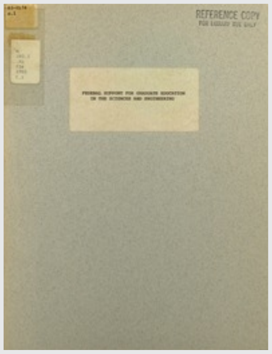

Federal Support for Graduate Education in the Sciences and Engineering: A Background Paper

DETAILS

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FEDERAL SUPPORT FOR GRADUATE EDUCATION IN THE SCIENCES AND ENGINEERING

A Background Paper Prepared by

Susan Fallows

for

The Ad Hoc Committee on Government-University Relationships in Support of Science

Committee on Science, Engineering, and Public Policy

National Academy of Sciences
National Academy of Engineering
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OVERVIEW

At present U.S. graduate institutions educate a large group of students in the fields of science and engineering. In 1980 total enrollment figures reached 383,000 for graduate programs in engineering, the physical sciences, the mathematical and computer sciences, the life sciences, and the social sciences.[1/] That year U.S. universities conferred an estimated 56,000 master's degrees and 18,171 doctorate degrees in the sciences and engineering.[2/]

With the addition of these new degree recipients to the labor force, the total supply of scientists and engineers in the United States numbered 2,980,100 in 1980.[3/] The most recent statistics for doctoral scientists and engineers indicate that in 1979, nearly 314,000 were employed in U.S. organizations (55 percent in educational institutions, 26 percent in business or industry, 8 percent in the federal government, and 9 percent in other organizations).[4/] In absolute numbers, the supply of scientists and engineers engaged in R&D in the United States puts the United States far ahead of most other countries; in fact, with 645,000 R&D scientists and engineers, the United States was second only to the Soviet Union in 1980.[5/] When viewed in relation to the size of the total labor force, the size of the U.S. R&D community is still larger than that of all other industrialized nations except the Soviet Union.[6/] However, the United States' comparative advantage has declined in recent years because the ratio of scientists and engineers to labor force has grown faster in Japan and West Germany than in the United States.

The large size of the U.S. science/engineering community at present results from deliberate efforts by many sectors of American society over the past several decades to enhance the size, stature, and productivity of American scientists and engineers. The federal government has played a major role in this effort, both in its funding of research and development and its support for the training of scientists and engineers.

This paper examines federal involvement in the support of graduate education in the sciences and engineering. It describes recent trends in graduate enrollments, degree production, and sources of support, and analyzes the impacts of recent changes in the character of federal financial assistance for graduate students on various features of the education experience (e.g., length of time needed to complete doctoral studies, interest in certain scientific fields, participation of foreign students in U.S. graduate programs).

It is possible to draw only a number of general conclusions from the limited aggregated data that exist on graduate education in the sciences and engineering. High-quality time series data on graduate enrollments, federal support, and degrees awarded do not exist for the entire post-World War II period, although there have been significant strides made in data collection in recent years. To get a picture of the trends in graduate student support, it is necessary to piece together bits of information from various sources of data, not all of which are entirely compatible. These data deficiencies prevent detailed analyses of causal relationships between changes in funding mechanisms and funding levels on the one hand, and enrollment levels and degree awards on the other. However, it is possible to look at general trends in these relationships. The evidence and conclusions will be discussed in some detail in the body of this paper but the major points can be summarized here.

Beginning in the early 1960s, there was enormous growth in enrollments in graduate science/engineering programs in the United States. Starting from a small enrollment base of 78,308 in 1960, and from a low number of master's degrees (20,012) and doctorate degrees (6,371) awarded annually, through the 1960s the size of the student population and the number of advanced degrees conferred increased greatly. Enrollments in the two largest fields of science/engineering--the social sciences and the life sciences--continued to grow during the 1970s while those in other fields levelled off. At present, graduate enrollments are four times their 1960 level, at 249,111 full-time science/engineering graduate students enrolled at all U.S. institutions in 1980.

Similar growth trends occurred in advanced-degree production over the 1960-1980 period. The 1960s saw large, steady increases in the number of science/engineering master's degrees conferred at U.S. institutions, with 49,318 awarded in 1970. Growth peaked around 1977 at 56,730 annual master's degree awards, and it has remained there until the present. Ph.D. production increased at a slightly faster rate during the 1960s and peaked earlier, with a high of 19,550 doctorate degrees awarded in scientific and engineering fields in 1973. In 1980, 18,200 Ph.D. degrees were conferred.[7/]

These high growth rates in enrollments and advanced degree awards over the 1960s and early 1970s resulted from numerous factors, including demographic conditions such as large increases in the size of the population cohorts eligible for graduate school (associated with the post-World War II baby boom) and higher participation rates for the eligible population (associated generally with increased education and affluence levels of the U.S. population).[8/]

Perhaps among the most important policy factors affecting growth rates were federal initiatives to help students obtain specialized training in the sciences and engineering in order to meet projected demand for college and university professors and for research scientists and engineers.[9/]

FEDERAL POLICY TOWARDS GRADUATE EDUCATION

The federal government has supported graduate training in the sciences and engineering only for the past 30 years. Its involvement has included two main components: direct financial assistance to students, and funding for R&D projects at universities and colleges.

World War II marked a turning point in attitudes about the proper role for the federal government in higher education. Before the War, the training of scientists and engineers was considered to be a responsibility of states, localities, private institutions, and families. But the successful war-time collaboration of the federal government and research scientists and engineers fostered favorable attitudes among policymakers towards federal investment in university-based R&D and in the training of a new generation of young researchers.

In his landmark study of the U.S. scientific research system (Science--The Endless Frontier, 1945), Vannevar Bush included two recommendations pertaining to federal support for education in the sciences and engineering: He called for federal funding of basic research in universities as a way to enhance the training experiences of young scientists. And he encouraged federal agencies to provide competitive fellowships to attract talented students to pursue education and careers in science and engineering. Bush's charges were the first clear enunciation of a federal responsibility for the development of scientific manpower for national needs.[10/]

Over time, the spirit of Bush's recommendations were embraced in a number of federal actions. The 1950s and 1960s were a period of expansion in federal funding for R&D at the nation's universities and colleges. The table below shows the growth (measured both in current and constant dollars) in federal expenditures for university-based R&D from 1953 to 1969.[11/] Federal funding for R&D at educational institutions resulted from a series of discrete programs administered by various mission agencies to enhance U.S. economic development, national security and scientific and technological capabilities. The primary sources of federal support for university-based R&D were the program budgets of the Departments of Defense, Agriculture, and Health, Education, and Welfare (particularly the Public Health Service and the National Institutes of Health), the Atomic Energy Commission, the National Aeronautics and Space Administration, and the National Science Foundation.[12/]

Federally Financed Expenditures on Research and Development At Colleges and Universities, Fiscal Years 1953-1978 (In Millions of Dollars)

Fiscal Year	Current Dollars	Constant 1972 Dollars
1953	138	234
1954	160	268
1955	169	277
1956	213	339
1957	229	352
1958	254	384
1959	306	453
1960	405	590
1961	500	722
1962	613	869
1963	760	1,048
1964	916	1,245
1965	1,073	1,433
1966	1,262	1,639
1967	1,409	1,775
1968	1,573	1,911
1969	1,595	1,850

The growth in federal R&D spending reflected the general trend of increased investment in R&D by all sectors of the U.S. economy during the 1950s and 1960s.[13/] In 1953, total spending on R&D in the United States was $5.1 billion. It had tripled by 1962, when it reached $15.4 billion. Through the 1960s, the rate of increase slowed, but growth continued. In 1970, the R&D spending level was $25.9 billion.

The ratio of national R&D spending to gross national product (GNP) grew through the 1950s, but peaked in 1964 at 2.96 percent. Since then, GNP expanded faster than R&D spending.[14/]

A peak in the percentage of R&D investment provided by the federal government also occurred in 1964. Two-thirds of the $18.8 billion spent on R&D that year came from the budgets of federal agencies. The level had dropped to 56 percent by 1970.[15/]

The proportion of total R&D investment spent at universities also increased gradually over the 1950s and 1960s. In 1953, 5 percent (or $255 million) was spent at universities or colleges. In 1970, the level was 9 percent (or $2,335 million).[16/] While the percentage of R&D expenditures at universities that came from federal sources also grew during the 1950s (from 54 percent in 1953 to 63 percent in 1960), it peaked in 1966 at 74 percent and has dropped slowly ever since.[17] In current dollar terms, federal spending for university-based R&D increased from $138 million in 1953 to $1,260 million in 1966, to $1,725 million in 1970.

The post-war growth in federal support for R&D, especially at universities and colleges, was paralleled by significant increases in federal aid to graduate students in the sciences and engineering. A fellowship program for science/engineering graduate students was authorized in 1950 as part of the National Science Foundation Act (PL 81-507). The intent of the fellowship program was to help create a supply of trained scientific manpower for teaching and research, along the lines Vannevar Bush had outlined in 1945. In 1952 NSF began to offer nationally competitive fellowships to support graduate students at the institutions of their choice.[18]

The NSF fellowship program remained modest in size until the late 1950s, when the Sputnik launching of 1957 increased public interest in boosting federal support for scientific training. Sputnik provided the impetus needed to enact an aid-to-education program that had been blocked in Congress for years: In 1958 Congress passed the National Defense Education Act (PL 85-864).[19] Among other things, this act authorized the Office of Education to offer fellowships in specific fields of science. It also provided subsidies to educational institutions to create low-interest loans for needy students in all disciplines. These loans would be forgiven for students who later went into teaching careers. The purpose of NDEA financial assistance was to help direct students into "national need" areas where manpower shortages were anticipated (e.g., teaching, mathematics, health sciences).

Soon after the passage of NDEA, the President's Science Advisory Committee published three successive reports calling for stronger support for scientific and engineering education by all sectors of American society. These reports were Education for the Age of Science (1959), Scientific Progress, The Universities, and the Federal Government (1960, also known as the Seaborg Report), and Meeting Manpower Needs in Science and Technology (1962, also known as the Gilliland Report). Together, these reports articulated the national need for greater numbers of scientists and engineers in the 1960s and 1970s, and for stronger federal support for the training of manpower for basic research and for university-level teaching.[20] The Gilliland Report was particularly innovative in its attempts to predict demand for and supply of science and engineering personnel. The projected deficits in certain fields helped to justify a significantly strengthened federal role in assisting graduate students in the sciences and engineering.[21]

Through the 1960s, the number of graduate students supported by federally funded fellowships and training grants increased greatly. (See a later section on sources of support for graduate students, for details on the levels and distribution of support for different years.) The major programs of this period included: NSF fellowships and traineeships, offered in all fields but targeted towards disciplines poorly supported by other mission agencies; NDEA Title IV Graduate Fellowships and Research Training Fellowships, administered by the Office of Education at DHEW; fellowships and traineeships in the life sciences and psychology offered by the National Institutes of Health; Public Health Service fellowships and traineeships; NASA traineeships, predominantly for engineers, mathematical and computer scientists, and physical scientists; and AEC fellowships and traineeships, also targeted to the physical sciences and engineering.[22]

While these programs were authorized and administered separately and without a common set of goals, together they created a *de facto* federal policy towards science/engineering education that emphasized manpower development in specific fields rather than support for graduate institutions *per se*.[23] Federal programs to assist graduate students were established incrementally to fill existing or projected deficits in trained personnel in specific R&D fields or in teaching. Agencies appeared to recognize the link between university-based research and the training of future scientists, in that they tended to fund research assistantships in the grants they awarded to principal investigators and universities.[24]

A different approach to supporting graduate students gained popularity in the mid-1960s, as part of a larger shift in federal policy towards aiding disadvantaged socio-economic groups. The Economic Opportunity Act of 1964 (PL 88-452) created the work-study program among other things. This program enabled graduate departments and researchers to hire low-income students at a small fraction of the costs of the students' wages, through federal wage subsidies. Students' eligibility for participation in work-study programs was based on their financial status, and not on their field of study. The work-study program was expanded under the 1965 Higher Education Act (PL 89-329). This legislation, administered by the Office of Education, also created the guaranteed student loan program, available to low-income graduate and undergraduate students in all fields.

These two laws, and their subsequent implementation, marked a significant shift in the emphasis of federal policy towards supporting equality of opportunity for economically disadvantaged and minority students. However, they maintained the focus on direct financial aid to individual students (rather than institutions) previously established under the manpower-development graduate education programs. And they reflected a continuation of the reactive, disjointed, mission-oriented pattern of federal support towards higher education that had developed in the post-war period.[25]

During the era of strong federal support in the 1960s, the array of mechanisms offered and financed by federal agencies provided multiple avenues through which highly qualified students were encouraged to pursue graduate education, the training costs of graduate programs were underwritten, and low-income students were able to attend graduate school.

Two mechanisms--fellowships and traineeships--were awarded on the basis of merit. They differ in that fellowships are awarded directly to individual students on the basis of a national competition and for use at the institution of their choice. Training grants are also competitive awards, but agencies grant them to specific graduate programs which use them to support training costs (e.g., equipment, administrative services) and graduate students. The institution and not the agency designates which of the students enrolled in the program will receive a traineeship. Fellowships and traineeships are similar in their financial provisions for students. But they differ in how they affect students' decisions about which graduate program to attend. Portable fellowships foster the operation of a market-like selection process, where top students act as decisionmakers about the relative quality of graduate programs. In training grants, agencies decide which graduate departments deserve support, in part by giving them money to attract good students.

These two merit-based mechanisms differ in concept from service-related support mechanisms, such as research assistantships, or need-based mechanisms, such as loans. Allocation decisions about research assistantships are made, at the first stage, by agencies and peers in the funding approvals of principal investigators and then, at the second stage, by the grant recipients who choose individual students to participate on the research project. In contrast, the federal government allocates loan subsidies to lending institutions and universities, which issue them to students on the basis of income eligibility criteria rather than academic merit or area of study.

The diversity of forms of support, along with the relatively high levels of federal funding for university-based R&D and for fellowships, traineeships, and loans helped to prompt the creation of new graduate programs and expand existing areas during the 1960s. And they boosted enrollments in science and engineering programs, as well as production of advanced degrees.[26]

These federal programs provided financial assistance to a record number of graduate students in the late 1960s and early 1970s. In 1970, 40,400 science/engineering graduate students were supported on a federal fellowship, traineeship, or training grant; this represents over one-fifth of all graduate students enrolled full-time in science or engineering programs. The same year 122,700 graduate students (in all fields) were supported by GI benefits and 110,000 graduate students took out a federally insured student loan.[27] This provision of financial aid by the federal government, along with the prospects of expanded job opportunities for scientists and engineers in industry, universities, and government agencies, helped boost graduate student enrollments and degree production to their high points in the early 1970s.

Since the early 1970s, the growth rates in enrollments in various fields have dropped off and there have been reductions in the total number of advanced degrees awarded in the sciences and engineering. These trends began approximately five years after significant reductions in federal support for R&D in general, and for graduate training in particular.[28] For example, beginning in 1967 many federal agencies began to reduce the number of students they supported through graduate fellowships and traineeships.[29] There were deep cuts in the fellowships and training grants offered in all fields but the life sciences and psychology (both of which continued to receive relatively strong support from NIH). And these reductions slowed down enrollment growth in other fields starting in the late 1960s.[30] The five-year time lag between federal cutbacks and reduced degree production corresponds roughly with the average length of time it took to complete a Ph.D. in the late 1960s.

During the same period, the federal government also decreased its overall support for basic research, applied research, and development (when federal expenditures are measured either in terms of constant dollars or in relation to the size of the gross national product).[31] Federal R&D expenditures at colleges and universities dropped in the late 1960s and early 1970s, especially for programs supported by the Department of Defense (DoD), NASA, AEC, and NSF.[32] Funding for biomedical research remained relatively strong over this period. These changes in federally funded R&D programs reduced the job opportunities open to researchers with advanced degrees, as well as the number of research assistantships available for funding graduate training for young scientists and engineers. Also, they created unevenness in enrollments, advanced-degree production, and employment for individuals and programs in certain fields. (See the later sections on support for graduate education and production of advanced degrees for more detailed descriptions of these trends.)

Another set of trends appears to be associated with reductions in federal support for graduate education over the post-war period: The graduate-school entry rates for holders of science/engineering baccalaureate degrees peaked in 1965 at 65 percent.[33] Across all fields, it now takes the average graduate student 1.5 years longer to complete a Ph.D. than it did in 1958.[34] Also since the early 1970s, the number of science/engineering graduate students enrolled in school part-time has increased by 20 percent (from 26 percent part-time enrollment in 1974 to 31 percent in 1980).[35] Additionally, over the same period the percentage of science/engineering graduate students who put themselves through school has increased.

The financial burden for graduate education in scientific and engineering fields has shifted in recent years so that students increasingly have to rely on personal resources (e.g., in-school earnings, spousal and family contributions, and loans) to pay for graduate school. As the percentage of science/engineering Ph.D. recipients supported by federal fellowships or traineeships has dropped (from a high of 60 percent for 1971 doctorates to a low of 28 percent for 1980 doctorates), the percentage of recipients who relied on personal earnings has risen from 25 percent in 1971 to 40 percent in 1980. Those who depended upon family contributions or loans rose from 29 percent in 1971 to 62 percent in 1980.[36/] Among all science/engineering graduate students enrolled in 1980, one-third listed personal resources as their major source of support.

