Chapter 2

Undergraduates in Science

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THE IMPORTANCE OF UNDERGRADUATE EDUCATION

A 4-year college degree is the first step toward a career in science or engineering.[1] For future scientists, college provides an education in the fundamentals of science and engineering, as well as experiences that help them to choose an appropriate career direction.

The undergraduate years are critical in shaping students' career plans. During college, most students decide on a particular field of study, and whether to go immediately to graduate school or look for a job. Students' experiences in and out of the classroom combine with their perceptions of the job market to steer them toward or away from particular majors. Many students enter college with broad plans — medicine, engineering, or biology — but rarely with a commitment to a specific career, such as academic research in virology. For example, the typical high school graduate interested in engineering may take some courses in mechanical engineering as a freshman, and then develop a specific interest in designing satellite steering mechanisms.

The quality of education students receive depends upon the resources, priorities, curricula, staff, fellow students, and ethos of the college they attend — the entire institutional environment. Given the preparation of entering students, colleges determine how many students graduate with science or engineering degrees, and the quality of their preparation for graduate school and entry to the work force.

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1. Nearly all scientists and engineers enter and graduate from 4-year colleges. However, over one-half of the 3,300 institutions of higher education are 2-year, or community, colleges. Community colleges fill two major roles related to science and engineering: training technicians and continuing education. Two-year institutions are an important source of technicians and technologists, who are a vital part of the research work force. Another role of community colleges is to help students "catch up" and transfer to 4-year institutions. Although not a significant source of baccalaureate level scientists, many 2-year institutions feed talent to engineering colleges. Unless otherwise noted in this chapter, colleges and universities refer to institutions that award at least the baccalaureate degree. See Cheryl Fields, "Community Colleges Discover They are at the Right Place at the Right Time," *Governing*, February 1988, pp. 30-35.

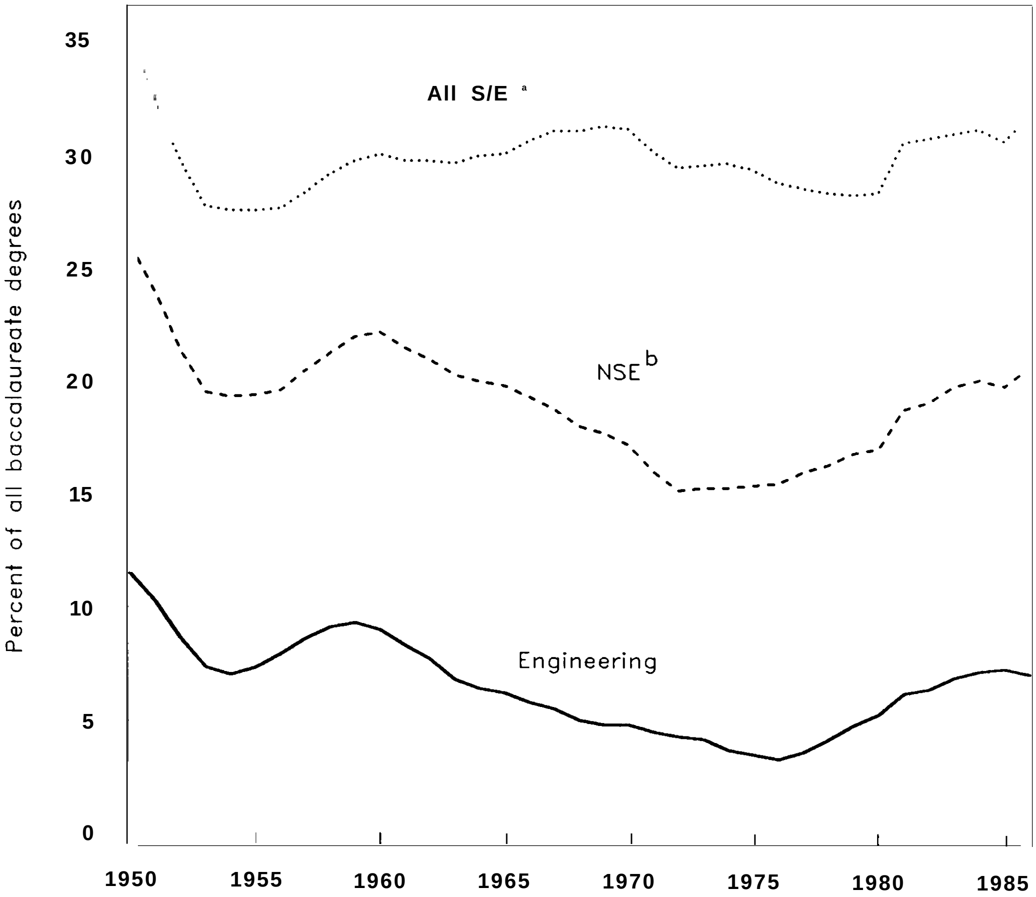
The Supply of College-Level Science and Engineering Students

