, South Korea, and Taiwan.

See appendix table 2-37. *Science & Engineering Indicators – 1996*

in S&E fields (research assistantships) is being constrained by reductions in rates of growth in both Federal and state research funding to universities. (See appendix table 2-38.)

Countries do not send students abroad in large numbers. Only 5 percent of the 42,000 Chinese students in U.S. universities (mainly in engineering graduate programs) are on Chinese government support. Students come to U.S. universities for a good education, for a prestigious credential, and because the current structure has offered research assistantships at the doctoral level. The vast majority of foreign doctoral students have been supported by research assistantships and teaching assistantships. (See Major Sources of Financial Support in this chapter.) The numbers of S&E doctoral students will not increase in universities with shrinking research funding. As Federal and state research funding constraints at universities decrease the number of research awards available in certain S&E fields, the number of research assistantships will decrease and fewer foreign students will be able to obtain an S&E doctorate in the United States.

Major Sources of Financial Support

Support for Overall Graduate Students in Science and Engineering Fields

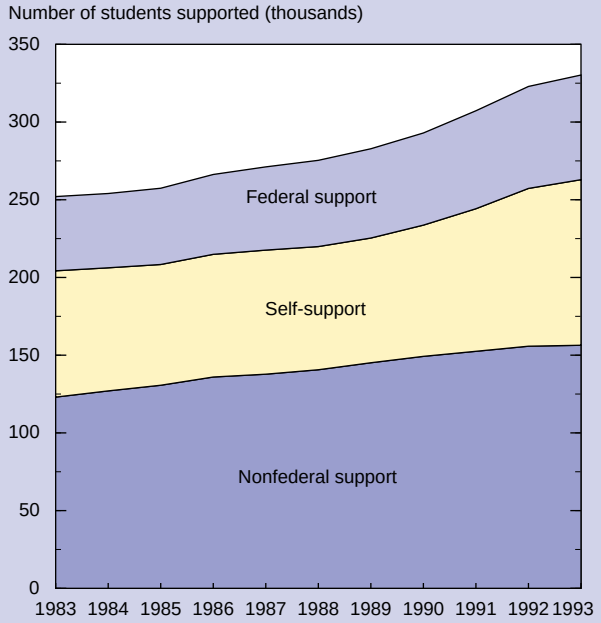
The number of overall S&E graduate students being supported by all sources continued to rise, but in certain fields, the number of students being supported leveled off or began to decline in the 1992–93 period. In the physical sciences, the number of students being supported increased from 1983 to 1992, but leveled off in 1993. The number of graduate engineering and mathematics students being supported increased from 1982 to 1992, but decreased in 1993.[24] In contrast, the number of students supported in the biological and social sciences increased over the entire period, from 1983 to 1993. There were also some trend changes in the sources and mechanisms of support.

Support by Source

In the NSF annual fall survey of Graduate Enrollment and Support, departments report the major source of support for each student, including Federal, nonfederal, and self-support. The reporting by the departments of so-called Federal sources includes only direct Federal support to a student. It omits major, indirect Federal support in the form of research funds to universities, which provide for graduate research assistantships. This support of students by federally funded research assistantships would show as institutional (nonfederal category) support, since the university chooses which of the 330,000 full-time graduate students they will support under the Federal research funds. (See figure 2-23 and appendix table 2-39.) Note that the Federal contribution to student

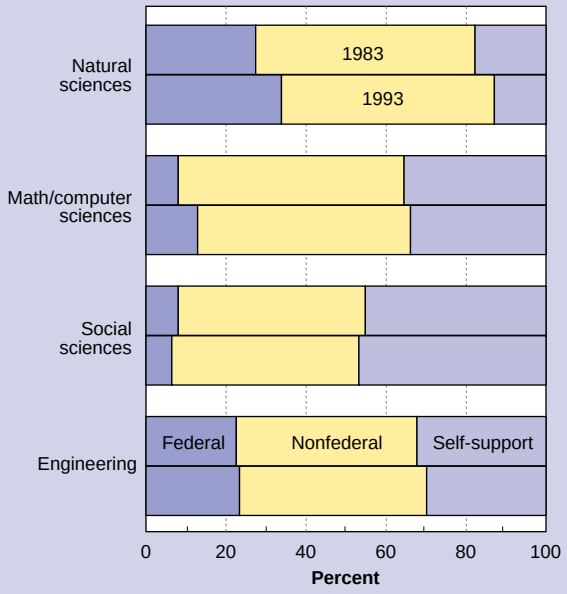
[24]Decreasing support is in fields in which foreign students are most highly represented.

Figure 2-23.
Major source of support for science and engineering graduate students



See appendix table 2-39. *Science & Engineering Indicators – 1996*

Figure 2-24.
Major sources of graduate student support, by field



See appendix table 2-40. *Science & Engineering Indicators – 1996*

support through assistantships provided to universities is underestimated. On the average, about 50 percent of institutional support is Federal; 50 percent is from states, but wide variations occur among individual states.