The data on graduate education in the sciences and engineering show a general inverse relationship between availability of federal financial support (in the form of fellowships, traineeships, and research assistantships) and reliance on personal financing of graduate school, part-time enrollments, and longer length of time to complete advanced degrees. Furthermore, there have also been significant reductions in the number of doctorates completed by U.S. citizens in several fields, especially engineering, the physical sciences, and the mathematical/computer sciences--all of which are fields with strong growth in the percentage of enrolled students and Ph.D. recipients who are non-U.S. citizens. In 1980, foreign citizens received 46 percent of engineering doctorates from U.S. institutions, 23 percent of physical sciences doctorates, and 27 percent of doctorates in the mathematical/computer sciences.[37/]

In general, then, changes in the availability of federal support for graduate students have coincided with a number of quantitative changes in graduate education in the sciences and engineering, although the fields vary in their sensitivity to federal support.[38/] The social sciences appear to be the least sensitive since, even though their enrollments and degree-production levels have always been among the highest, they have historically received a relatively small share of federal fellowships, traineeships, and research assistantships. Even relatively severe cutbacks in federal assistance to the social sciences did not significantly reduce enrollments or degree awards. The life sciences and the physical sciences appear more sensitive to changes in federal support, since the students in these fields have historically depended upon federal support mechanisms, and enrollment and degree-production levels in these fields have related directly to the availability of federal research assistantships, fellowships, or training grants. In the physical sciences enrollments levelled off and degree awards dropped after federal fellowships and traineeships were reduced in the early 1970s. A relatively strong base of federally supported research assistantships has helped to maintain the size of enrollments in programs in the physical sciences. Students in the life sciences have been relatively well funded by federal training grants and federal research assistantships over the past two decades, and enrollments and degree production have remained high in these fields, especially in the biological and health sciences. Enrollments and degree award levels in engineering and computer sciences have been unstable in recent years and seem to relate to the combined effects of erratic conditions in the job market for engineers and the changing availability of federal research assistantships and training grants.

The general patterns of federal support for graduate education in the sciences and engineering are described in more detail below. That discussion is preceeded by a brief description of trends in graduate enrollments, and will be followed by descriptions of the previously cited trends in science and engineering education. These areas include: number of educational institutions, production of advanced degrees in scientific or engineering fields, participation of foreign students in U.S. graduate programs, part-time enrollments, length of graduate training, and job outlooks for scientists and engineers. A summary of findings appears at the end of the paper.

GRADUATE ENROLLMENTS IN SCIENCE/ENGINEERING FIELDS

Over the 1960-1980 period, full-time enrollments in graduate science and engineering programs at U.S. institutions increased nearly fourfold. Starting from a relatively small enrollment base of 78,308 students in 1960, the growth rate was high through the 1960s, with an average annual growth rate of 15.5 percent during the first half of the decade, and slowing down to an average annual rate of 7 percent in the late 1960s:

year	number of full-time graduate science/engineering students enrolled at U.S. institutions	average annual growth rate
1960	78,308	>15.5%
1965	139,096	> 7.0
1970	187,843	> 4.1
1975	226,774	> 2.0
1980	249,111	

Growth rates continued to slow during the 1970s, and by 1980 enrollments across all fields of science and engineering had virtually stabilized.[39]

In 1980 total graduate enrollments (full-time and part-time students at all U.S. institutions) included 383,210 students, of which 249,111 (or 65 percent) were full-time students and 134,097 (35 percent) were part-time students. Most science/engineering students (87 percent) attended doctorate-granting institutions in 1980.

The absolute increases in the number of students enrolled in science/engineering graduate programs mask the fact that over the 1970s there has been near stabilization in the number of students enrolled per 10,000 population (21 years old and over). Recent enrollment increases have coincided with the growth in the proportion of the total U.S. population that is over 20 years old (i.e., increases that were boosted in part by the aging of the baby-boom generation):40/

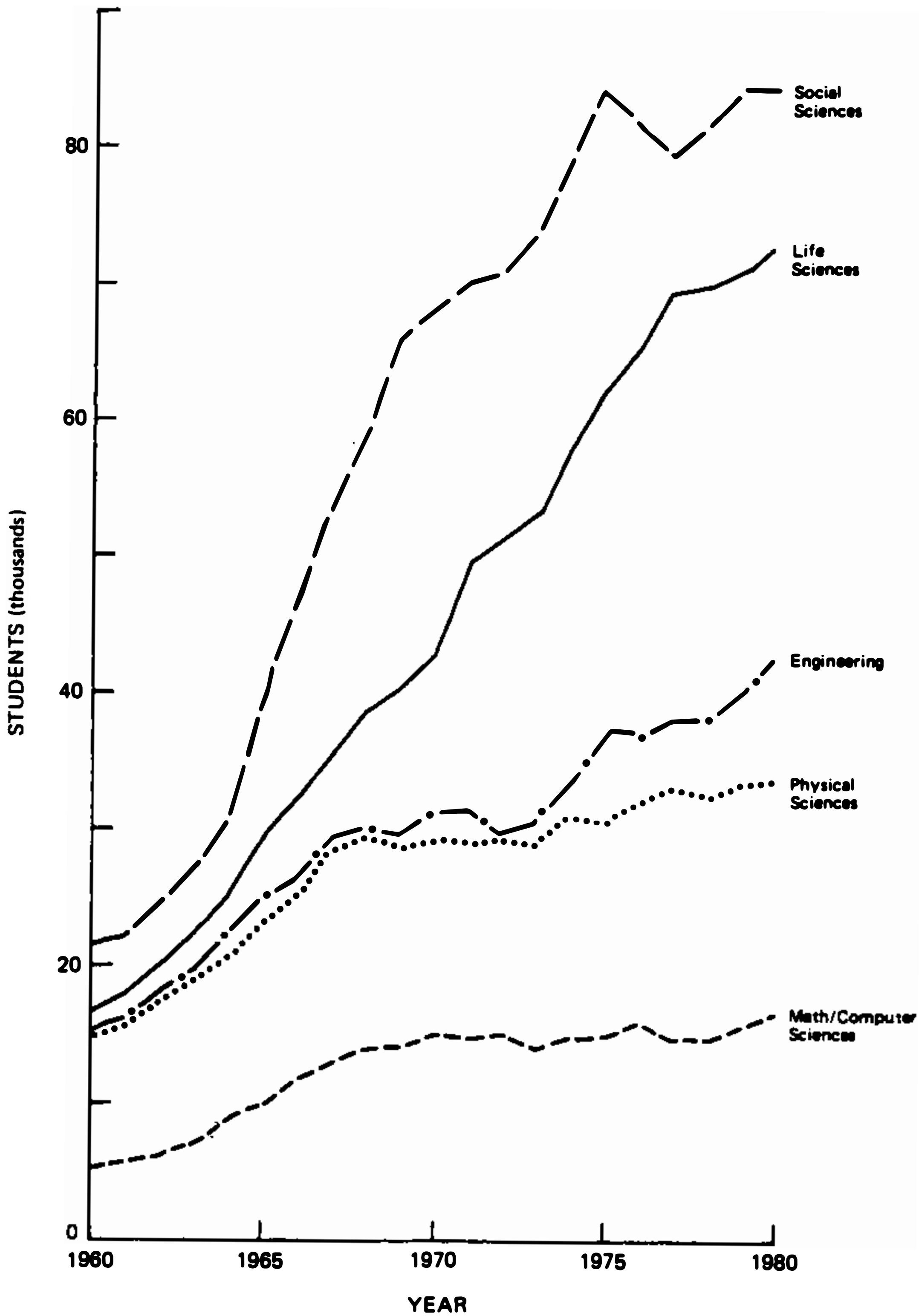
year	Total U.S. Population over 20 years old	Population Over 20 years old as Percentage of Total U.S. Population	Total Full-time, Science/ Engineering Graduate Enrollment	Number of Science/Engineering Graduate Students per 100,000 persons (over 20 years old)
1960	108,856,000	60.3%	78,300	7.19
1970	124,031,000	60.5%	196,700	15.86
1975	134,776,000	63.1%	226,800	16.83
1978	142,416,000	65.1%	235,100	16.51
1979	145,098,000	65.8%	242,400	16.70

When viewed in this context, graduate enrollments in all fields of science and engineering have virtually stabilized over the 1970s.

Over the 1960-1980 period, enrollment levels and growth rates have varied for the different fields of science and engineering (see Figure 1). All fields experienced strong increases in graduate enrollments during the 1960s. This coincided with the strong financial incentives provided by the federal government to encourage students to obtain graduate training in scientific and engineering fields after 1962. Enrollments climbed as students and graduate programs responded positively to the opportunities provided by federal support. (See the following section for a more detailed account of the financial support mechanisms and levels provided to graduate students by federal agencies at this time.)

Figure 1 shows nearly parallel growth curves for all fields during the early 1960s. Enrollments in the social sciences began to rise more rapidly than in other fields at this point, perhaps a response to assistance targetted to these fields under the National Defense Education Act fellowship program and to increased interest in the social sciences associated with federally supported social programs. Enrollments in the social sciences continued to grow through the 1970s: Increases were especially strong in psychology, which continued to receive strong NIH fellowship and traineeship support in the early 1970s, even after other fields of social science lost federal assistance. The growth curves for the other fields of science and engineering remained roughly parallel through the early 1970s, except for the life sciences, whose growth rate rose sharply in the late 1960s and early 1970s. This increase corresponds with increases in federal funding for biomedical research and for fellowships and training grants in the life sciences. Enrollments in the fields of engineering, physical sciences, and mathematical/computer sciences started to

FIGURE 1 Full-time graduate enrollments in science/engineering at U.S. institutions, by field and by year: 1960-1980.



stabilize in the early 1970s after the federal government began to reduce the number of fellowships and traineeships it made available to graduate students interested in space and defense-related research.

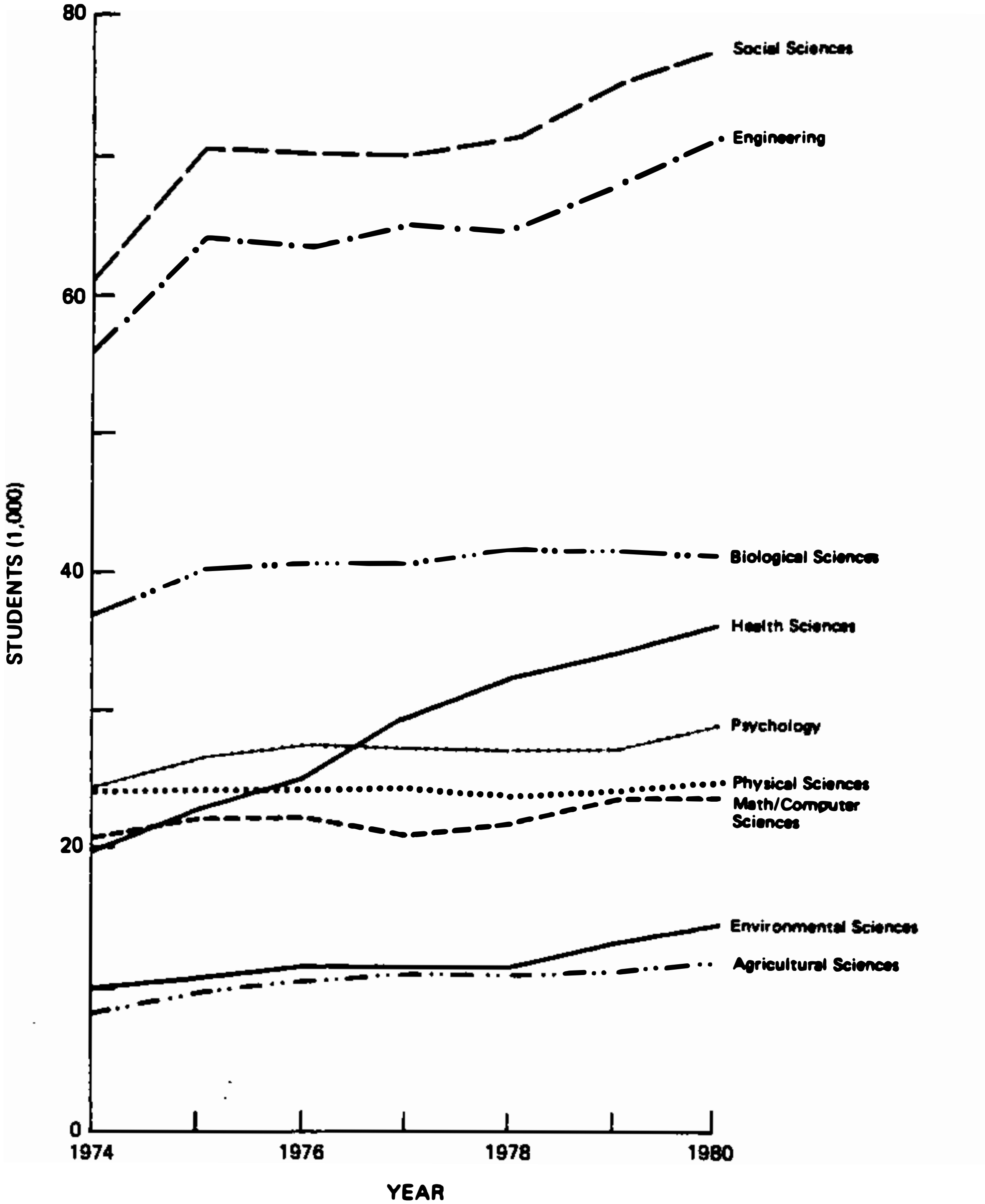
In the past five years, enrollments in most fields have levelled off. Figure 2 shows the enrollment curves for the different fields of science and engineering for the 1974-1980 period. (Note that while Figures 1 and 2 both chart graduate enrollment trends for separate fields, Figure 1 displays full-time enrollments at all institutions and Figure 2 shows all graduate students enrolled at doctorate-granting institutions. The fields vary with respect to those variables. Also, Figure 2 uses a more detailed breakdown of the fields.) Enrollments in the biological sciences, physical sciences, agricultural sciences, environmental sciences, and psychology have all nearly stabilized with very slow rates of growth. However, the social sciences (here, excluding psychology), engineering, and the health sciences have shown relatively strong increases in enrollments during this recent period.

As shown in Figures 1 and 2, the social sciences have always had the highest number of full-time graduate students. The social sciences (including psychology) currently enroll one out of every three graduate students in the sciences and engineering, although social sciences' share has been declining since it reached a peak of 40 percent in 1969. Since then, the life sciences have made up an ever larger share of graduate enrollments. Currently, 29 percent of all full-time graduate science/engineering students are enrolled in the biological sciences (15 percent), health sciences (10 percent), or agricultural sciences (4 percent). This total share for the life sciences is up from 19 percent in 1960. Engineering students make up another 18 percent of graduate students in the sciences or engineering; this proportion has decreased by a few percentage points over the 1960-1980 period. The physical and environmental sciences enroll another 13 percent of the graduate students, down from 20 percent in 1960. Enrollments in the mathematical and computer sciences have always been the smallest during the past two decades, with only 7 percent of the 1980 graduate students in the sciences and engineering.

SOURCES AND MECHANISMS OF SUPPORT FOR SCIENCE/ENGINEERING GRADUATE STUDENTS

In the post-World War II period, the sources of outside support available to graduate students in the sciences and engineering have changed dramatically. The U.S. federal government has, however, continued to be a major source of financial aid to graduate students over this period. Starting in the late 1950s, the federal government began to offer extensive assistance by way of GI benefits (available to students who were veterans), nationally competitive fellowships (awarded directly to individual students on the basis of merit), and traineeships (allocated to fields and awarded to graduate programs, which in turn awarded them to students), subsidized student loans (allocated to eligible students through institutions), and research

FIGURE 2 Science/engineering graduate students enrolled in doctorate-granting institutions, by field and by year: 1974-1980.



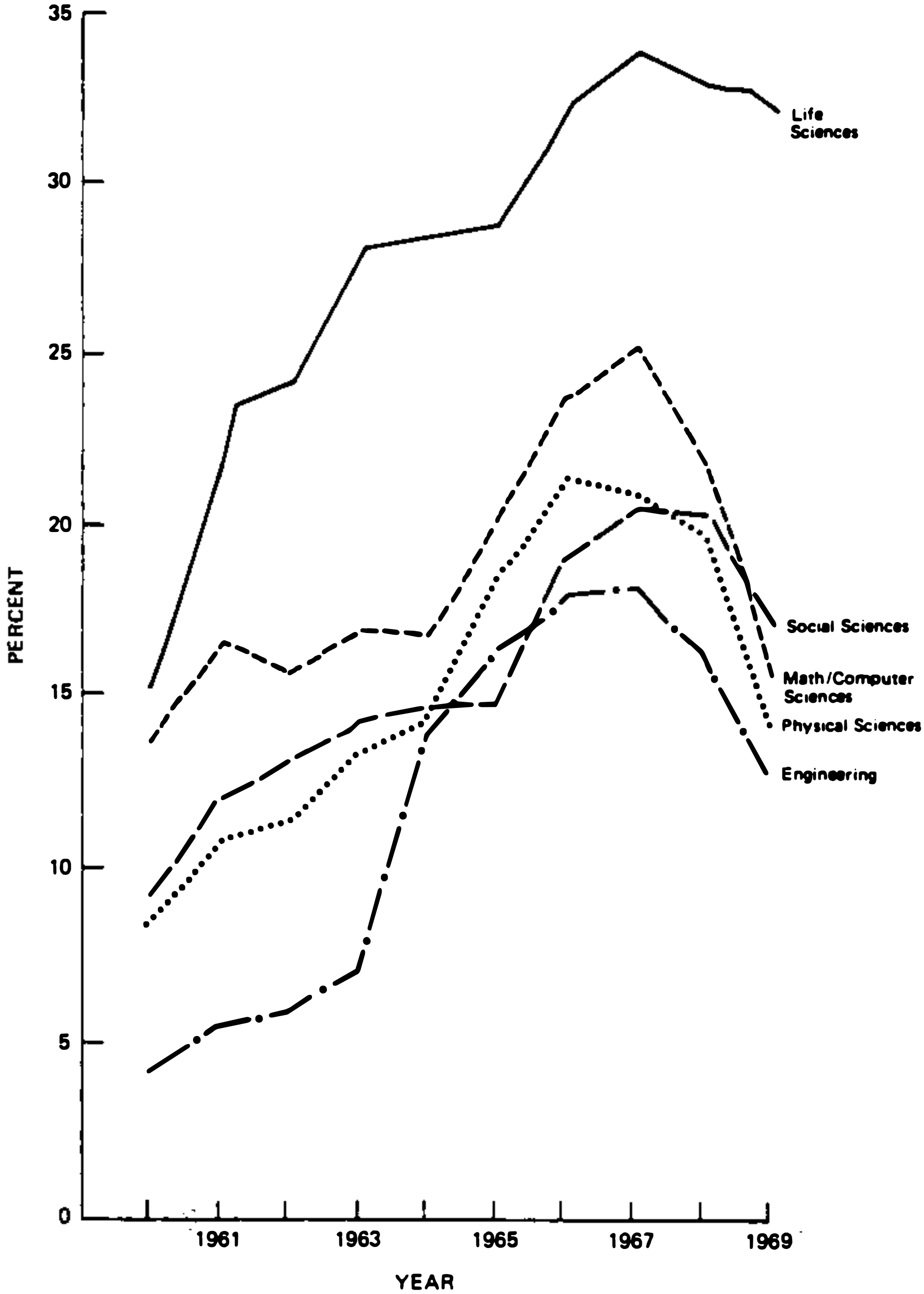
grants (awarded to principal investigators, who hired student research assistants). Federal aid has declined over the past decade, both in the number and percentage of students supported by federal fellowships and training grants. Many federal fellowship and traineeship programs (e.g., NDEA fellowships, NASA traineeships, AEC fellowships, NSF fellowships and traineeships) were cut back or phased out altogether after previous manpower shortages in several fields had been eliminated.[41]

Only limited data exist to trace the relationship between federal support and graduate enrollments and degree production in various fields. Data from a 1970-1971 study (by the now defunct Federal Interagency Committee on Education [FICE]) of federally funded fellowships and training grants indicate patterns of support during the era of generous federal funding in the 1960s.[42]. Figure 3 shows the percentage of graduate students in different scientific and engineering fields whose graduate studies were supported through a federal fellowship, traineeship, or training grant over the 1960-1970 period. The trend lines for the various fields show the effect of increased federal assistance on student-support levels. The peak in federal fellowship and traineeship assistance for all fields of science/engineering occurred in 1969, at 40,400 students so funded.