American higher education attracts and educates an ample supply of potential scientists and engineers. Over a million new students enter 4-year colleges each year. Over one-third of these freshmen are interested in science and engineering. And despite the large proportion of students abandoning technical majors during college, U.S. colleges and universities graduate large numbers of baccalaureate scientists and engineers each year. Natural science and engineering (NSE) have maintained a steady share among baccalaureate degrees, around 20 percent (with ups and downs in various fields) (see figure 2-l).

Students respond well to changing demand in the labor market, for science or engineering as well as other fields. For instance, the late-1970s' boom in engineering and computer science jobs powered a large, rapid increase in engineering enrollments among new freshmen as well as students already in college. Several disquieting trends, however, now challenge the assumption that this baccalaureate largess will continue. By far the most important, the number of college-age youths in America is dropping and will hit its lowest point around 1996, with modest increases expected early in the next century. Most observers anticipate that this foreshadows a substantial dip in college enrollments, with science and engineering suffering a proportionate drop. This decline might be compensated in part by aggressive college recruiting of women, members of racial and ethnic minorities, and the physically handicapped, and, in part, by increasing general interest in science and engineering (see box 2-A). However, rising student interest in high-paying business careers and the historic low participation of minorities and women in science bode ill for this strategy. Equity of access to college in general and to science and engineering majors in particular remain contentious issues in practice, if not in principle.[2]

2. A host of factors — test scores, grades, extracurricular activities, teacher recommendations, student interviews — are weighed by colleges to predict freshmen performance and make admission decisions. The use of standardized tests, the SAT and ACT, has been controversial. Critics claim that these tests, normed to the national population of college-bound high school seniors, contain systematic biases against all but white males. The issue is not the test scores themselves but how they are used in admissions. A recent report, based on interviews and surveys at seven institutions that no longer require standardized tests for admission, shows that applications have increased with announcement of the new policies. See National Center for Fair and Open Testing, Beyond Standardized *Tests: Admissions Alternatives That Work* (Cambridge, MA: FairTest, 1987). Also see Elizabeth Greene, "SAT Scores Fail to Help Admission Officers Make Better Decisions, Analysts Contend," *The Chronicle of Higher Education*. July 27, 1988, p. A20.

Figure 2-1.–Science/Engineering as Percent of All Baccalaureate Degrees, 1 950–86



KEY: S/E = science/engineering.
NSE = natural science and engineering.

[a]Includes the social sciences.
[b]Includes engineering and the physical, life, mathematical, and computer sciences, but not social sciences.

SOURCE: Betty M. Vetter and Henry Hertzfeld, "Federal Funding of Science and Engineering Education: Effect on Output of Scientists and Engineers, 1945– 1985, " OTA contractor report, 1987, based on U.S. Department of Education data.

The near-term irreversibility of demographic trends and increased "competition" among careers and curricula for students raise several concerns about the ability of undergraduate institutions to continue to produce a well-prepared supply of baccalaureate scientists and engineers. Such concerns include:

- the factors influencing undergraduates' decisions to major in science or engineering, and the factors attracting or discouraging them from pursuing these fields;
- the access to college and to technical majors for students of all backgrounds, for women and men, for Blacks, Hispanics, and Asians as well as whites (ensuring a broad enrollment base);
- the ability of colleges and universities to provide a high-quality and appropriate undergraduate education for students pursuing technical jobs or graduate study; and
- the effects of the labor market, Federal policies, and college experiences on students' decisions to seek careers in science or engineering.