The decade-long trend of steady increases in overall Federal support of graduate students in S&E continued, but there were decreases in select fields and in select agencies. The number of graduate students in science being primarily supported by Federal agencies rose from 30,000 in 1983 to 43,000 in 1993, an annual increase of almost 4 percent. In the physical sciences, however, the number of students supported by the National Science Foundation and U.S. Department of Defense declined from 1988 to 1993. In fields of engineering, Federal support increased from 11,000 students in 1985 to 17,000 in 1993, an average annual increase of 5 percent. (See figure 2-24 and appendix table 2-40.)

Nonfederal sources of support for science students also continued throughout this time, but at 2 percent annually, the growth rate was lower than that for Federal sources. Only in the nonfederal sources of support for engineering did the number of students being supported level off from 1991 to 1993 (at around 35,000), after a decade of 5-percent annual increases in the number of engineering students being supported. In 1993, nonfederal sources slightly decreased the number of students supported in electrical, chemical, and mechanical engineering.

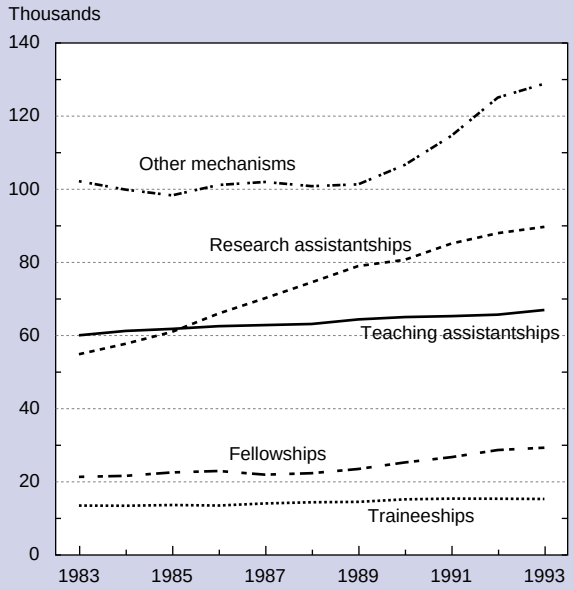
The number of students who were self-supporting increased 6 percent annually from 1988 to 1993, reaching 30 percent of graduate S&E students in 1993. Large variations exist across different fields. Only 7 percent of the physical science students were self-supporting. In contrast, 44 percent of graduate computer science students surveyed were self-supporting in 1993. In addition, 43 percent of the social science students, 37 percent of civil engineering students, and 47 percent of industrial engineering students were self-supporting. (See appendix table 2-40.)

Support by Mechanism

There is growing concern that major government support of graduate students is being accomplished through research assistantships. This form of support focuses doctoral programs on the training needs of the funded research projects, rather than on the broader educational needs of the students. The Committee on Science, Engineering, and Public Policy of the National Academy of Sciences has recently recommended shifting graduate student support to education/training grants (COSEPUP, 1995). The support of students through traineeships and teaching assistantships has grown very slowly (1 percent annually) from 1983 to 1993. (See figure 2-25 and appendix table 2-38.)

Research assistantships were still the dominant mechanism of support for S&E graduate students in 1993, particularly for graduate students in fields of physical sciences (40 percent), earth, atmospheric, and oceanographic sciences (42 percent), biological sciences (41 percent), and engineering (38 percent). However, the long-term trend of high annual growth rates in the numbers of these assis-

Figure 2-25.
Major mechanisms of graduate support



See appendix table 2-38. *Science & Engineering Indicators – 1996*

tantships stopped in 1992–93. Almost 90,000 students received their primary support from research assistantships in 1993, about half from Federal sources and half from nonfederal.[25] From 1983 to 1992, S&E graduate students with research assistantships as their primary source of support grew more than 5 percent annually; from 1992 to 1993, however, the growth rate was less than 1 percent.

Fellowships and research assistantships from various sources have recently leveled off or declined. Direct Federal fellowships, which had increased at more than 11 percent annually between 1988 and 1992, decreased slightly in 1993. National Science Foundation fellowships followed this pattern, increasing from 1987 to 1992, and slightly decreasing in 1993. Nonfederal research assistantships were the major source of support for an increasing number of students from 1983 to 1992, but leveled off in 1993. Research assistantships from the National Science Foundation also leveled off in 1993.

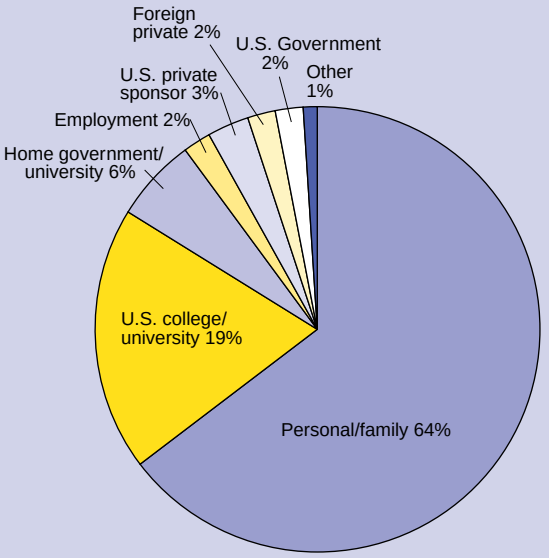
Sources of Support for Foreign Students in the United States

Approximately half of all foreign students in 1992–93 were enrolled in undergraduate levels: 50,000 in associate degree programs and 160,000 in bachelor programs. These students generally pay tuition—a high percentage of them have been recruited to private schools. (About 34 percent of foreign students attend private schools; only 17 percent of U.S. students attend private schools.) An estimate of the total dollar amount paid by foreign students for tuition and living expenses (based on an average amount of $16,400 for tuition and living expenses for 365,000 foreign students) is $6 billion per year for their study in the United States.