For individual fields, the peaks in the percentage of students supported took place between 1966 and 1969. In each field the peak followed a gradual decline in the number of federal fellowships and traineeships available, along with a more rapid decrease in the percentage of students supported, since enrollments in the sciences and engineering continued to climb during this period (see the previous section on enrollments). In all fields except psychology (which is included in the social sciences category here) and the life sciences--both of which still receive relatively large numbers of NIH/NIMH traineeships and training grants--the percentage of students who received federal support in 1980 dropped to below 5 percent.

As Figure 3 also shows, students in certain science/engineering fields have consistently received proportionately more federal fellowships and traineeships than other students. The life sciences (especially the biological and health sciences) have always had a relatively high percentage of their graduate students supported by these means. The life sciences retained a high level of traineeship support, despite massive cutbacks that radically reduced the percentage of graduate students supported by federal fellowships or traineeships in all other science/engineering fields by the 1980s. A large number of students in the social sciences, and especially in psychology, have been funded by federal fellowships or traineeships over the years, but because the social sciences enroll so many students, a relatively low percentage receive funding from these sources. The percentages of students in engineering and the mathematical/computer sciences supported by federal fellowships or traineeships has consistently been among the lowest.

FIGURE 3 Percentage of full-time science/engineering graduate students supported by federal fellowships, traineeships and training grants, by field and by year: 1960-1980.



Analogous data are missing for the 1970s on federal fellowship and traineeship support for full-time science/engineering graduate students. It is, however, possible to infer trends in students' reliance on those mechanisms over that decade by drawing on another data base: the annual Survey of Earned Doctorates.[43] Each year since 1968, the National Research Council (NRC) has collected information on the sources of financial support used by doctorate recipients from U.S. universities. This data base is somewhat problematic for the purposes of detailed analyses of support conditions, since it does not distinguish between major and minor sources of support for each student, nor between research assistantships or loans that were federally funded (or subsidized) as opposed to non-federally sponsored aid. Nonetheless, it is useful for identifying major trends in sources and mechanisms of support used by Ph.D. recipients from U.S institutions over the 1968-1980 period.

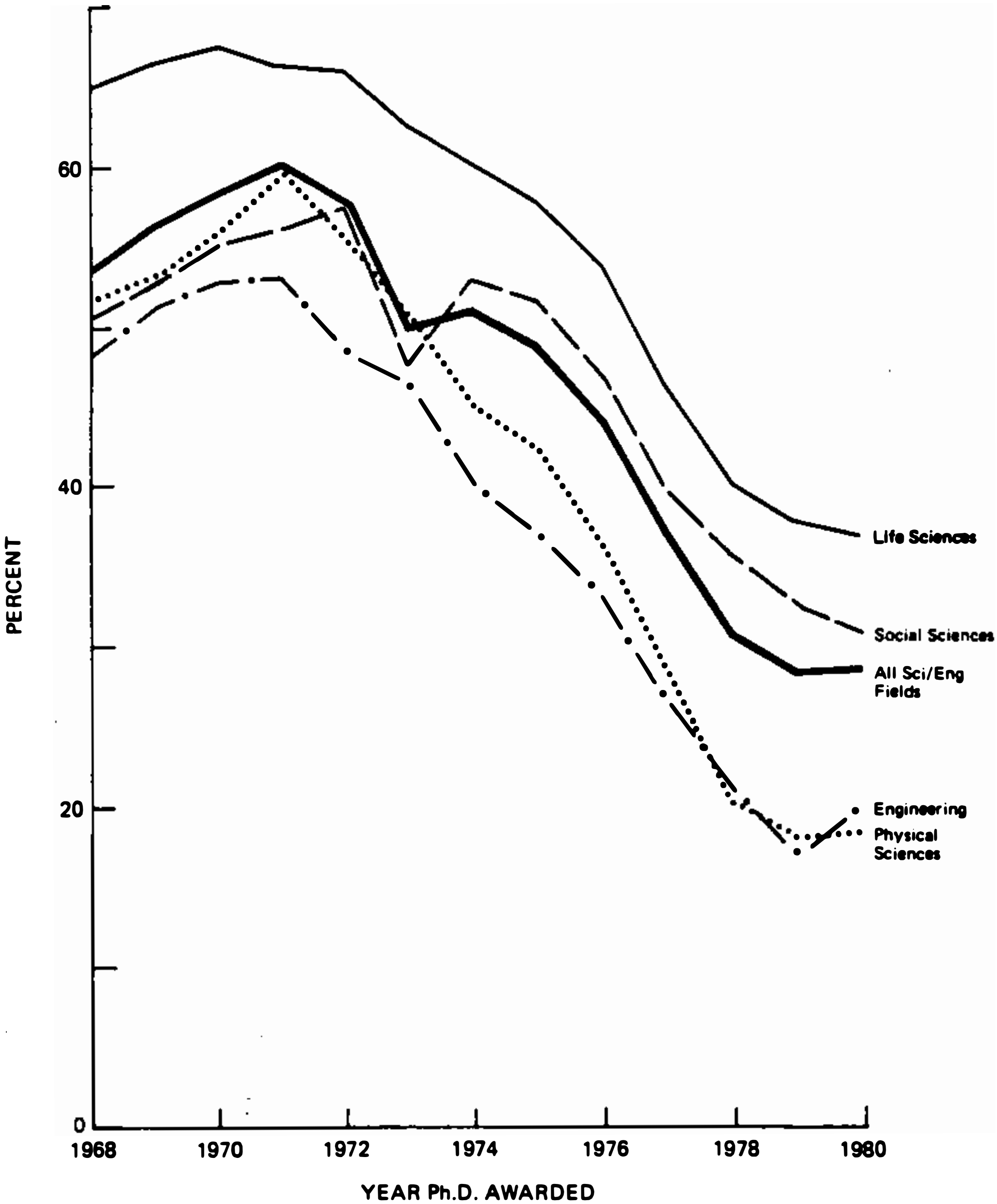
Data from the NRC survey reveal a number of interesting things about how science/engineering doctorate recipients have financed their graduate education in recent years. For example, these data can be used to partially complete the picture of declining fellowship/traineeship support begun in Figure 3. That graph pointed out the peak in the late 1960s for all in the percentage of graduate students in all fields of science and engineering who held a federal fellowship or traineeship. Figure 4, which uses the NRC data, shows the delayed effects of cutbacks in federal support on the percentage of Ph.D. recipients who were supported by either a fellowship or traineeship during their graduate training. (Note that Figure 4 collapses the physical sciences and the mathematical/computer sciences into a single category, while Figure 3, based on the FICE classification scheme, separates them into two fields.)

The curves for each separate field in the two graphs match up well: the peaks and downward trends in the percentage of doctorate recipients funded by a federal fellowship or traineeship (shown in Figure 4) correspond with a time lag of 4-5 years to the peaks and cutbacks in the percentage of all graduate students attending school on a federal fellowship or traineeship. Federal fellowship offerings peaked in 1967-1968 and, on average, students supported by one would have completed their doctorates between 1971-1972.

Figure 4 shows that in all fields, the percentage of students supported by a federal fellowship or traineeship dropped dramatically during the 1970s. The relative position of fields in terms of the strength of fellowship/traineeship support, was maintained over that time. The life sciences always received relatively strong support from these programs, while engineering and the physical sciences received relatively low support from these mechanisms.

By the end of the decade, comparatively few science/engineering Ph.D. recipients had been supported by federal fellowships (18.4 percent of all 1980 science/engineering doctorates). One thing

FIGURE 4 Percentage of doctorate recipients supported by federal fellowships, traineeships or training grants by field and by year, 1968-1980.



these data do show (when combined with the information in Figure 3) is that a high percentage of the science/engineering graduate students who eventually complete their doctorates received funding from federal fellowships or traineeships, when compared to the percentage of all science/engineering students who had federal fellowships or traineeships. (In 1980 the percentage of students enrolled full-time in graduate science/engineering programs who received a federal award was 8.6 percent for fellowships and 7.5 percent for traineeships. For doctorate recipients, it was 28.2 percent for both fellowships and traineeships.) This could mean either that fellowships consistently go the better students or that students who lack such support have a harder time completing their studies and drop out of school before finishing their degrees.

The NRC data also show that research assistantships (federally sponsored and non-federally sponsored combined) provide support for a large number and percentage of science/engineering doctorate recipients. Figure 5 presents data on the extent to which doctorate recipients relied on a research assistantship during school. It is unknown what proportion of these research positions was paid for by federal funds, although it is reasonable to assume that it was a large percentage. From other data, it is known that half of the research assistantships that supported science/engineering graduate students in 1980 were federally sponsored.[44] While the percentage of students thus supported has fluctuated over the past years, it tended to hover around 49 percent (plus or minus 5 percent) of Ph.D. recipients between 1968 and 1980. Compared to other sources of funding, research assistantships have provided a remarkably stable base of support over the same period. Ph.D. students in engineering and the physical sciences have received substantial and growing support from research assistantships. In comparison, students in the social sciences fared poorly on this funding mechanism over the 1968-1980 period. Overall, the trend lines show that students tended to find support on research assistantships when fellowship or traineeship availability declined. Research assistantships thus constitute a major funding source for scientists' and engineers' graduate education. Even though approximately 20 percent of all full-time science/engineering graduate students relied on a research assistantship (federal or non-federal) as a major source of funding in 1980, approximately half of all doctorate recipients in those fields were supported by a research assistantship at some point in their graduate education.[45]

Figure 6 also uses the NRC survey data and charts the number of doctorate recipients in all science/engineering fields by source of support and by the year in which the doctorate was earned. This graph reveals a generally inverse relationship between Ph.D. recipients' reliance on federal fellowships and traineeships, and their dependence on personal finances (loans, earnings and spouse/family contributions) to put themselves through graduate school. The curves for each of these personal-support mechanisms rose slowly during the late 1960s and early 1970s, when graduate students in general still received

FIGURE 5 Percentage of doctorate recipients supported by research assistantships, by field and by year: 1968-1980

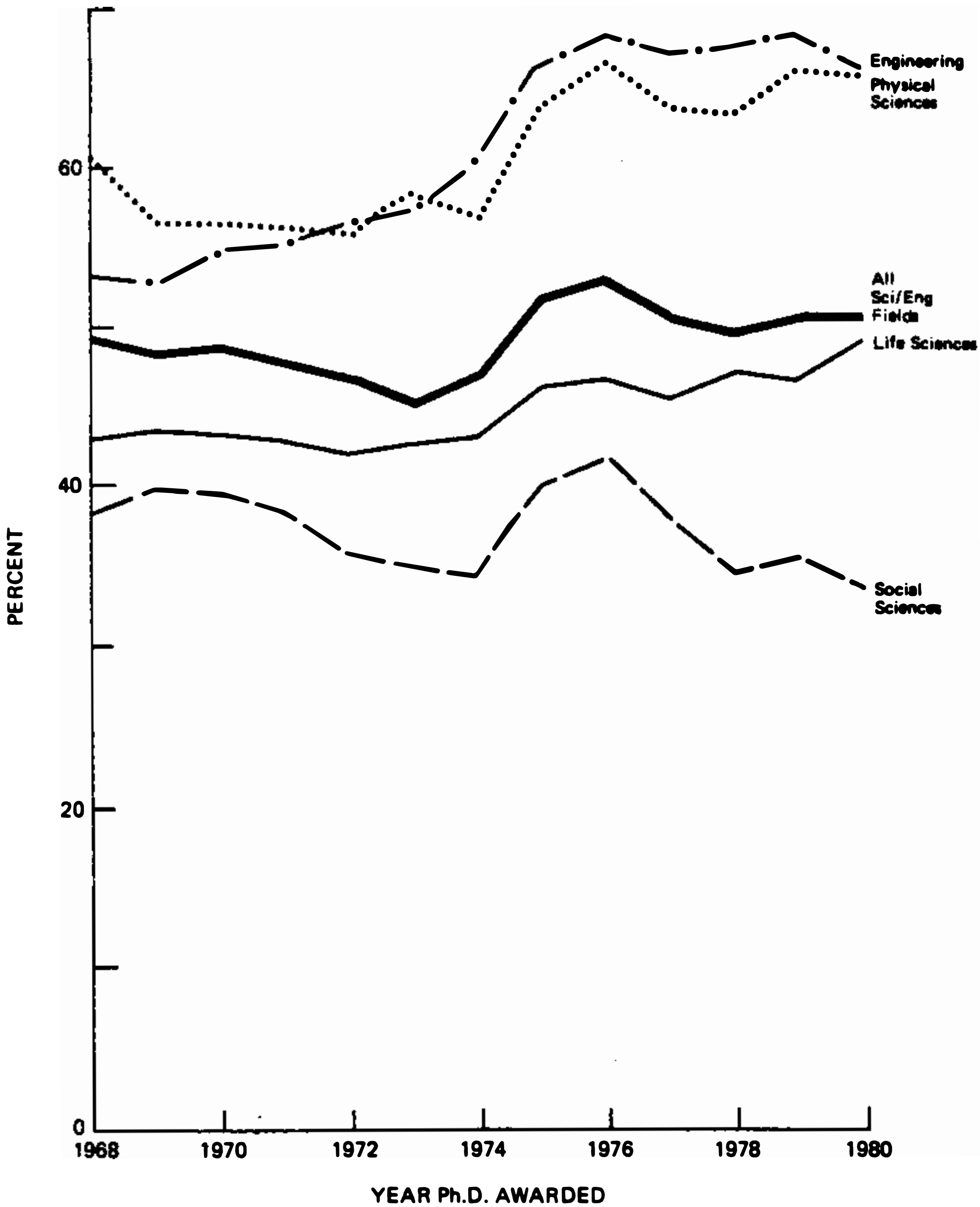
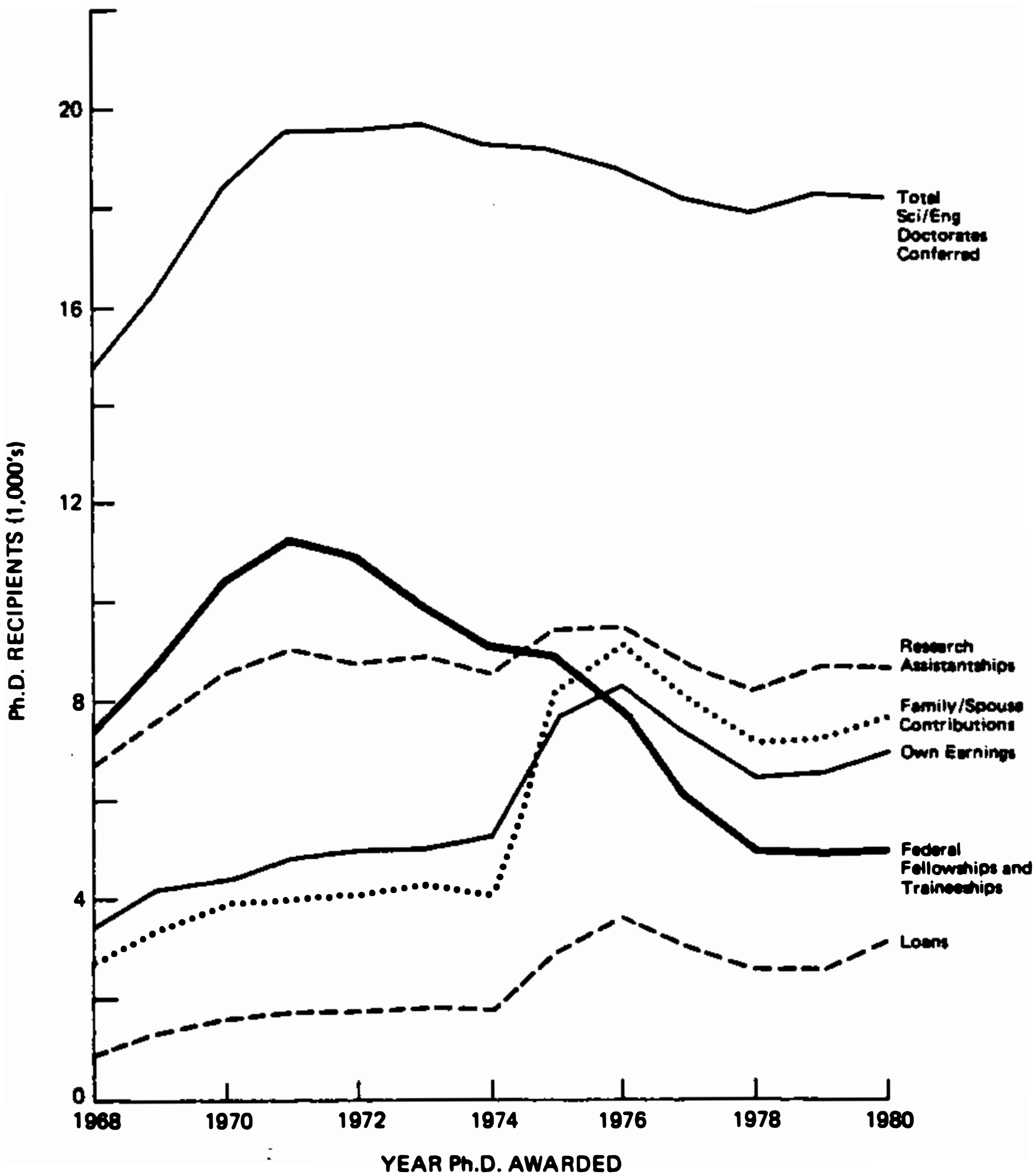


FIGURE 6 Number of science/engineering doctorate recipients by source of support and by year: 1958-1980.



strong federal assistance and other institutional aid in the form of fellowships, traineeships, and teaching assistantships. As these sources of support became more scarce and harder to obtain, and as the number and percentage of students who had to turn to alternative funding sources rose, personal funds became increasingly important as means of support for doctoral students and recipients in the mid-1970s. Over the course of their graduate education (and also even within a single school term), students had to piece together a package of financial support from various sources. A huge peak in the number and percentage of students supported by loans, in-school earnings, or family contributions occurred in 1976; this peak results from a methodological change in the survey that year rather than from a change in students' behavior.46/ It is important, therefore, to use these data to observe general trends only, as in the overall increase in reliance upon personal resources over the 1968-1980 period.