This chapter looks at each of these areas in turn, focusing on the Federal role in each.

Student Interest in Science and Engineering

The many motivations underlying the choice of college and major are not well understood[3] (see table 2-l). Students develop interests early; many science and engineering students do so before high school. These interests reflect many factors, including innate aptitude, experiences in and outside of school, and the combined influences of family, friends, teachers, and society.[4]

In the aggregate, students' early intentions predict actual college enrollments and declaration of career plans (although individual plans often shift). Students who are

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3. See U.S. Congress, Office of Technology Assessment, *Educating Scientists and Engineers: Grade School to Grad School, OTA-SET-377* (Washington, DC: U.S. Government Printing Office, June 1988), pp. 23-25, 33-34.

4. Factors affecting the development of students' interest in science and engineering, and their preparation for college-level science and engineering, are discussed in U.S. Congress, Office of Technology Assessment, Elementary *and Secondary* Education *for Science and* Engineering, SET-TM-41 (Washington, DC: U.S. Government Printing Office, December 1988).

Table 2-1.-Factors Affecting Undergraduates' Choice of a Science or Engineering Major

Most students have decided on a major by the time they enter college. Innate interest, school experiences, and teacher influences play a large role. Demographic factors, particularly socioeconomic advantages, parents' backgrounds, and education and career values associated with certain ethnic groups, confer preferences that are difficult to affect through policy. However, there is substantial readjustment during the college years, as students tackle college-level courses, encounter new subjects, and face the prospect of earning a living. Many students leave science or engineering altogether; some shift among the sciences; and a few enter from nontechnical majors. Various factors <u>during</u> the college years encourage students to enter or stay in science or engineering.

<u>Factors that attract students:</u>

- Job market for scientists and engineers
- Academic preparation and achievement in high school (particularly including coursework in mathematics; science and computer coursework are also important)

<u>Factors that reduce attrition</u> (and improve the chances of college graduation in any field, not just in science or engineering):

- University attention to student completion ("institutional nurturing")
- Intervention programs and peer support
- Research participation
- Good teaching
- Financial support
- Part-time work or cooperative study

SOURCE: Office of Technology Assessment, 1988.

interested in science and engineering early on in high school are more likely to stay with and graduate in science or engineering.[5] Similarly, freshmen plans, in the aggregate, have foreshadowed the supply of baccalaureate scientists and engineers in various fields 4 years later.[6] Most science and engineering baccalaureates had a serious interest in these fields by the time they completed high school, although many changed majors during college. While students still enter the science and engineering pipeline during the first 2 years of college, the entry gate is closed for most midway through college because of the need to choose among courses for any given major.

Entering freshmen also take note of the current job market.[7] Salary and job opportunity trends are good lead indicators; rapid rises in starting salaries suggest a shortage, and students usually respond. Since salaries rarely go down, adequate supplies or surpluses are usually indicated by little or no real growth in salaries.[8]

The influence of Federal policies on undergraduate student interest is remote and indirect, limited mostly to influence on the job market for scientists and engineers and high-visibility research and development (R&D) initiatives. While Federal student aid is instrumental in getting students into college, such aid is given irrespective of major and does not influence students' choice of field.

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5. Kathleen G. Sparrow, "A Profile Differentiating Female College Science Majors From Conscience Majors: A Predictor Set of Variables," presented at the National Convention of the National Association for Research in Science Teaching, Washington, DC, April 1987.