Another 193,000 foreign students were enrolled in graduate schools in 1992–93, approximately 100,000 of them studying S&E for a master's or doctoral degree. Foreign students within this pool, particularly at the doctoral level, account for those receiving university funds as their primary source of support. These foreign students are working their way through school by qualifying, through their academic standing, to receive teaching assistantships and research assistantships.

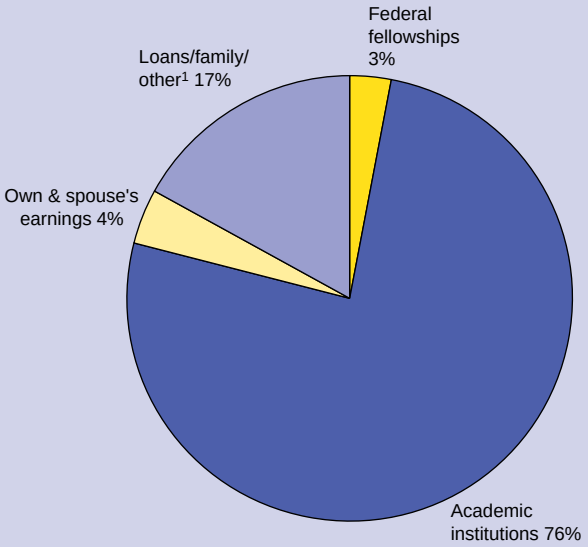
The majority of funding support for foreign students at all levels of higher education is from non-U.S. sources. In 1993, two-thirds of the foreign students in the United States said their families were their primary source of support. (See figure 2-26 and appendix table 2-41.) An additional 8 percent of funding comes from their home governments, universities, and foreign private sponsors. U.S. sources are the primary funding support for 24 percent of foreign students. This support is provided by U.S. colleges and universities (19 percent), the U.S. Government (2 percent), and U.S. private sponsors (3 percent); 2 percent of foreign students cite employment as their primary support source (IIE, 1993).

Figure 2-26.
Foreign students in all levels and fields of U.S. higher education, by sources of support: 1991



See appendix table 2-41. *Science & Engineering Indicators – 1996*

Figure 2-27.
Foreign doctoral students in science and engineering, by primary source of support: 1991



NOTE: Foreign doctoral students on temporary visas.
[1]Other includes business/employer.

See appendix table 2-42. *Science & Engineering Indicators – 1996*

In striking contrast, U.S. sources are the primary funding support of 80 percent of all foreign S&E students at the doctoral level.[26] (See figure 2-27 and

[25]Nonfederal sources are mainly academic institutions that provide research assistantships from the research funds received from state, local, and Federal sources.

[26]Data on primary source of support at the doctoral level are from the SRS/NSF Doctorate Records File (SRS, 1995a); data on foreign student support at all levels are from IIE (1993).

appendix table 2-42.) Since U.S. universities had rising research budgets in the 1980s, they were able to offer research assistantships to S&E doctoral students—regardless of citizenship—in NS&E fields. Foreign doctoral S&E students are concentrated almost exclusively in these fields. More than three-quarters of foreign S&E doctoral students receive their primary funding support in the form of either research assistantships (including some research funds to universities from Federal grants), teaching assistantships, or university fellowships. Only 3 percent comes from Federal fellowships or traineeships, which, for the most part, are not open to foreign students. About 20 percent of foreign doctoral S&E students cite various forms of self-support (family, loans, earnings, and spouse's earnings) as their primary funding support.

Conclusion

The diffusion of science and engineering knowledge throughout the world is partly based on greater access to higher education in several geographic regions and to the large number of foreign students who obtained an S&E education in advanced industrialized countries over the past decade. In the United States, this broader access is reflected in the increasing number and proportion of S&E degrees earned by women and minorities. But greater access to S&E education in several Asian and European countries also means that the majority of scientists and engineers are educated and reside outside the United States. China will be the main educator and supplier of engineers at the bachelor's degree level in the Asian region, and Japan is beginning to assume a greater role in the advanced education of scientists and engineers in this region. The United States is one of several countries with a large proportion of foreign students in its doctoral programs. However, the number of foreign students studying S&E fields in the United States seems to have peaked in 1992. Besides increased access to within-country education and study abroad, the diffusion of S&E knowledge is fostered by emerging reforms of doctoral programs in science and engineering in all major countries. These reforms are designed to educate people who are more able to utilize new knowledge and discoveries to address societal needs.

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