The discussion so far has focused primarily on federal fellowship and traineeship support for science/engineering graduate students. Relatively good disaggregated data on the full array of support mechanisms exists for a subset of this student population: science/engineering graduate students enrolled full-time at doctorate-granting institutions.47/ While this sample is imperfect for analytic purposes (i.e., the fields of science/engineering vary in terms of full-time vs. part-time registration patterns at Ph.D.-vs.-master's-granting institutions), it is still useful for analyzing general patterns of federal support for a large percentage of graduate students in science and engineering. (Eighty-seven percent of all graduate science/engineering students attended Ph.D-granting institutions in 1980, and 69 percent of these students were enrolled full-time.)

Tables 1 and 2 present data for 1974-1980 on the number and percentage of full-time science/engineering graduate students enrolled at Ph.D.-granting institutions by field and by major source of support. The support categories in these tables are: federal sources (e.g., fellowships, traineeships, research assistantships funded by federal grants, GI benefits, other financial aid, but not loans); self (e.g., loans, including federally subsidized loans, earnings, family and spouse contributions); and other sources (e.g., institutional, non-federal government, foreign, and other outside funding). These tables show that in recent years (1974-1980), while the number of students enrolled in each field has increased, the percentage of students funded by federal sources has not. The availability of federal support for science/engineering graduate students has not kept pace with enrollments. Students primarily supported by federal sources increased from 47,989 in 1974 to 52,852 in 1980; as a percent of all students, the federally supported group dropped from 24.6 percent in 1974 to 22.9 percent in 1980.

These decreases in the percentage of students receiving federal support were greater in certain fields than in others. In the social sciences (including psychology), the only field with reductions in the

TABLE 1 Distribution of Full-Time Science/Engineering Graduate Students in Doctorate-Granting Institutions By Field, By Major Source of Support and By Year: 1974-1980

Field	Source of Major Support	1974	1976	1978	1980
All Science/ Engineering Fields	Federal	47,989	48,593	51,273	52,852
	Self	35,867	65,593	66,347	69,932
	Other	91,599	96,896	98,993	107,815
	Total	195,455	214,082	216,613	230,601
Engineering	Federal	10,178	10,565	10,642	11,272
	Self	9,049	10,577	10,768	12,274
	Other	14,408	15,347	16,016	18,905
	Total	33,635	36,489	37,426	42,451
Physical/ Environmental Sciences	Federal	8,728	9,226	10,078	10,964
	Self	3,742	4,154	3,843	3,523
	Other	17,166	17,682	17,393	17,799
	Total	29,636	31,062	31,274	32,286
Mathematical/ Computer Sciences	Federal	1,580	1,425	1,471	1,722
	Self	3,421	3,959	3,472	4,132
	Other	8,738	9,151	8,766	9,425
	Total	13,739	14,505	13,709	15,279
Life Sciences	Federal	16,816	17,770	19,641	20,617
	Self	14,455	18,104	18,334	17,768
	Other	23,769	26,143	27,350	29,316
	Total	55,030	62,017	65,345	67,701
Social Sciences	Federal	10,687	9,607	9,481	8,277
	Self	25,200	31,799	29,910	32,237
	Other	27,528	28,573	29,468	32,370
	Total	63,415	69,979	68,859	72,884

absolute number of students receiving federal support over this period, the number of federally funded students dropped from 11,687 in 1974 to 8,288 in 1980. The percentage of students supported dropped from 16.9 percent in 1974 to 11.3 percent in 1980. Students in the social sciences have apparently had to personally absorb the impact of reductions in federal support, since the percentage of them who supported themselves through graduate school rose dramatically between 1974 and 1980 (from 34.3 percent to 42.1 percent for psychology, and from 42.1 percent to 45.1 percent for other social sciences). The percentage of students who support themselves has always been relatively high for students in the social sciences.

TABLE 2 Percentage Distribution of Full-Time Science/Engineering Graduate Students in Doctorate-Granting Institutions By Field, By Major Source of Support and By Year: 1974-1980

Field	Source of Major Support	1974	1976	1978	1980
All Science/ Engineering Fields	Federal	24.6	22.7	23.7	22.9
	Self	28.6	32.0	30.6	30.3
	Other	46.8	45.3	45.7	47.8
	Total	100.0	100.0	100.0	100.0
Engineering	Federal	30.3	28.9	28.4	26.6
	Self	26.9	29.0	28.8	28.9
	Other	42.8	42.1	42.8	44.5
	Total	100.0	100.0	100.0	100.0
Physical/ Environmental Sciences	Federal	29.5	29.7	32.1	34.0
	Self	12.6	13.4	12.3	10.9
	Other	57.6	56.9	55.6	55.1
	Total	100.0	100.0	100.0	100.0
Mathematical/ Computer Sciences	Federal	11.5	9.8	10.7	11.3
	Self	24.9	27.2	25.3	27.0
	Other	63.6	63.0	64.0	61.7
	Total	100.0	100.0	100.0	100.0
Life Sciences	Federal	30.6	28.6	30.1	30.5
	Self	26.0	29.2	28.1	26.2
	Other	43.2	42.2	41.8	43.3
	Total	100.0	100.0	100.0	100.0
Social Sciences	Federal	16.9	13.7	13.8	11.4
	Self	39.7	45.4	43.4	44.2
	Other	43.4	40.9	42.8	44.4
	Total	100.0	100.0	100.0	100.0

Federal funding has kept pace with enrollments in the mathematical/computer sciences and in the life sciences. This represents a strong federal commitment to the biological and health sciences, in particular: A relatively large percentage of graduate students in these fields receives federal support (in 1980, 30 percent of students in the biological sciences and 36 percent of students in the health sciences Enrollments in these fields are high (in 1980, there were 35,278 students in biological sciences and 22,771 in health sciences). And the average annual growth rate over the 1974-1980 period was also high (for the health sciences, it was 7.1 percent).

Other fields have been relatively well funded by the federal government. A relatively high percentage of students in the physical and environmental sciences (34.0 percent in 1980) receives federal support. A low percentage of students in these fields supports themselves through graduate school (12.6 percent in 1974, and 10.9 percent in 1980).

Figures 7 and 8 present relatively recent (1980) comparative data collected by NSF on sources of support for full-time graduate students in various fields of sciences and engineering at graduate institutions in the United States.[48] These data reinforce the information presented in previous graphs and tables, but they point out interesting differences among fields in the extent to which graduate students currently rely on alternative sources of support and funding mechanisms. Figure 7 displays a series of bar graphs that represent for each funding mechanism (e.g., fellowship, traineeship, research assistantship, and other mechanisms) and for each field the precentage of support provided by each funding source (e.g., federal government, foreign sources, institutional or other U.S.-governmental or foundation sources, self). Figure 8 draws its information from the same data base but presents it differently: Here are a series of matrices, for each field of science/engineering, whose cells represent the percentage of graduate students enrolled in the field that received its major financial support from mechanism of support x (horizontal) and source of support y (vertical).

Together these graphs reveal that in 1980 58.7 percent of full-time science/engineering graduate students were supported by either a fellowship (of which one in four was federal), a traineeship (three out of four were federal), a research assistantship (two out of three were federal), or a teaching assistantship (virtually none of which were federal). Overall, 22 percent of all graduate science/engineering students received federal support (not counting assistance through federally insured student loans, which were not included in the federal category in this data base). One-third of all science/engineering graduate students provided their own support for graduate education in 1980.

The fields of science and engineering varied considerably in the extent to which graduate students received outside support from different sources in 1980. For example, the students in the physical sciences received the highest percentage of federal support: One out of every three graduate students in the physical sciences had a federal research assistantship, fellowship, or traineeship as his/her major means of support. The physical sciences received 14 percent of all federal money used to support graduate students in the sciences and engineering, even though its students made up only 9 percent of all science/engineering enrollments. Students in the physical sciences were well supported by combined outside sources of support: Only 7 percent relied on personal resources--the least of all fields. Most students in the physical sciences (45 percent) were supported by a university-sponsored teaching assistantship. Another 36 percent had a

FIGURE 7 Distribution of support for full-time science/engineering students at all graduate institutions by source and mechanisms of support and by field: 1980.

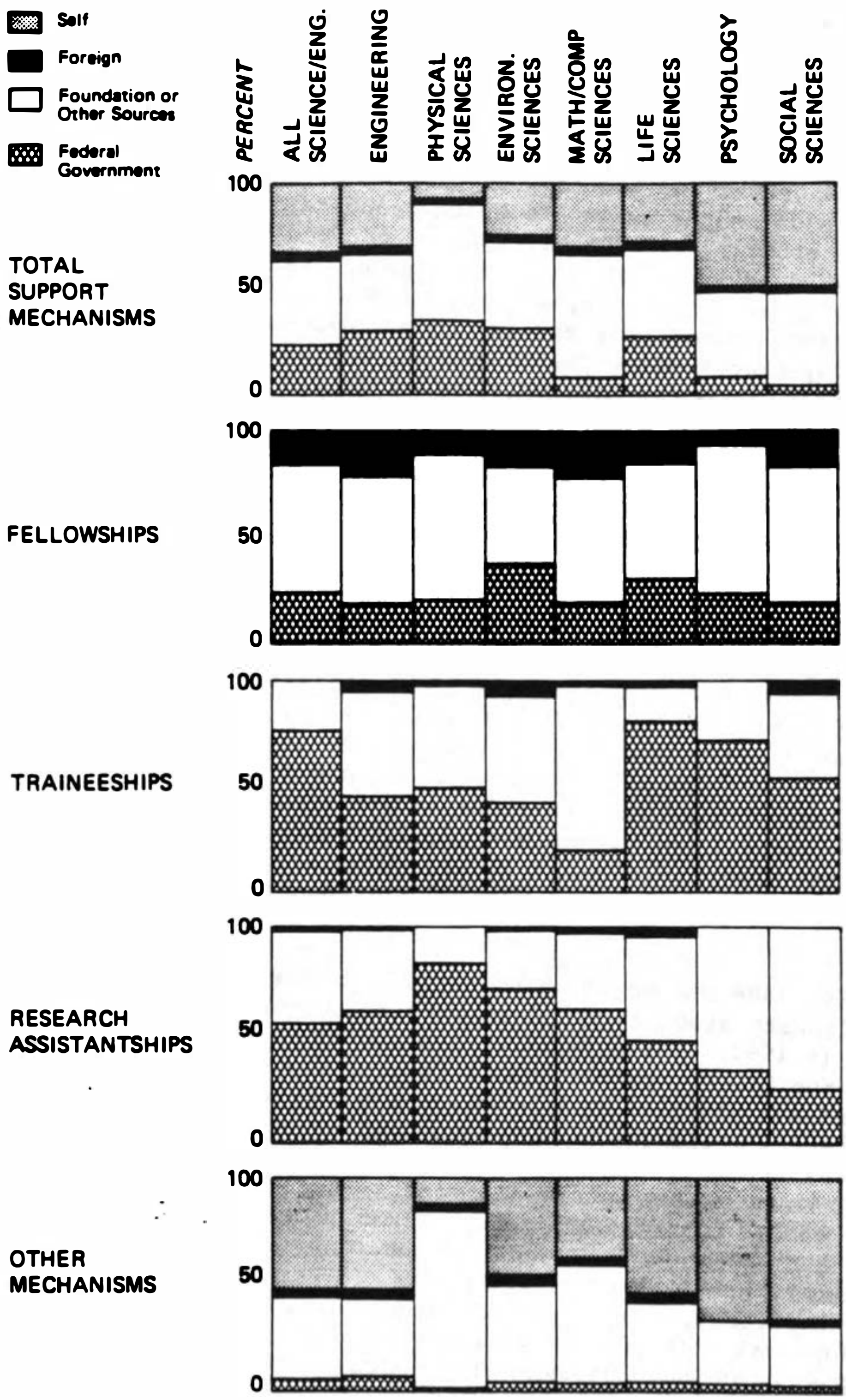


FIGURE 8 Percentage distribution of full-time science/engineering graduate students at all institutions by field, by major source of support and by mechanisms of support: 1980.

All Science/Engineering Fields

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	1.9	–	6.6	8.5
Traineeship	5.8	–	1.8	7.6
Res. Asst.	11.8	–	9.1	20.9
Teach. Asst.	0.3	–	21.4	21.7
Other	2.1	33.1	6.1	41.3
Total	21.9	33.1	45.0	100.0

Math/Computer Sciences

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	1.2	–	5.2	6.4
Traineeship	0.2	–	1.0	1.2
Res. Asst.	6.7	–	4.4	11.1
Teach. Asst.	0.2	–	42.8	43.0
Other	2.8	29.3	6.2	38.3
Total	11.1	29.3	59.6	100.0

Engineering

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	1.5	–	7.2	8.7
Traineeship	1.0	–	1.2	2.2
Res. Asst.	19.7	–	12.7	32.4
Teach. Asst.	0.3	–	16.7	17.0
Other	3.4	29.8	6.5	39.7
Total	25.9	29.8	44.3	100.0

Life Sciences

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	2.2	–	5.2	7.4
Traineeship	14.6	–	2.1	16.7
Res. Asst.	10.6	–	11.4	22.0
Teach. Asst.	0.4	–	17.2	17.6
Other	1.6	28.4	6.3	36.3
Total	29.4	28.4	42.2	100.0

Physical Sciences

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	1.5	–	6.4	7.9
Traineeship	0.9	–	0.9	1.8
Res. Asst.	30.3	–	5.9	36.2
Teach. Asst.	0.3	–	44.4	44.7
Other	0.7	6.7	2.0	9.4
Total	33.7	6.7	59.6	100.0

Psychology

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	1.5	–	4.6	6.1
Traineeship	5.4	–	2.1	7.5
Res. Asst.	3.4	–	6.2	9.6
Teach. Asst.	0.1	–	17.6	17.7
Other	2.1	49.7	7.3	59.1
Total	12.5	49.7	37.8	100.0

Environmental Sciences

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	2.9	–	5.0	7.9
Traineeship	0.8	–	1.1	1.9
Res. Asst.	25.2	–	9.7	34.9
Teach. Asst.	0.3	–	24.5	24.8
Other	2.1	23.9	4.5	30.5
Total	31.3	33.9	44.8	100.0

Social Sciences

Mechanism of Support	Source of Support: Federal	Self	Other	Total
Fellowship	2.3	–	9.8	12.1
Traineeship	2.7	–	2.3	5.0
Res. Asst.	2.7	–	7.2	9.9
Teach. Asst.	0.1	–	16.2	16.3
Other	2.0	47.6	7.1	56.7
Total	9.8	47.6	42.6	100.0

research assistantship (of which four out of five were paid for by federal grants and contracts, representing the highest concentration of federal research support across the different fields); 8 percent were on fellowships (of which one in five was federal); and 2 percent received support from a training grant (one-half of which were federal). Federal support for students in the physical sciences came primarily from the NSF, Department of Energy (DOE), NASA, and NIH.

The environmental sciences were also well funded by the federal government in 1980. Like the physical sciences, this is a small field in terms of the number of students enrolled (4 percent of all science/engineering graduate students), but one which received a larger-than-average share of federal support (i.e., 6 percent of federal funding for science/engineering graduate students went to the environmental sciences). One third of all environmental sciences students received federal support, predominantly from NSF, the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), and DOE. Patterns of support in this field tend to mirror those in the physical sciences: 36 percent of the students worked as research assistants (75 percent of which were federally funded); 25 percent served as teaching assistants; 8 percent were supported on fellowships (a relatively high percentage--40 percent--of which were federal); and 2 percent were supported by training grants. More students in the environmental sciences than students in the physical sciences had to support themselves (24 percent relied on personal resources).

Engineering students were also relatively well funded by outside sources in 1980. Thirty-three percent of all engineering students had research assistantships (of which two out of three were federally funded, predominantly from NSF, DoD, NASA, and the Department of Transportation). Seventeen percent had a teaching assistantship. And 11 percent were on a fellowship or traineeship, of which one-fifth were federal. A higher-than-average number of fellowships in engineering were provided by foreign sources. Engineering students received relatively generous federal funding compared to students in other fields: 26 percent of all engineering graduate students were federally supported. The field received 21 percent of all federal money available to science/engineering graduate students, even though its students constituted only 17 percent of all full-time science/engineering enrollments.