6. Trend data on B.S. awards and freshmen interest illustrate this relationship. One example is freshmen interest in engineering in the early 1970s. This was a period of upheaval for technical personnel: in addition to the shutdown of Apollo, Congress had decided not to fund supersonic transport development, defense contracts were declining, and large numbers of engineers in areas near major aerospace contractors such as Boeing, Hughes, and Lockheed were out looking for work. As the job market for engineers began to recover in the mid-1970s, so too did freshmen interest in engineering majors. The increase in engineering degree awards in the late 1970s correlates almost perfectly with the trends in freshmen majors in survey data 4 years earlier (see Kenneth C. Green, University of California, Los Angeles, personal communication, 1987). The downturn in freshmen interest in engineering majors and careers that began in 1982 should manifest itself in the last years of the 1980s (indeed, the most recent data show a slight decrease in engineering degree awards).

7. U.S. Congress, Office of Technology Assessment, *Demographic Trends and the Scientific and Engineering Work Force*, OTA-TM-SET-35 (Washington, DC: U.S. Government Printing Office, December 1985), pp. 34-40.

8. Nestor E. Terleckyj, "Employment of Natural Scientists and Engineers: Recent Trends and Prospects," presented at the Workshop on the Prospective and Expected Economic Effects of the Changing Age Structure of the U.S. Population, National Science Foundation, Washington, DC, July 1987.

Changes in social values also affect students' career plans. According to surveys, students of the 1980s increasingly value high salaries, career advancement, professional reputation, and comfortable lifestyles, and place far less importance on community and environmental activism and self-exploration than did students in the 1960s.[9] Majors leading to highly-paid, visible careers have grown the fastest. Within the sciences, engineering and computer science majors have grown, while social science majors have dwindled.

Information on entering college students, and their eventual college performance and degrees, can help describe who chooses and stays with science. A large proportion of entering freshman are interested in science and engineering majors. Among incoming full-time freshman in 4-year institutions, about one-quarter plan to major in NSE, and slightly over 30 percent over all science and engineering fields.[10]

However, student preferences have shifted away from science. The share of incoming college freshmen interested in NSE has declined slightly, from 27 percent of first-time, full-time freshmen in 1978, to 24 percent in 1986. During that same period, interest in all of science and engineering, including the social sciences, declined from 37 percent to 34 percent.[11] Figure 2-2 shows the 1977-87 trend in planned majors among freshmen at 2- and 4- year institutions.[12]

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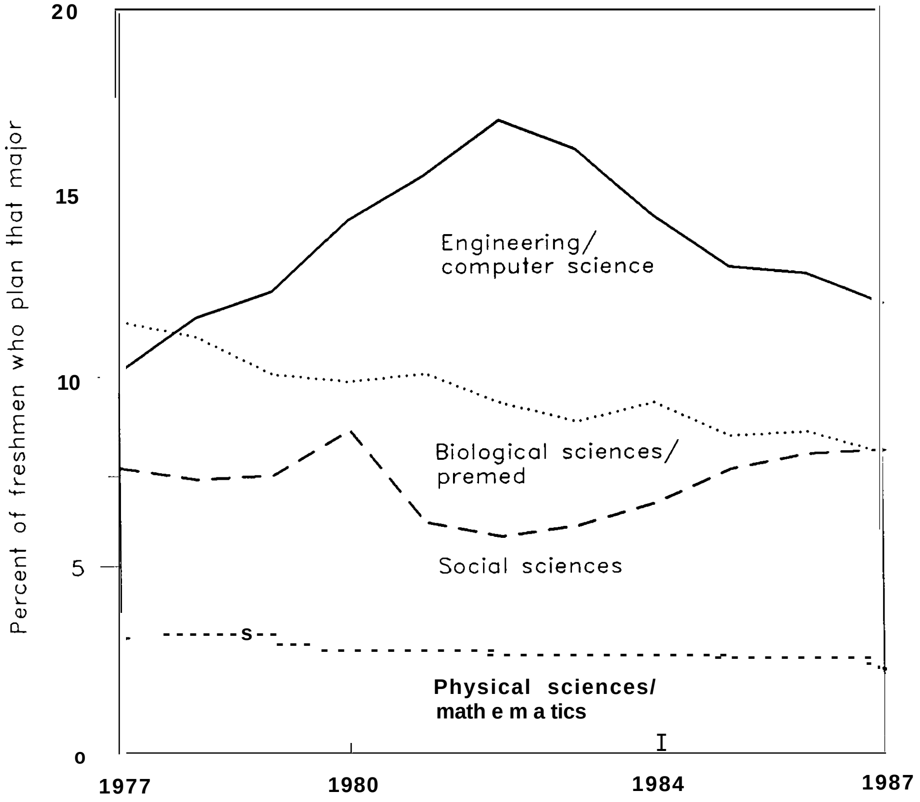
9. Alexander W. Astin et al., *The American Freshman: Twenty Year Trends 1966-1985* (Los Angeles, CA: University of California at Los Angeles, Cooperative Institutional Research Program, January 1987), pp. 14-26, 97.