Another field with relatively high federal support is the life sciences. Nearly one-third of all graduate students in the biological, health, and agricultural sciences received federal assistance in the form of a fellowship, a traineeship, or a research assistantship. The largest share (39 percent) of federal money for all science/engineering students went to the life sciences; and even though this field enrolled the highest percentage of science/engineering graduate students (29 percent), its share of students is far lower than its proportion of federal support. Most federal money came through training grants (especially from NIH and other HHS sources): 17 percent of life sciences students had traineeships, 85 percent of which were federal. 22 percent of the students worked as research assistants (of which half were federal); 18 percent were teaching assistants (a relatively low percentage compared to other fields of science and engineering); and 7 percent had fellowships (a third of which were federal). 28 percent of students in the life sciences supported themselves in 1980.

The three remaining fields received relatively small shares of the federal support provided to science/engineering graduate students in 1980. In the mathematical/computer sciences, only 11 percent of the students received federal assistance. This field is, of course, small, comprising only 7 percent of all science/engineering graduate students; however, the field as a whole receives an even smaller share (3 percent) of federal support extended to graduate students. Forty-three percent of students in the math/computer sciences were on teaching assistantships. Few (11 percent) were on research assistantships (of which two-thirds were federal). Another 6 percent were on fellowships (25 percent of which were federal, and another 25 percent were from foreign sources), and 1 percent were on training grants (20 percent of which were federal).

By comparison, however, students of psychology and the social sciences received an even smaller proportion of funding from outside sources: only 42 percent of the students in those combined fields were supported by either a research or teaching assistantship, a fellowship, or a training grant. Only 12 percent of psychology students and 10 percent of other students in the social sciences obtained their major source of funding from the federal government. These are particularly small percentages compared to the natural sciences. But they are also low considering that even though the social sciences enrolled 23 percent of all science/engineering students and psychology enrolled another 11 percent, they received small shares of federal aid for graduate students: 10 percent went to the social sciences, and 6 percent went to psychology. Few students (10 percent in each field) relied on research assistantships, only a third of which were federally supported. Relatively few were teaching assistants: 16 percent for students in the social sciences and 18 percent for psychology students. Compared to other fields, a relatively large percentage of students in the social sciences (12 percent) did receive a fellowship, a third of which were federally funded. And psychology students were relatively well funded by training grants, especially from NIH. However, in both psychology and the other social sciences, nearly half of the students relied on personal resources to fund their graduate studies. These percentages are the highest among the fields of science and engineering.

NUMBER OF INSTITUTIONS OF HIGHER EDUCATION

One element of the changing environment of graduate education in the post-World War II period was the growth in the number of institutions of higher education in the United States.[49] The expansion occurred in part because of the need to provide educational opportunities for the baby-boom generation. But it also came in response to federal programs that offered direct financial aid to students and program development funds to selected institutions of higher education.

Immediately before World War II, the total number of colleges and universities in the United States was 1,700. During each of the two following decades, there was a net gain of 150 institutions, so that by the 1960s approximately 2,000 institutions were enrolling students and awarding degrees. A large number of new colleges and universities opened during the 1960s: Over that decade, there was a net increase of 500 new institutions (despite at least 100 closings of colleges or universities). Expansion continued during the 1970s but at a slower rate. By 1980 there were approximately 3,150 public or private institutions of higher education (including branch campuses). This meant a net increase of approximately 400 institutions, after taking into account 140 closings and several hundred branch additions to existing institutions.

Of the 3,150 institutions operating in 1980, 40 percent offered graduate degrees. Nearly 500 offered master's degrees as the highest degree. Another 650 offered studies beyond the master's degree, but only 450 of these institutions confer doctorate degrees.

In 1980 doctorate-granting institutions enrolled the largest percentage of science/engineering graduate students.[50] They enrolled 333,658 graduate students in 8,527 departments. This represented 87 percent of all science/engineering graduate students enrolled that year. At master's-granting institutions there were 1,403 departments in science or engineering fields. These departments enrolled 49,552 graduate students, of which 37 percent registered on a full-time basis.

Over the 1970s the number of science/engineering departments at master's-granting institutions had remained relatively stable, while the number at doctorate-granting institutions increased gradually, up from approximately 7,500 in 1974.

PRODUCTION OF ADVANCED DEGREES

Among the other trends associated with the changing availability of federal support for graduate education in the sciences and engineering are fluctuations in the production of advanced degrees by U.S. graduate institutions. Between 1960 and 1980, the total number of advanced degrees awarded by U.S. universities rose dramatically, with significant growth occurring in the late 1960s and early 1970s. This growth period corresponds directly to the timing of large infusions of financial assistance to graduate students provided by the federal government through the 1960s.

For Ph.D. degrees, this growth followed on increases in degree awards that had begun after World War II. From 1945 to 1960, the number of doctorates conferred annually increased fourfold, building from a small base of 1,990 doctorate awards in 1945, to 9,132 in 1960. As Figure 8 indicates, the number of annual doctorates awarded tripled again by 1970, when it reached 29,479. The peak in annual Ph.D. awards occurred in 1976, when it hit nearly 33,000. And the number of degrees awarded annually since then has hovered between 31,000-32,000.

Over the 1960-1980 period, the number of science/engineering doctorates conferred each year has also grown, from 6,371 in 1960 to 18,171 in 1980. However, as Figure 9 shows, this curve peaked earlier, in 1972, and its rate of growth is lower than that for doctorates awarded in all fields. Therefore, the percentage of doctorates that have been earned by science and engineering students has declined slowly over the two decades, from about 65 percent in 1960 to approximately 58 percent in 1975.

The drop-offs in doctorate awards have been particularly acute in several fields, especially engineering and the physical and environmental sciences (see Figure 10). These are the same fields which have, on the one hand, depended highly upon federal financial support and, on the other hand, been the focus of cutbacks in federal funding over the past decade. There have also been declines in degree production in the other fields, but none of these fields have experienced the extreme reductions in annual degree awards that have hit engineering and the physical and environmental sciences. Annual doctorate awards in the life sciences began to slow up and drop off in the early 1970s, but have once again begun to increase, perhaps as a result of relatively gentle reductions in federal training-grant support for the health and biological sciences. The mathematical/computer sciences hit a plateau in doctorate production in the early 1970s and, perhaps because they receive a relatively small share of federal assistance, were able to maintain their production levels in spite of cutbacks in federal support. The most curious growth curve is that of the social sciences, which continued to experience increases in the number of doctorates conferred up through 1976--several years beyond the peak in Ph.D. production for other fields. Federal support for students in the social sciences was severely cut back in the 1970s, yet this condition did not have observable impacts on the production of Ph.D.s for many years thereafter. Perhaps one explanation is that students in the social sciences are relatively poorly funded by federal sources anyway, so that degree production was relatively insensitive to reductions in federal support.

When viewed in the context of overall population growth in the United States over the post-World War II period, the absolute declines in the number of science/engineering doctorates awarded in recent years seem larger still. From 1950 to 1980, there were large increases in

FIGURE 9 Number of doctorates awarded by U.S. institutions, by field and by year, 1958-1980.

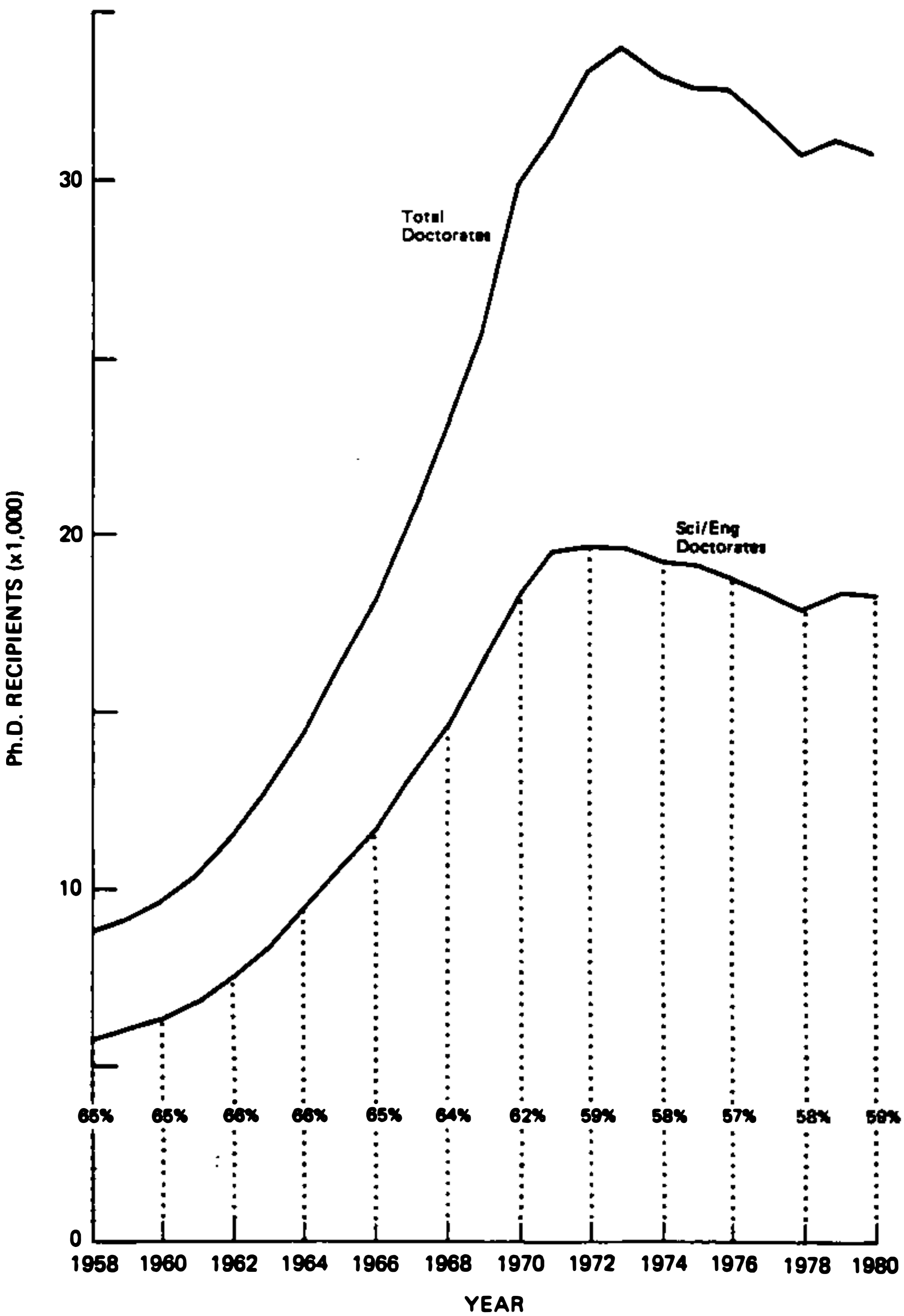
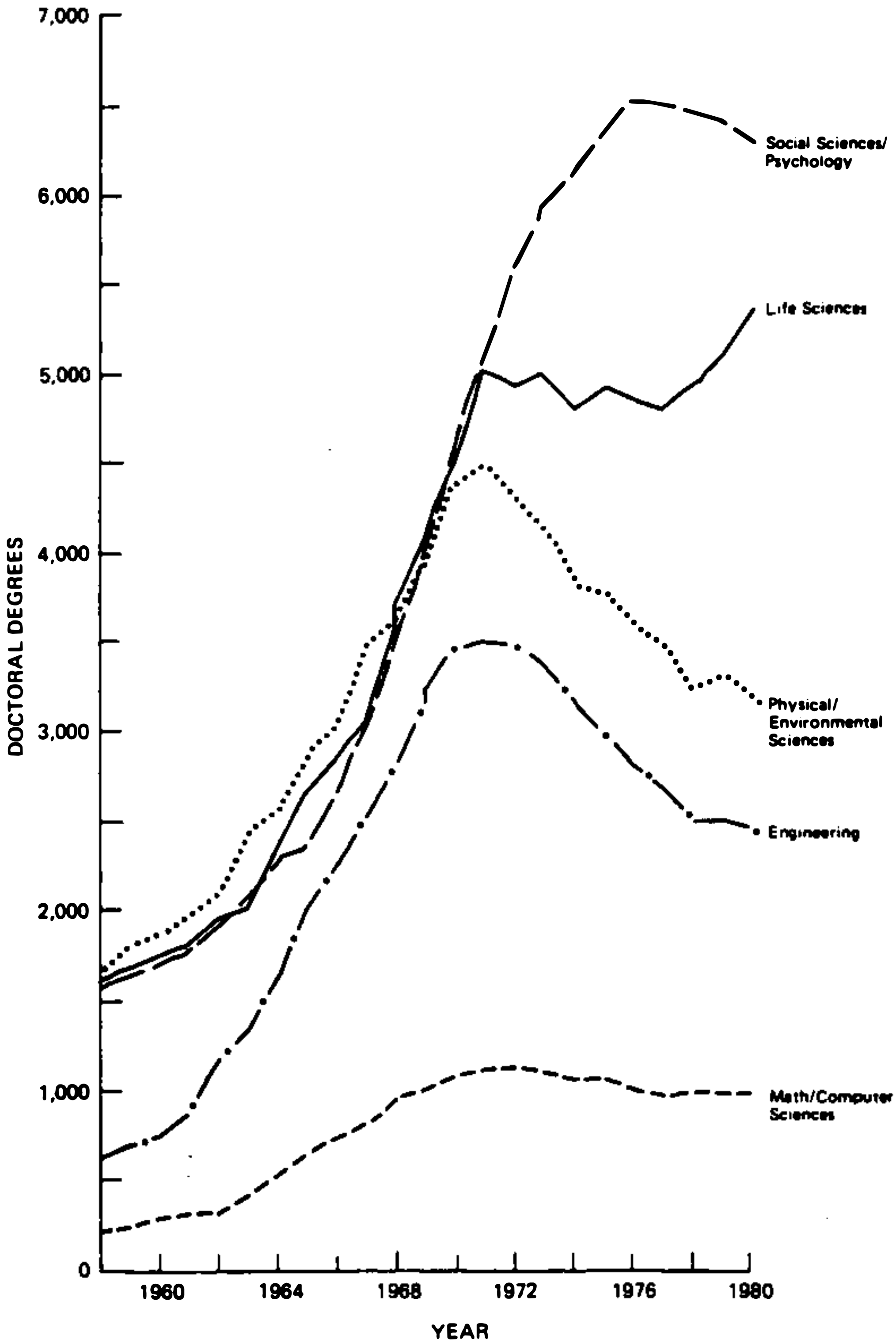


FIGURE 10 Doctorate degrees awarded by U.S. universities, by field and by year: 1958-1980.



the size of the population cohort old enough to complete Ph.D. studies:[51]

	Size of U.S. Population 25 Years Old or Older	Number of Science/ Engineering Doctorates Awarded by U.S. Universities That Year	Science/Engineering Doctorates Per Million Persons (25 Years or Older)
1950	88,918,000	4,200	47.23
1960	100,018,000	6,371	63.70
1970	110,497,000	18,252	165.18
1975	119,702,000	19,048	159.13
1979	128,729,000	18,247	141.75

These statistics show that the rates at which the U.S. population generated doctorate recipients in the sciences and engineering grew dramatically over the 1950s and 1960s, but have been slowly declining since the early 1970s. This is a combined effect of the absolute reductions in the number of doctorates earned by science/engineering students and the large post-War increases in the size of the population cohort old enough to complete advanced degrees.

Another way to view the recent reductions in the rate of production of science/engineering doctorates in the United States is in relation to the number of baccalaureate degrees awarded at U.S. institutions.

From World War II through the early 1970s the number of baccalaureates earned by science and engineering students increased steadily. In 1955, there were 80,990 science/engineering baccalaureates awarded. The peak in the number of degrees conferred occurred in 1974, at 294,000 bachelor's degrees.[52] The rate at which these baccalaureate holders entered graduate school similarly increased through the 1950s and peaked in 1965 at 65 percent. In 1976 it had declined to 44 percent, lower than its rate in the late 1950s.[53]

The rate at which science/engineering baccalaureate recipients completed advanced degrees also varied over the post-war period. The ratio of science/engineering Ph.D. awards to science/engineering bachelor's degree awards (conferred 6 years earlier) increased through the 1950s:[54]

Year of Bachelor's Degrees	Year of Doctorate Degree	Number of Ph.D. degrees per 1000 Bachelor's degrees
1956	1962	8.6
1960	1966	9.6
1964	1970	11.9
1968	1974	9.0
1972	1978	6.4
1974	1980	6.0

Even though the number of bachelor's degrees conferred peaked in 1974 and the level of science/engineering Ph.D's earned peaked in 1973, the ratio of doctorate-to-bachelor's degrees peaked in 1970. This was two years after the introduction of significant reductions in federal fellowship and traineeship support for graduate students. A concurrent phenomenon that perhaps confounded the relationship of Ph.D. production to bachelor's degree production was that the length of time it took to complete a doctorate degree was increasing over this period, as students increasingly had to use in-school earnings and personal resources to finance graduate school.

Another dimension of the recent declines in the number of science/engineering doctorates conferred by U.S. universities is that a decreasing percentage of Ph.D. recipients are U.S. citizens. Just as the baby-boom generation entered the age cohort eligible for graduate work, there have been declines in the availability of federal support for graduate students, lower percentages of U.S. citizens are enrolling in graduate school, fewer are completing their degrees, and foreign citizens are receiving high percentages of the doctorates awarded in all fields of science and engineering. This is especially the case for engineering (where 46 percent of the doctorates went to foreign citizens in 1980), the physical sciences (23 percent of the Ph.D's were earned by non-U.S. citizens), and the mathematical/computer sciences (27 percent of doctorate degrees went to foreign citizens). These are the very fields experiencing the most severe reductions in the number of degrees awarded. This means that drop-offs in the number of American citizens who earned doctorates in engineering, the physical sciences, and the mathematical/computer sciences are even larger than indicated in Figure 10 or the table above.

FOREIGN STUDENTS IN GRADUATE SCIENCE/ENGINEERING PROGRAMS

From 1974-1980 (the time period for which disaggregated data on foreign students are available), the number of non-U.S. citizens enrolled in U.S. graduate science/engineering programs has steadily increased. In 1974 31,687 students (16 percent of all full-time science/engineering graduate students) were non-U.S. citizens. In 1980 one in four graduate science/engineering students was a foreign citizen.