10. The more restrictive definition, natural sciences or engineering, is used throughout this section, although science and engineering are often defined broadly to include social and behavioral sciences.

11. The absolute numbers have been declining as well. In the fall of 1986, 246,260 students, or 24 percent of first-time, full-time freshmen in the Nation's 4-year colleges and universities, planned to major in natural science or engineering (NSE). In 1978, 285,557 entering students (27 percent of the freshmen in 4-year institutions) expressed a preference for NSE majors. Enrollments are surprisingly stable in the Nation's 4-year colleges and universities, considering demographic trends and recent reductions in government-funded student aid. Unless otherwise indicated, all references to student populations refer to the population of first-time, full-time freshmen entering the Nation's 4-year colleges and universities each fall, as surveyed by the Cooperative Institutional Research Program (CIRP), Higher Education Research Institute, University of California at Los Angeles. Natural sciences and engineering includes premed majors (in 1986, 3.8 percent of all freshmen). See Green, op. cit., footnote 6. The trend data cited below on freshmen preferences are derived from this source.

12. The lack of comparability in the population of institutions, more than the change from 1986 to 1987, accounts for the differences reported here. Nevertheless, the differences are small.

Figure 2-2.–Freshmen Planned Majors, by Science/Engineering Field, 1977-87



SOURCE: Cooperative Institutional Research Program, The American Freshman (Los Angeles, CA: University of California, Los Angeles, annually).

The decline has not been steady or consistent. Freshman interest in selected science and technical majors such as computer science and engineering rose fairly steadily between 1977 and 1983,[13] as students seeking recession-proof careers gravitated toward high-technology fields. The boom in the semiconductor and computer industries attracted undergraduates while interest in other science fields dropped correspondingly. Freshman interest in engineering in 4-year institutions rose from 10.2 to 11.4 percent between 1978 and 1983, while interest in computer science majors tripled from 1.2 to 4.9 percent during the same period. Beginning in 1984, however, both engineering and computer science declined sharply in popularity, while interest in social sciences began to rise. Most shifts occur between related fields, as students already interested in science in general seek a specialty with healthy job prospects.

Freshman interest in careers, as might be expected, parallels interest in majors. About one-third of NSE majors plan to be engineers, and nearly one-fifth plan medical careers. Interest in a research career dropped from 9.5 percent in 1978 to under 7 percent in 1986, although this varies by field. Physical science majors are twice as likely to be interested in a research career as other NSE majors.

Very few NSE students are interested in teaching: in 1986, just over 1 percent of these freshmen expressed interest in a career in elementary or secondary school teaching, compared to 10 percent of students in other majors. The already low proportion of freshman NSE majors planning teaching careers is only likely to decline further while these students progress through college; in all likelihood many will be recruited away from education and encouraged to pursue academic, research, or other "professional" careers by family, friends, and faculty. Role models are very important in recruiting undergraduates into careers. "Who is to teach mathematics and science?" has become a more urgent refrain than "who is to do research?"