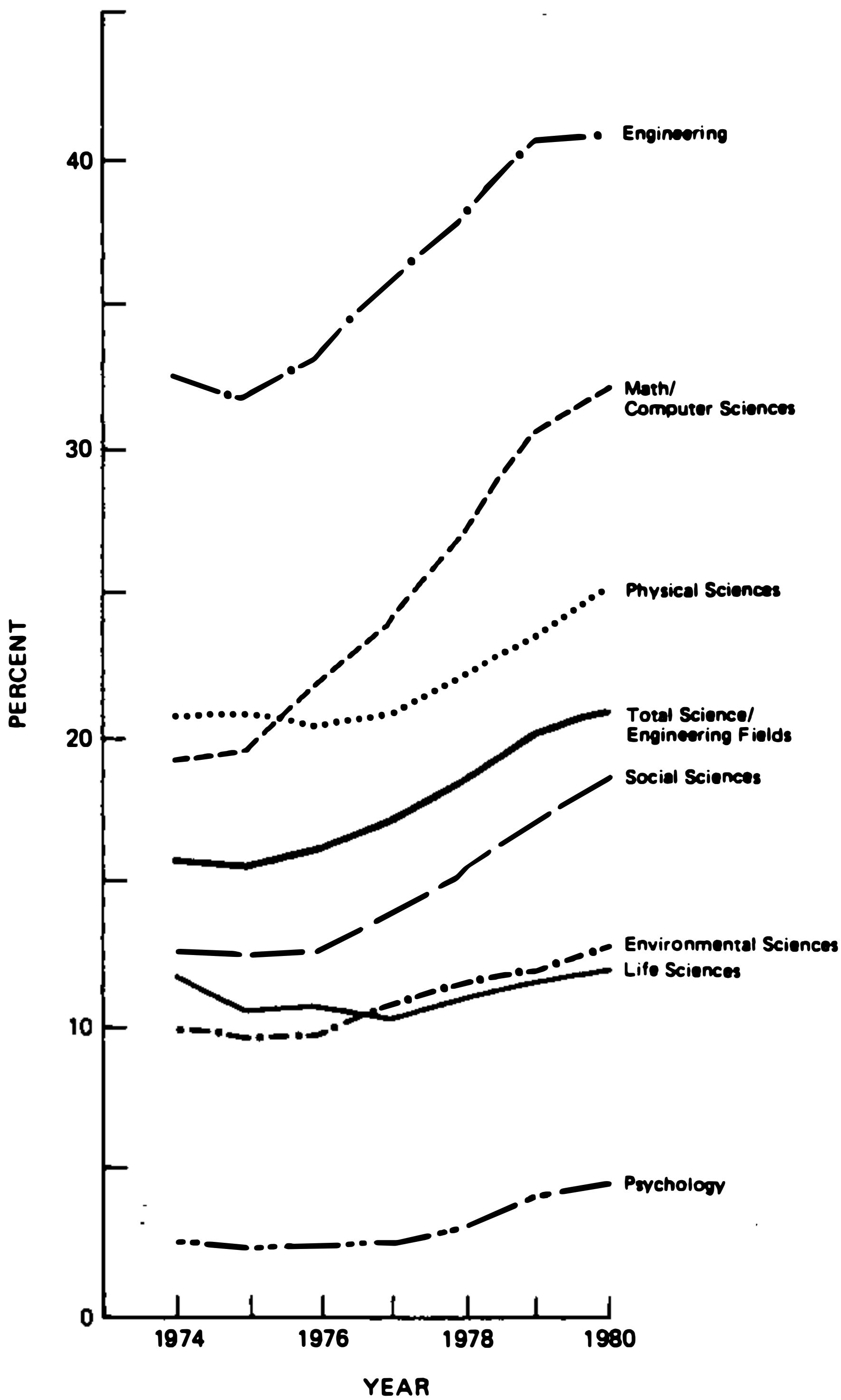
Increased rates of participation of foreign students in U.S. science/engineering graduate programs are another condition associated with decreased availability of federal financial assistance for graduate students. As the cost of graduate education at U.S. universities has risen at the same time that federal sources of funding have contracted, American students have presumably found it increasingly difficult to afford graduate training in the sciences and engineering. Graduate departments have turned to foreign citizens to help fill their programs. Foreign enrollments have increased dramatically in recent years.

Foreign students cluster in different institutions and in different fields than U.S. citizens. Among full-time students enrolled in graduate science/engineering programs in 1980, for example, foreign students tended to concentrate more heavily than U.S. students in engineering, the physical sciences, and the mathematical/computer sciences:55/

	distribution of full-time science/engineering students among fields of science and engineering	
	U.S. citizens	foreign citizens
engineering	13 %	36 %
physical sciences	9	11
environmental sciences	4	3
math/computer sciences	6	10
agricultural sciences	4	4
biological sciences	17	9
health sciences	11	4
psychology	13	2
social sciences	23	20
	100%	100 %

This distribution of foreign students means that while foreign enrollments in all science/engineering fields have risen over the past decade, certain fields have acquired high percentages of non-U.S. citizens in recent years. Figure 11 indicates the percentage of graduate students in each science/engineering field that are non-U.S. citizens for the 1974-1980 period. The two technological fields of engineering and computer sciences have the strongest attraction for foreign students. Engineering enrollments included 41 percent foreign students in 1980 (up from 33 percent in 1974); and in the mathematical/computer sciences, 33 percent of the students were foreigners (up from 19 percent in 1974). The physical and social

FIGURE 11 Foreign citizens as percentage of full-time science/ engineering graduate students enrolled at U.S. doctorate-granting institutions, by field and by year: 1974-1980.



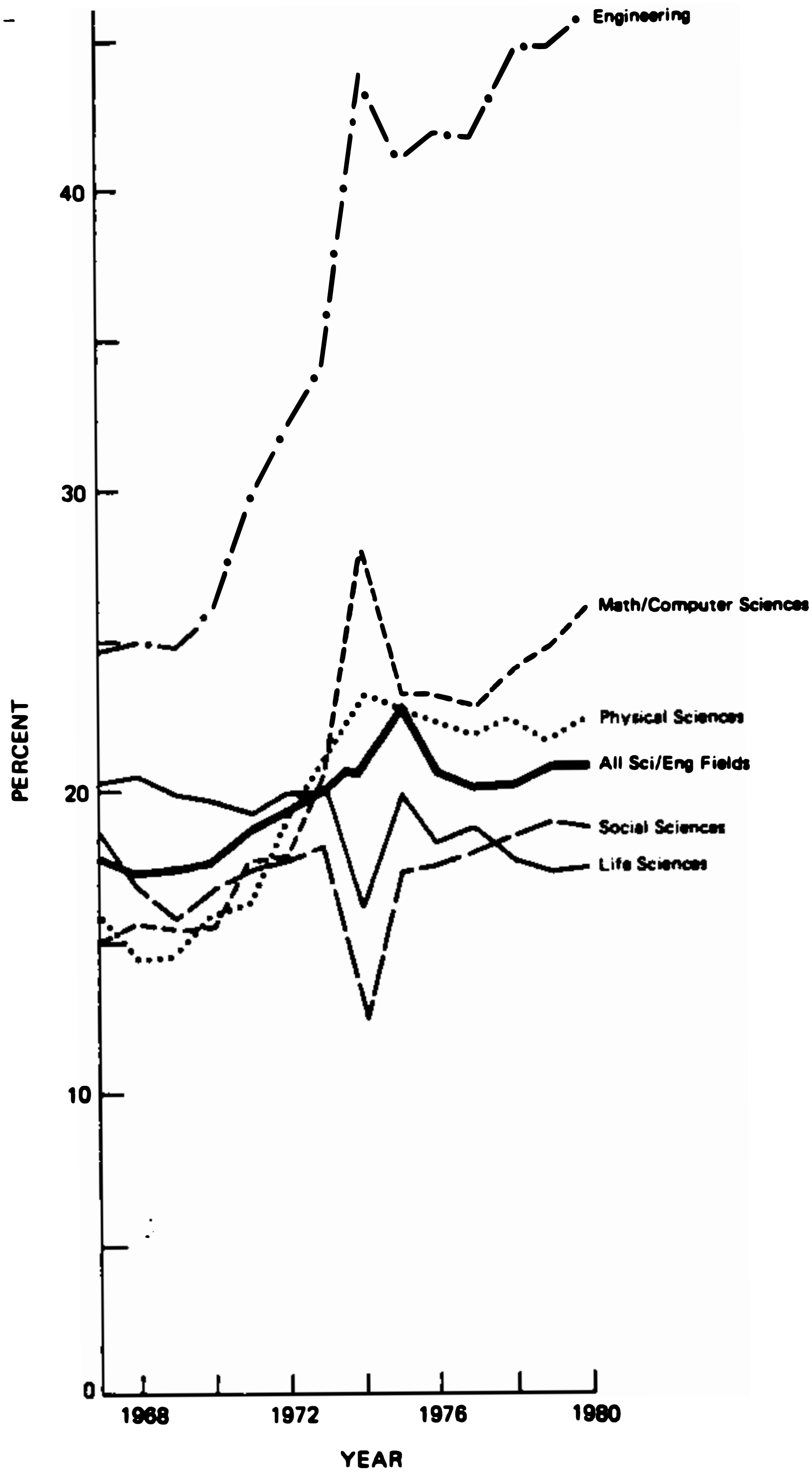
sciences (especially economics) draw the next highest percentages of foreign students.

Among science/engineering doctorate recipients from U.S institutions, the percentage of recipients that are foreign citizens is also high and has been increasing over time. Figure 12 shows that the percentage of science/engineering doctorates earned by non-U.S. citizens increased from approximately 18 percent in 1967 to 21 percent in 1980. The same fields that experienced strong increases in foreign student enrollments also showed strong growth in the percent of doctorates awarded to non-U.S. citizens over the 1967-1980 period. The percentage of engineering doctorates earned by foreign citizens increased from 24 percent in 1967 to 46 percent in 1980. The percentage of physical sciences doctorates awarded to non-U.S. citizens grew from 16 in 1967 to 23 in 1980. And 27 percent of doctorates awarded in mathematical/computer sciences in 1980 went to foreign citizens, up from 16 percent in 1967. The life sciences and psychology showed slight decreases in the percentage of doctorates awarded to foreign citizens.

The overall percentage changes from 1967 to 1980 mask an interesting feature of the data: In 1973, significant changes occurred in nearly all fields in the percentage of doctorates awarded to foreign citizens. Engineering, physical sciences, and mathematical and computer sciences all experienced sharp increases in the percentage of degrees earned by foreigners. Social sciences and life sciences showed sharp declines at that time. Although the cause of these irregularities in the data is unknown, they coincide with the delayed effects of reductions in federal support from graduate science/engineering students that began in 1968. Taking into account an average five-year time frame for completion of a doctorate degree,[56] any sharp decrease in federal support in 1968 that indirectly affected the number of U.S. citizens enrolling in graduate programs (and therefore constituting the classes of students eligible to complete doctoral programs) might show up five to six years later in terms of a lower percentage of Ph.D. recipients awarded to U.S. citizens. In fact, enrollments in most fields did slow up during this period.

The data on sources of financial support for foreign students are poor. But from the limited information available, it is possible to sketch out general relationships between availability of federal funding and support for foreign students. The summary data on doctorate recipients from U.S. universities for 1980,[57] for example, show that among the 4,918 doctorate recipients who were foreign citizens (76 percent of whom were in science/engineering fields), 1,448 received direct federal financial assistance for their graduate studies. This direct aid came in the form of a fellowship or traineeship for 1,343 foreigners and through a federally issued student loan for 105 foreigners. Three percent of the non-U.S. citizens who

FIGURE 12 Foreign citizens as percentage of science/engineering doctorate recipients from U.S. universities, by field and by year: 1967-1980.



received a science/engineering doctorate obtained direct federal assistance as their major source of funding.

It is likely that many more foreign students received federal support indirectly: Foreign students in the sciences and engineering are well funded through research assistantships that are sponsored by U.S. sources, including federal research grants. In engineering 48 percent of foreign Ph.D. recipients in 1980 obtained primary funding for their doctorate studies from a research assistantship. The percentage of these research assistantships that was federally sponsored is unclear, although it is known that for all engineering students on research assistantships in 1980, two-thirds were federally funded. Among foreign citizens who were Ph.D. recipients in the physical sciences and mathematical/computer sciences, 30 percent received major support from a research assistantship. Again, it is known only that 80 percent of all research assistantships in the physical sciences and 67 percent of all research assistantships in the mathematical/computer sciences were federally sponsored in 1980. Additionally, students enrolled in engineering and mathematical/computer sciences receive a relatively high percentage of funding from foreign fellowships (see Figure 7).

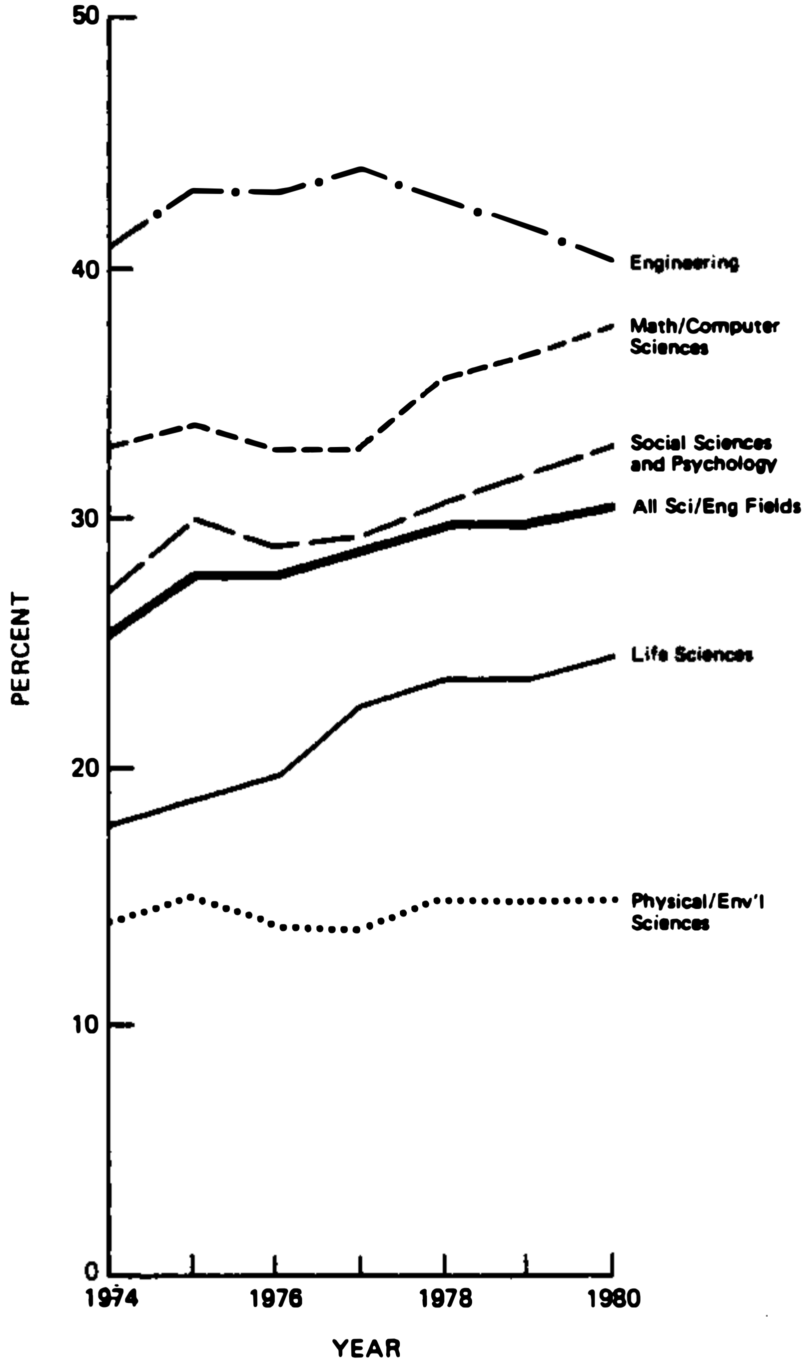
Among all foreign citizens who received their doctorates from U.S. universities in 1980, 2,398 (or 51 percent) took employment outside the United States immediately after completion of their studies. It is unknown what proportion of these students were supported directly or indirectly by federal funding.

PART-TIME GRADUATE ENROLLMENTS IN SCIENCE/ENGINEERING FIELDS

Another phenomenon associated with reductions in outside financial support for science/engineering graduate students in recent years is that increased percentages of students are enrolling part-time in graduate school. For all fields of science and engineering, the percentage of graduate students enrolled part-time at doctorate-granting institutions increased from 26 to 31 percent between 1974 and 1980. (See Figure 13.)

The fields with the lowest percentages of students enrolled full-time in 1980 were engineering (59 percent full-time), mathematical/computer sciences (61 percent), and social sciences (67 percent). Between 1974 and 1980, part-time enrollments decreased in engineering, and increased in the mathematical/computer sciences and the social sciences. Both the social sciences and the mathematical/computer sciences are poorly funded by institutional sources of support such as the federal government. Increasingly, students in the health sciences (among life sciences students) have also been enrolling part-time, in spite of relatively strong institutional support for graduate training.

FIGURE 13 Part-time students as percentage of science/engineering graduate students enrolled at all institutions, by field and by year: 1966-1980.



LENGTH OF GRADUATE EDUCATION IN THE SCIENCES/ENGINEERING

Over the past 25 years, the median length of time it has taken graduate students to complete a Ph.D. has increased for all fields of science and engineering. This trend coincides not only with reduced outside funding for graduate education, but also with students' having to rely increasingly on personal resources to pay for their graduate studies, and with increases in the number of students attending graduate school on a part-time basis.

Figure 14 shows that in 1980, it took the average science/engineering doctorate recipient 1.1 years longer to complete his/her degree than it took the average student in 1958. (Here, length of graduate education is measured in terms of the time between baccalaureate and doctorate degrees, when the student is registered in school.) In 1958, the median time it took to complete a science/engineering doctorate was 5.2 years; in 1980, it was 6.3 years.

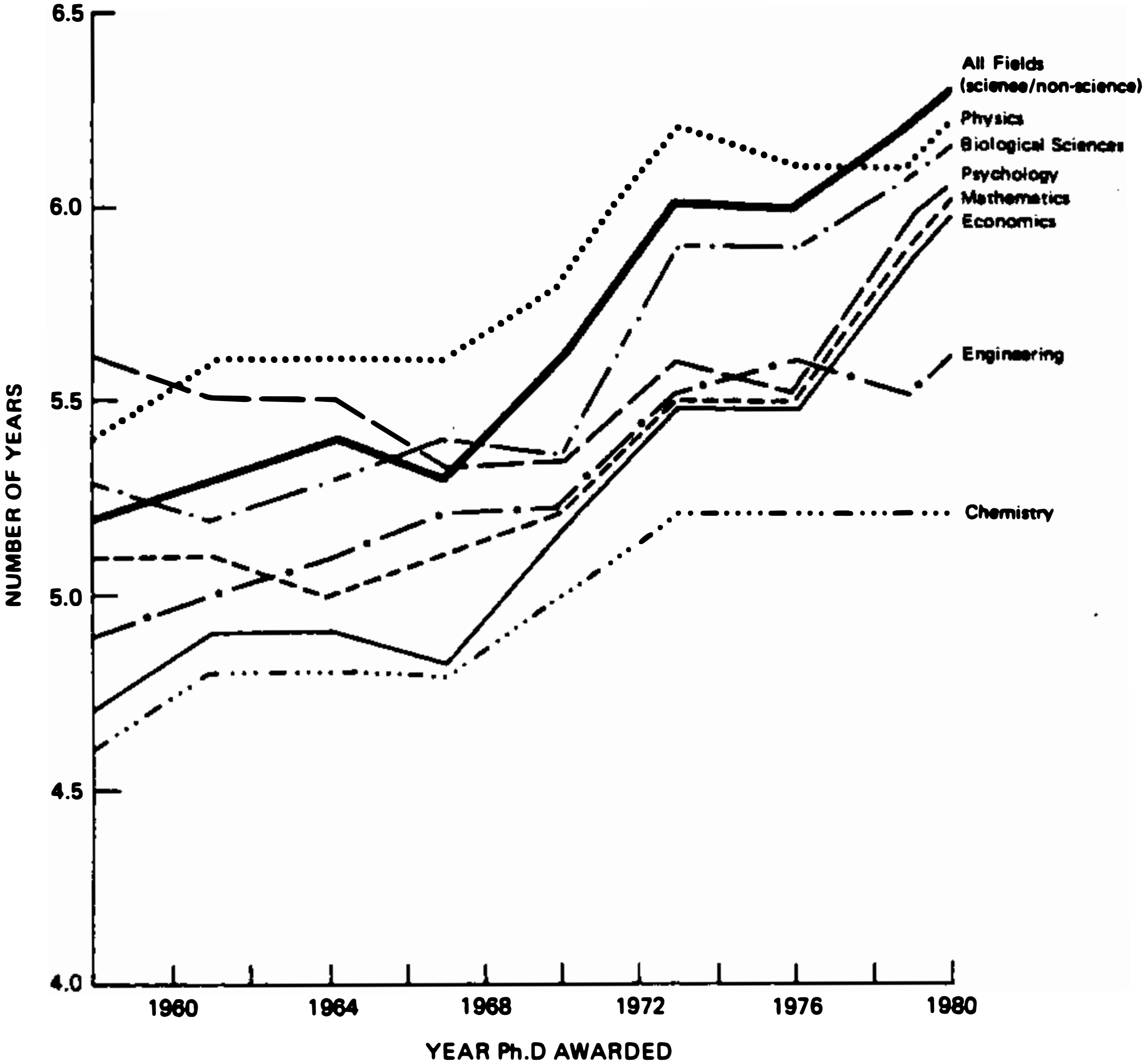
The length of graduate education varies for different science/engineering fields. It has always taken less time to complete a Ph.D. in chemistry than, say, in engineering or physics. However, all fields have shown increases in the length of time to complete the doctorate over the 1958-1980 period. Also, the length of graduate schooling in most fields of science and engineering jumped significantly during the period from 1967 to 1973, a time which coincides with increases in the cost of graduate education as well as cutbacks in outside sources of financial support for graduate students. Starting at this time, increasing numbers of students had to fund their studies through personal earnings, loans or teaching assistantships, none of which contribute directly towards advancing the candidate towards his/her degree.

Also, over the past decade, the median age of doctorate recipients has risen in some fields: Between 1971 and 1980, the median age for doctorate recipients in the social sciences increased from 30.8 to 32.7 years old, for psychology doctorate recipients from 29.3 to 30.6 years old, and for mathematical/computer sciences recipients from 28.9 to 29.4 years old.[58/] These are fields with lowest funding levels provided by outside sources of support. The other fields of science and engineering did not experience significant change in the median age of doctorate recipients.

JOB OUTLOOK FOR SCIENTISTS AND ENGINEERS

Employment prospects for scientists and engineers have been favorable relative to other groups in the United States even though scientists and engineers, like other occupational groups, have felt the effects of changing conditions in the general economy and labor market. In 1979 the unemployment rate for the total U.S. labor force reached 5.8 percent, while it was only 1.6 percent for scientists and 1.4 percent for engineers.[59/] Unemployment among doctoral scientists and engineers was 1.0 percent.

FIGURE 14 Median time registered in graduate school between baccaluareate and doctorate degrees for Ph.D. recipients, by field and by year: 1958-1980.



Among the different fields of science and engineering, physical and environmental scientists had the highest unemployment rates, but even this was only 2.0 percent in 1978. Doctorate scientists in those fields experienced only 1.1 percent unemployment. The tightest labor market existed for engineers and computer scientists: Jobs for doctoral computer scientists reportedly have gone unfilled since 1978 (when the unemployment rate was zero percent), and only 0.3 percent of all computer science workers were unemployed. The unemployment rates for doctoral engineers and for all levels of engineers were 0.6 percent and 1.3 percent respectively in 1978.[60]

The fields also vary with respect to the labor force participation rates of their members and the extent to which these employed workers occupy science/engineering jobs. Computer science professionals and engineers had the highest participation rates in the labor force and in science and engineering jobs. These rates were all above 95 percent in 1979. According to a report issued in 1980 by the NSF and the Department of Education,[61] there are currently shortages of trained computer science professionals and most types of engineers at all degree levels. And, assuming no change in the production rates of new professionals in these fields, the report predicts that current shortages of computer personnel will persist through the 1980s and there will be an inadequate supply of doctoral engineers and computer scientists. At present a relatively low percentage of engineers and computer science personnel hold doctorate degrees (4 percent of engineers and 3 percent of computer personnel held Ph.D.s in 1978).[62]

The labor market for scientists in other fields is looser by comparison, although it is still relatively tight for doctoral scientists, whose labor force participation rate in 1979 was 95 percent. Twenty-five percent of all scientists hold a Ph.D. degree.[63] While nine out of ten doctoral scientists work in science/engineering jobs, a high percentage of professionals in the mathematical, life, and social sciences occupy non-science/engineering jobs (52 percent for mathematicians, 31 percent for life scientists, and 46 percent for social scientists).[64] According to various employment projections reviewed by NSF and the Department of Education in 1980, the current supply of scientists is adequate to meet existing demand, except in computer sciences and in a few subfields of physical and biological sciences.[65] By 1990, the aggregate number of science graduates at all degree levels is expected to exceed the number able to find jobs in the field in which they were trained.

In terms of their work activities, 41 percent of all scientists and engineers are involved in R&D: 5 percent in basic research, 6 percent in applied research, 19 percent in development, and another 11 percent in managing R&D. Another 10 percent report teaching as their primary activity.[66] Two-thirds of all scientists and engineers are employed in business or industry. Of these, 44 percent work in R&D, either as researchers, engineers, or managers. The table below shows the detailed distribution of engineers and scientists by sector of employment and by primary work activity in 1978:[67]

Percent of:	Primary Work Activity R&D	Managing R&D	Other Management	Teaching	Other
Scientists					
Business/ Industry	15.0	6.4	3.7	0.5	22.8
Educational Institution	7.8	1.6	0.7	19.3	2.0
Federal Government	2.6	1.3	2.1	0.1	2.9
Other	3.1	1.8	1.3	0.1	5.0

Percent of:	Primary Work Activity R&D	Managing R&D	Other Management	Teaching	Other
Engineers					
Business/ Industry	26.4	7.9	14.1	--	30.8
Educational Institution	0.6	0.4	0.4	1.8	0.7
Federal Government	1.9	1.2	1.7	--	2.1
Other	2.5	0.8	2.9	--	3.6

Four out of five engineers worked for business or industry. One out of three engineers was engaged in conducting or managing R&D in that sector. Only 4 percent of all engineers worked for institutions of higher education. Among doctoral engineers, 52 percent reported teaching as their primary activity in 1979. Another 32 percent were involved in R&D as researchers or managers.68/

Scientists tend to concentrate less heavily in business or industry, although 18 percent worked in that sector in 1978. One out of every five scientists is engaged in conducting or managing R&D in business or industry. Another 30 percent work in institutions of higher education: Two-thirds of these cited teaching as their primary activity, and nearly all of the rest were engaged in R&D there. Among all scientists, 40 percent are engaged in R&D activities in one sector or another. Physical and environmental scientists are disproportionately involved in R&D. Sixty-one percent of these scientists work directly in R&D (16 percent in basic research, 19 percent in applied research, and 13 percent in development). Additionally, 17 percent of all life scientists and 10 percent of social scientists work in basic research. Another 10 percent and 8 percent in those respective fields are involved in applied research.69/

Among doctoral scientists, 52 percent taught students as their primary activity in 1979. Another 31 percent were engaged in R&D. These percentages varied by field: Ph.D. scientists in the physical and environmental sciences had employment patterns roughly parallel to all doctoral scientists. Computer science doctorates are concentrated in teaching activities. Half of all employed life sciences doctorates worked in R&D, and only a third were in teaching. Nearly two-thirds of Ph.D.s in the social sciences were teachers, while only 15 percent worked as researchers or R&D managers.

Overall, employed doctoral scientists concentrate in educational institutions, although the proportion employed there has been declining in recent years. In 1953 the proportion was 59 percent, and it declined to 55 percent by 1979.70/ Over the same time, business and industry increased their share of Ph.D. scientists from 24 percent to 26 percent.

In 1979 educational institutions employed a total of 274,650 full-time-equivalent scientists and engineers, of which 54,300 (20 percent) were engaged in R&D as their principal activity. Among doctoral scientists and engineers employed at universities and colleges in 1979, 26 percent conducted R&D (18 percent in basic research, 7 percent in applied research, and 1 percent in development). Another 6 percent worked as managers of R&D.71/ Fifty-five percent of doctoral scientists and engineers at educational institutions were primarily engaged in teaching.

From 1973 to 1979 the percentage of doctoral scientists and engineers under 35 years of age and working at educational institutions declined by 30 percent, from 27 percent in 1973 to 19 percent in 1979. Reductions were especially pronounced in the mathematical, physical, and computer sciences.72/ Over the same period, the number of science/engineering Ph.D.s holding postdoctoral appointments doubled, from 5,700 to 10,200. Of these postdoctorates, 82 percent were at educational institutions.

The NSF/Department of Education report on Science and Engineering Education for the 1980s and Beyond predicts that over the next decade new doctorate recipients in fields of science will continue to experience difficulty in obtaining tenure-tract or other permanent positions at educational institutions.73/ In the fields of engineering and computer sciences, however, colleges and universities will have trouble acquiring and retaining high quality teaching faculty, due to rapidly increasing enrollments, decreasing Ph.D. outputs (especially among U.S. citizens), and a widening gap between academic and non-academic salaries.

SUMMARY

Since World War II, federal policy towards graduate education in the sciences and engineering has emerged as the result of a series of disjointed, remedial programs aimed at solving perceived problems, such as shortages of adequately trained personnel in specific fields, or lack of educational opportunity for economically disadvantaged students. This "national needs," mission-oriented approach has been accompanied by sudden shifts in program priorities and levels of support, as problems were solved or at least perceived to be less important over time. No conscious, cross-agency plan has guided federal policy towards graduate education, although a pattern of reactive, manpower development policy has emerged from the series of programs implemented by federal agencies.

Over the past three decades the size of the student population in science and engineering graduate programs in the United States has risen significantly. Most of the growth occurred during the 1950s and 1960s. Overall, science/engineering enrollments continued to rise through the 1970s, although at a much slower rate. Most fields have maintained fairly constant enrollments over the last decade; only enrollments in the social sciences, engineering, and the health sciences are continuing to increase.

Recent data on changes in the size of graduate enrollments in the sciences and engineering mask a number of important conditions that have developed over the past decades. These conditions include:

1. The ratio of full-time graduate enrollments in science/engineering programs to size of the population over 20 years of age has nearly stabilized over the 1970s. The ratio was approximately 16.5 graduate students per 10,000 population during most of that decade. Both enrollments and population are increasing, at roughly similar, slow rates of growth.

2. The total number of science/engineering Ph.D.s conferred annually by U.S. institutions has declined since its peak of 19,555 in 1972-1973. It was 18,170 in 1980.

3. The ratio of science/engineering Ph.D. awards to size of the population 24 years old and over has declined since 1970. In 1970, the rate was 165.2 doctorates awarded per million population older than 24 years. It went down to 141.7 in 1979.

4. Ph.D.-degree production is still rising in certain fields: The number of doctorates awarded in the health and biological sciences is still increasing. Ph.D. awards in the social sciences and mathematical/computer sciences have declined slightly over the past decade. The most significant declines have been in the physical sciences (from a peak of 3,944 in 1971 to 2,523 in 1980) and engineering (from a peak of 3,495 in 1971 to 2,499 in 1980).

5. The proportion of all doctorates awarded to scientists and engineers has dropped slightly over the past 20 years, from 65 percent in 1960 to 59 percent in 1980.

6. The number and percentage of science/engineering doctorates awarded to U.S. citizens declined in the 1970s, especially in engineering, the physical sciences, and the mathematical/computer sciences. In 1980, foreign citizens earned 46 percent, 23 percent, and 27 percent of the doctorates in those respective fields.

7. Enrollments of foreign students in science/engineering graduate programs also increased over the past decade. Non-U.S. citizens have been especially attracted to the high-technology fields of engineering, computer sciences, and the physical sciences.

8. Graduate school entry rates for holders of science/engineering bachelor's degrees have declined since 1965, when it was 65 percent. It is currently lower than 44 percent.

9. In the past 10 years, the number of science/engineering Ph.D. degrees produced per 1,000 bachelor's degrees has dropped. In 1970 it peaked at 11.9, and was 6.0 in 1980.

10. The average length of time it has taken students to complete their doctorate degrees has increased by 1.1 years over the past two decades. On average, it took 5.2 years in 1958, 5.6 years in 1970, and 6.3 years in 1980.

11. Increasing numbers and percentages of science/engineering graduate students are having to work during school or use personal funding sources (e.g., loans, family or spousal contributions) to pay for school.

12. Over the past decade increasing percentages of science/engineering students have been enrolling in graduate school on a part-time basis.

13. Employment prospects for scientists and engineers are still good relative to the rest of the labor force. Unemployment is relatively low (apprximately 1.5 percent in 1979). In fact,

there is a shortage of engineers and computer scientists, both in business/industry and in educational institutions. There are poor job prospects for most other doctoral scientists at educational institutions.

It is unknown which, if any, of these conditions are directly caused by reductions in the availability of outside sources of support for graduate education. However, the data show historical associations between those trends and declines in federal fellowship/traineeship support. The data also suggest that students in some fields are more sensitive than others to changes in different federal funding mechanisms: the life sciences rely especially on federal fellowships and traineeships; the physical/environmental sciences depend upon federal research assistantships; and the social sciences rely on loans and fellowships.

NOTES

1. This enrollment figure is for full-time and part-time graduate students. The categories of science and engineering used in this report are the ones adopted by the National Science Foundation (NSF) in its 1980 survey of graduate education. The five general fields are: (1) Engineering; (2) Mathematical/Computer Sciences (i.e., mathematics, statistics, computer sciences); (3) Physical Sciences (i.e., physics, chemistry, environmental studies); (4) Life Sciences (i.e., agricultural sciences, biological sciences, health sciences); and (5) Social Sciences (i.e., psychology, social sciences). NSF, Academic Science: Graduate Enrollments and Support--Fall 1980 (Washington, D.C.: NSF, 1980), p. 164.

2. NSF, Science and Engineering Personnel: A National Overview (Washington, D.C.: Government Printing Office, 1980), Table B-30, p. 44.

3. This includes working and non-working individuals with a bachelor's, master's or doctorate degree in a field of science or engineering. NSF, Science and Engineering Personnel, Table B-39, p. 48.

4. National Science Board (NSB), Science Indicators 1980 (Washington, D.C.: Government Printing Office, 1981), Table 5-14, p. 310.

5. The U.S.S.R had between 1,412,000 and 1,254,000 R&D scientists and engineers in 1980. The countries with the next largest communities of scientists and engineers were Japan (with 273,100 in 1977) and West Germany (with 111,000 in 1976). These international comparisons of R&D scientists and engineers are in terms of full-time-equivalent work in R&D. NSB, Science Indicators, Table 1-1, p. 208.

6. The standard measure used to compare countries here is the number of FTE scientists and engineers engaged in R&D per 10,000 labor force population. The data for the four countries with the highest ratios show that the U.S. has been losing its relative advantage in recent years.

	1965	1970	1975	1978
U.S.S.R.				
(low-high options)	44.8-48.2	58.4-48.2	78.2-87.5	82.9-93.3
U.S.A.	64.1	63.6	56.4	58.3
Japan	24.6	33.4	47.9	49.4
West German	22.7	30.9	41.0	NA

From: NSB, Science Indicators, Table 1-1, p. 208.

7. NSF, Science and Engineering Personnel, Table B-30, p. 44; and National Research Council (NRC), Summary Report--Doctorate Recipients from U.S. Universities (Washington, D.C.: National Academy Press, for each year from 1967 to 1981).

8. Federal Interagency Committee on Education (FICE), "Federal Policy and Graduate Education" (Washington, D.C.: FICE, 1975); and National Board on Graduate Education (NBGE), Graduate Education: Purposes, Problems, and Potential (Washington, D.C.: NBGE, 1972). See also: U.S. Bureau of the Census, Statistical Abstract of the U.S.: 1980 (Washington, D.C.: Government Printing Office, 1980) Table 238, p. 149.

9. D. Allan Bromley, "The Other Frontiers of Science," Science 215: 4536 (February 26, 1982), p. 1039.

10. NSF and the Department of Education, Science and Engineering Education for the 1980s and Beyond (Washington, D.C.: Government Printing Office, 1980), p. 21.

11. The Sloan Commission, A Program for Renewed Partnership: The Report of the Sloan Commission on Government and Higher Education (Cambridge, Mass.: Ballinger Publishing Co., 1980), Appendix 2: Table 4, p. 281.

12. The Sloan Commission, A Program for Renewed Partnership, Appendix 2, Table 6, p. 284:

TABLE 6 Federal Research and Development Obligations To Colleges and Universities, By Agency (In Millions of Dollars)

Fiscal Year	DOD	AEC/DOE	DHEW	USDA	NSF	NASA	Other
1955	67	15	27	20	7	--	4
1956	83	18	31	25	11	--	4
1957	83	20	64	30	18	--	4
1958	118	30	79	31	21	--	3
1959	127	29	110	32	43	10	5
1960	155	34	158	32	56	10	4
1961	158	43	221	33	64	18	3
1962	259	46	310	39	86	53	9
1963	211	58	350	41	108	78	9
1964	310	60	419	49	120	89	14
1965	292	74	474	58	134	124	32
1966	292	82	538	62	180	117	56
1967	280	90	628	64	209	124	68
1968	244	93	671	61	221	131	69
1969	279	103	667	64	192	122	69
1970	266	101	615	67	201	127	69
1971	249	96	696	75	217	129	91
1972	244	87	879	89	335	112	107
1973	233	85	904	94	349	103	104
1974	184	94	1,129	97	376	92	109
1975	191	119	1,192	111	397	100	116
1976	212	138	1,281	124	429	107	117
1977	267	187	1,436	142	477	114	150
1978*	439	222	1,701	176	552	128	189
1979*	473	249	1,807	196	706	128	205

*Estimated

13. NSF, National Patterns of Science and Technology Resources--1980 (Washington, D.C.: Government Printing Office, 1980), Table 1.

14. NSB, Science Indicators, Figure 2-2.

15. NSF, National Patterns of Science and Technology Resources, Table 1, 5.

16. NSF, Academic Science--R&D Funds Fiscal Year 1980 (Washington, D.C.: Government Printing Office, 1981), Table B-1.

17. NSF, Academic Science--R&D Funds Fiscal Year 1980, Table B-1.

18. NSF, Science and Engineering Education for the 1980s and Beyond, p. 21.

19. Advisory Commission on Intergovernmental Relations, The Federal Role in the Federal System: The Dynamics of Growth--The Evolution of a Problematic Partnership: The Feds and Higher Education (Washington, D.C.: ACIR, 1981), p. 17.

20. NSF, Science and Engineering Education for the 1980s and Beyond, p. 22.

21. Bromley, "The Other Frontiers of Science," p. 1039; and NSF, Science and Engineering Education for the 1980s and Beyond, p. 22.

22. Federal Interagency Committee on Education, Report on Federal Predoctoral Student Support (Washington, D.C.: FICE, Part 1-1970, Part 2-1971).

23. Robert Rosenzweig, "Advanced Graduate Training." (Unpublished paper distributed by the Committee on Graduate Education of the Association of American Universities, Washington, D.C., 1982). Also: NSF, Science and Engineering Education in the 1980s and Beyond; and FICE, "Federal Policy and Graduate Education."

24. National Commission on Research (NCR), Funding Mechanisms: Balancing Objectives and Resources in University Research (Washington, D.C.: NCR, 1980), p. 13.

25. Rosenzweig, "Advanced Graduate Training."

26. Sloan Commission, A Program of Renewed Partnership; and Rosenzweig, "Advanced Graduate Training."

27. National Board of Graduate Education (NBGE), Federal Policy Alternatives Toward Graduate Education (Washington, D.C.: NBGE, 1974), Tables A.7-A.10, pp. 117-119.

28. NCR, Funding Mechanisms: Balancing Objectives and Resources in University Research, p. 13; and FICE, "Federal Policy and Graduate Education."

29. See FICE, "Federal Policy and Graduate Education;" and NBGE, Federal Policy Alternatives Towards Graduate Education.

30. National Center for Education Statistics (NCES), Students Enrolled for Advanced Degrees, Fall 1976 (Washington, D.C.: Government Printing Office, 1979, and for each enrollment year 1966-1975), Table 3; and National Science Foundation (NSF), Academic Science: Graduate Enrollment and Support--Fall 1980, Tables B-3, C-5.

31. The Sloan Commission, A Program for Renewed Partnership: The Report of the Sloan Commission on Government and Higher Education Table 1-appendix, p. 277. Also, NSB, Science Indicators, pp. 50-56.

32. Sloan Commission, A Program for Renewed Partnership, Table 6, p. 284.

33. NSF, Science and Engineering Personnel, Table B-32.

34. NRC, Summary Reports 1980--Doctorate Recipients from U.S. Universities, Table 2.

35. NSF, Academic Science: Graduate Enrollment and Support, Tables C-1, C-32.

36. NRC, Summary Reports--Doctorate Recipients from U.S. Universities (for each year, 1968-1980), Tables 3, 5.

37. NRC, Summary Reports--Doctorate Recipients from U.S. Universities (for each year 1968-1980), Tables 1-2.

38. NSF, Academic Science: Graduate Enrollment and Support, Tables C-1, C-7, C-12 through C-16, IV-A-1 through IV-A-10.

39. NSF, Academic Science: Graduate Enrollment and Support, Table 1.

40. U.S. Bureau of the Census, Statistical Abstract of the U.S.: 1980, Table 34, p. 30.

41. NBGE, Federal Policy Alternatives Toward Graduate Education, pp. 116-118; and FICE, "Federal Policy and Graduate Education."

42. FICE, Report on Predoctoral Student Support.

43. NRC, Summary Report 1980--Doctorate Recipients from U.S. Universities.

44. NSF, Academic Science: Graduate Enrollment and Support, Table IV-A-1.

45. NSF, Academic Science: Graduate Enrollments and Support, Table IV-A-1; and NRC, Summary Report--Doctorate Recipients (for each year 1968-1980), Table 3.

46. This change is described in NRC's Summary Report 1977--Doctorate Recipients from U.S. Universities, p. 13: "In previous years, the questionnaire was worded, 'Please check each source of support from which you received some support during graduate studies. Check as many sources as apply.' In

1977, the questionnaire was modified to request indication of primary and secondary sources of support in addition to all other sources. It appears that many respondents who used the new form provided information only on primary and secondary sources of support so that almost every percentage in Table 3 is lower for 1977 than for 1976....The table still provides useful information. There is no reason to question the relative position of well-spaced numbers, e.g., the field with the largest number of Ph.D.s with support from NSF fellowships was the physical sciences."

47. NSF, Academic Science: Graduate Enrollment and Support, Tables C-1, C-7, C-12 through C-16.

48. NSF, Academic Science: Graduate Enrollment and Support, Tables IV-A-1 through IV-A-10.

49. Data on the growth in the number of institutions come from: National Center for Education Statistics, Digest of Education Statistics--1981 (Washington, D.C.: Government Printing Office, 1981), Tables 95, 100, 107.

50. NSF, Academic Science: Graduate Enrollment and Support, Tables 1-2, 1-3, A-1.

51. U.S. Bureau of the Census, Statistical Abstract of the U.S.--1980, Table 34, p. 30. The number of science/engineering doctorates awarded in 1950 is estimated at 65 percent of all doctorates awarded by U.S. universities that year. NRC, Summary Report 1958-1966--Doctorate Recipients from U.S. Universities, p. 4.

52. NSF, Science and Engineering Personnel, Table B-33.

53. NSF, Science and Engineering Personnel, Table B-32.

54. NSF, Science and Engineering Personnel, Table B-33; NSF, National Patterns of Science and Technology Resources, Tables 80, 82; and NRC, Summary Reports--1980 Doctoral Recipients, Table 1.

55. NSF, Academic Science: Graduate Enrollment and Support, Table A-6.

56. See the later discussion on length of graduate education in the sciences and engineering.

57. NRC, Summary Report 1980 Doctorate Recipients, Table 5, Text Table F.

58. NRC, Summary Reports--Doctoral Recipients from U.S. Universities (for each year 1971-1980), Table D.

59. NSB, Science Indicators, Appendix Table 5-25.

60. NSB, Science Indicators, Appendix Tables 5-1, 5-5.

61. NSF and the Department of Education, Science and Engineering Education for the 1980s and Beyond, p. 16-18.

62. NSF, Science and Engineering Personnel, p. 3.

63. NSB, Science Indicators, p. 3.

64. NSB, Science Indicators, Appendix Table 5-1.

65. NSF and the Department of Education, Science and Engineering Education for the 1980s and Beyond, p. 16.

66. NSB, Science Indicators, Appendix Table 5-19.

67. Other primary work activities include: production and inspection, reporting and statistics, computing, and other. Other sectors of employment include: state and local governments, consulting firms, nonprofit organizations, and other. NSB, Science Indicators, Appendix Table 5-20.

68. NSB, Science Indicators, Appendix Table 5-23.

69. NSB, Science Indicators, Appendix Table 5-19.

70. NSB, Science Indicators, Appendix Table 5-14.

71. NSB, Science Indicators, Appendix Table 5-22.

72. NSB, Science Indicators, p. 138.

73. NSF and the Department of Education, Science and Engineering Education for the 1980s and Beyond, p. 16-17.

BIBLIOGRAPHY

Advisory Commission on Intergovernmental Relations. The Federal Role in the Federal System: The Dynamics of Growth - The Evolution of a Problematic Partnership: The Feds and Higher Education. (Washington, D.C.: Advisory Commission on Intergovernmental Relations, 1981).

Anderson, Ray, "Financial Assistance for Graduate Students: 1980 and Beyond." Columbia University, unpublished manuscript, 1982.

Bok, Derek. "Student Aid and the Public Interest," Harvard Magazine, 84:5 (May/June, 1982), pp 43-49, 74-79.

Bowen, William G. "The Role of the Federal Government in Higher Education." Princeton University, unpublished manuscript, January, 1982.

Breneman, David. "Effects of Recent Trends in Graduate Education on University Research Capability in Physics, Chemistry and Mathematics." In Smith, Bruce L.R. and Karlesky, Joseph J. (editors), The State of Academic Science: Background Papers. (New Rochelle, New York: Change Magazine Press, 1978) pp 133-162.

Breneman, David. "Graduate Schoold Adjustments to the 'New Depression' in Higher Education." (Washington, D.C.: National Board on Graduate Education, February 1975).

Bromley, D. Allan. "The Other Frontiers of Science," Science 215: 4536 (February 26, 1982), 1035-1044.

Bush, Vannevar. Science: The Endless Frontier. (Washington, D.C.: U.S. Government Printing Office, 1945).

Carnegie Commission on Higher Education. Higher Education: Who Pays? Who Benefits? Who Should Pay? (New York: McGraw-Hill, 1973).

Carnegie Commission on Higher Education. Institutional Aid: Federal Support to Colleges and Universities. (New York: McGraw-Hill, 1972).

Carnegie Council on Policy Studies in Higher Education. Three Thousand Futures: The Next Twenty Years of Higher Education. (San Francisco, California: Jossey-Bass, 1980).

Commission on Human Resources. Research Excellence Through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research. (washington, D.C.: National Academy of Sciences, National Research Council, 1979).

Federal Education Grants Directory. (Washington, D.C.: Capitol Publications, 1978).

Federal Interagency Committee on Education. Federal Policy and Graduate Education. (Washington, D.C.: Federal Interagency Committee on Education, 1975).

Federal Interagency Committee on Education. Federal Policy and Graduate Education. (Washington, D.C.: Federal Interagency Committee on Education, 1975).

Federal Interagency Committee on Education. Report on Federal Predoctoral Student Support: Part I - Fellowships and Traineeships. (Washington, D.C.: Federal Interagency Committee on Education, April 1970).

Federal Interagency Committee on Education. Report on Federal Predoctoral Student Support: Part II - Students Supported Under Training Grants of the National Institutes of Health and the National Institute of Mental Health. (Washington, D.C.: Federal Interagency Committee on Education, April 1977).

Finn, Chester. Scholars, Dollars and Bureaucrats. (Washington, D.C.: The Brookings Institution, 1978).

Freeman, Richard B. and Breneman, David. "Forecasting the Ph.D. Labor Market: Pitfalls for Policy." (Washington, D.C.: National Board on Graduate Education, 1974).

Hooper, Rose Marie. "Documentation for Survey of the Types, Sources and Dissemination of Support for Graduate Education of Graduate Research Project Institutions of the Consortium on the Financing of Higher Education." University of Michigan, unpublished manuscript, 1981.

National Academy of Sciences. Science and Technology: A Five-Year Outlook. (San Francisco, California: W.H. Freemen and Company, 1979).

National Board on Graduate Education. Doctorate Manpower Forecasts and Policy. (Washington, D.C.: National Board on Graduate Education, 1973).

National Board on Graduate Education. Federal Policy Alternatives Toward Graduate Education. (Washington, D.C.: National Board on Graduate Education, 1974).

National Board on Graduate Education. Graduate Education: Purposes, Problems and Potential. (Washington, D.C.: National Board on Graduate Education, 1972).

National Center for Education Statistics. The Condition of Education. (Washington, D.C: U.S. Government Printing Office, 1979).

National Center for Education Statistics. Digest of Education Statistics, 1980. (Washington, D.C.: U.S. Government Printing Office, 1980).

National Center for Education Statistics. Fall Enrollments. (Washington, D.C.: U.S. Government Printing Office, for each year from 1964 through 1980).

National Center for Education Statistics. Projections of Education Statistics to 1986-87. (Washington, D.C.: U.S. Government Printing Office, 1978).

National Commission on Research. Funding Mechanisms: Balancing Objectives and Resources in University Research. (Washington, D.C.: National Commission on Research, 1980).

National Commission on Research. Research Personnel: An Essay on Policy. (Washington, D.C.: National Commission on Research, 1980).

National Research Council. Summary Report: 1958-1966 Doctorate Recipients from U.S. Universities. (Washington, D.C.: National Research Council, 1967).

National Research Council. Summary Report: 1980 Doctorate Recipients from U.S. Universities. (Washington, D.C.: National Academy Press, 1981). Also each year from 1967 through 1979.

National Science Board. Graduate Education: Parameters for Public Policy. (Washington, D.C.: U.S. Government Printing Office, 1969).

National Science Board. Science Education for the 1980's. (Washington, D.C.: National Science Foundation, 1980).

National Science Board. Science Indicators, 1980. (Washington, D.C.: U.S. Government Printing Office, 1981).

National Science Board. Toward a Public Policy for Graduate Education in the Science. (Washington, D.C.: U.S. Government Printing Office, 1969).

National Science Foundation. Academic Science: Graduate Enrollment and Support, Fall 1980: Detailed Statistical Tables. (Washington, D.C.: U.S. Government Printing Office, 1981).

National Science Foundation. R & D Funds, Fiscal Year 1980. (Washington, D.C.: U.S. Government Printing Office, 1981).

National Science Foundation. Academic Science 1972-1977: R & D Funds; Scientists and Engineers; Graduate Enrollment and Support. (Washington, D.C.: U.S. Government Printing Office, 1980).

National Science Foundation. National Patterns of R & D Resources: Funds and Personnel in the United States: 1953-1978/79. (Washington, D.C.: U.S. Government Printing Office, 1978).

National Science Foundation. National Patterns of Science and Technology Resources, 1980. (Washington, D.C.: U.S. Government Printing Office, 1980).

National Science Foundation. Projections of Science and Engineering Doctorate Supply and Utilization: 1982 and 1987. (Washington, D.C.: U.S. Government Printing Office, 1979).

National Science Foundation. Science and Engineering Personnel: A National Overview. (Washington, D.C.: U.S. Government Printing Office, 1980).

National Science Foundation. Science Education Databook. (Washington, D.C.: U.S. Government Printing Office, 1980).

National Science Foundation and U.S. Department of Education. Science and Engineering: Education for the 1980's and Beyond. (Washington, D.C.: U.S. Government Printing Office, 1980).

Office of Management and Budget. Special Analysis: Budget of the United States Government Fiscal Year 1981. (Washington, D.C.: U.S. Government Printing Office, 1980). Also for Fiscal Year 1982.

President's Commission on Higher Education. Higher Education for American Democracy. (Washington, D.C.: U.S. Government Printing Office, 1947).

President's Science Advisory Committee. Education for the Age of Science. (Washington, D.C.: U.S. Government Printing Office, 1959).

President's Science Advisory Committee. Meeting Manpower Needs in Science and Technology. (Washington, D.C.: U.S. Government Printing Office, 1962).

President's Science Advisory Committee. Scientific Progress, the Universities, and the Federal Government. (Washington, D.C.: U.S. Government Printing Office, 1960).

Rosenzweig, Robert. "Advanced Graduate Training." Stanford University, unpublished manuscript, 1982.

Sloan Commission. A Program for Renewed Partnership: The Report of the Sloan Commission on Government and Higher Education. (Cambridge, Massachusetts: Ballinger Publishing Company, 1980).

Smith, Bruce and Karlesky, Joseph. The State of Academic Science: The Universities in the Nation's Research Efforts. Volume I, Summary of Major Findings. (New Rochelle, New York: Change Magazine Preess, 1978).

Smith, Bruce and Karlesky, Joseph. The State of Academic Science: The Universities in the Nation's Research Efforts. Volume II, Background Papers. (New Rochelle, Neww York: Change Magazine Press, 1978).

United States Bureau of the Census. Statistical Abstract of the United States, 1980. (Washington, D.C.: U.S. Government Printing Office, 1980).

United States Department of Education. Catalog of Federal Education Assistance Programs - 1980. (Washington, D.C.: U.S. Government Printing Office, 1981).

Wolk, Ronald. Alternative Methods of Federal Funding for Higher Education. (Berkeley, California: Carnegie Commission on the Futuree of Higher Education, 1968).