Freshmen at different types of institutions tend to have different major and career preferences (see table 2-2 and table 2-3) Students at private institutions are slightly more likely to be interested in science, and less likely to go into engineering. And interest in science and engineering majors is much stronger among freshmen at more select institutions, particularly for women, as shown in table 2-4.[14] Freshmen at the

13. Astin et al., op. cit., footnote 9.
14. Ibid., pp. 69-71, 85-86. "Select" is defined as mean SAT scores of freshmen.

Table 2-2. — Planned Majors and Careers of Freshmen at All Institutions, by Sex, Fall 1987
(in percent)

	Total	Men	Women
Major			
S/E pool	29.3	31.7	22.6
Engineering	9.4	12.0	2.7
Social sciences	8.1	5.6	10.5
Biological sciences	5.5	6.4	4.5
Pre-medicine	2.5	2.5	2.5
Physical sciences	2.2	2.9	1.5
Computer science	1.6	2.3	0.9
Career			
Engineer	8.5	15.2	2.6
Scientific researcher	1.5	1.8	1.2

NOTE: Biological sciences includes agriculture and forestry; physical sciences includes mathematical sciences. Total is first-time, full-time freshmen at all institutions, including 2-year institutions. Total number of students in the unweighed sample was 209,627; percentages reflect weighted national norms.

SOURCE: Alexander Astin et al., *The American Freshman: National Norms for Fall 1987* (Los Angeles, CA: University of California, Los Angeles, Cooperative Institutional Research Program, 1988), pp. 21-22, 37-38, 53-54.

Table 2-3. — Freshmen's Planned Majors and Careers by Type of Institution Attended, Fall 1987
(in percent)

	All institutions (incl. 2-year)	*4-Year* colleges	All universities
Major			
S/E pool	29.3	27.3	40.2
Engineering	9.4	6.9	13.8
Social sciences	8.1	9.8	10.4
Biological sciences	5.5	4.0	6.6
Pre-medicine	2.5	2.4	4.9
Physical sciences	2.2	2.4	3.1
Computer science	1.6	1.8	1.4
Career			
Engineer	8.5	5.9	12.6
Scientific researcher	1.5	1.4	2.4
Teacher	8.1	10.9	4.2

NOTE: Biological sciences includes agriculture and forestry; physical sciences includes mathematical sciences. The total unweighed number of institutions (including 2-year institutions) in the sample used for calculating national averages was 390, with an unweighed student population of 209,627. This included 53 universities, with an unweighed student population of 91,993; and 278 4-year colleges, with an unweighted student population of 101,221. For sampling and weighting methodology, see source below, pp. 99-105.

SOURCE: Alexander Astin et al., *The American Freshman: National Norms for Fall 1987* (Los Angeles, CA: University of California, Los Angeles, Cooperative Institutional Research Program, 1988), pp. 21-22, 37-38, 53-54.

Table 2-4. — Freshmen Interest in Science and Engineering Majors
by Selectivity of University Attended and Sex, Fall 1987
(in percent)

	Men				Women			
	Public univ.		Private univ.		Public univ.		Private univ.	
	Least select	Most select	Least select	Most select	Least select	Most select	Least select	Most select
S/E Major	45.7	50.8	37.5	56.1	28.6	37.5	29.2	47.1
Natural science	16.4	18.8	14.9	17.4	12.8	17.6	11.7	17.6
Social science	4.6	9.7	9.6	14.7	11.3	15.9	14.6	20.0
Engineering	24.7	22.3	13.0	24.0	4.5	4.0	2.9	9.5
S/E Career								
Sci. researcher	2.0	3.4	1.8	4.5	1.5	2.7	1.3	3.7
Engineer	21.9	22.6	11.3	17.9	4.5	4.3	2.6	7.8

NOTE: The 53 universities in the unweighted survey sample included 27 public universities, with an unweighed student population of 64,392; and 26 private universities, with an unweighed student population of 27,601. The percentages reflect weighted national estimates. Selectivity level of low, medium, or high determined by mean total SAT/ACT scores of freshmen. See source below, p. 103, for details.

SOURCE: Alexander Astin et al., *The American Freshman: National Norms for Fall 1987* (Los Angeles, CA: University of California, Los Angeles, Cooperative Institutional Research Program, 1988), pp. 69-71.

most select universities are twice as likely as freshmen at the least select universities to plan careers as scientific researchers.

Trends in Degrees: Field Differences

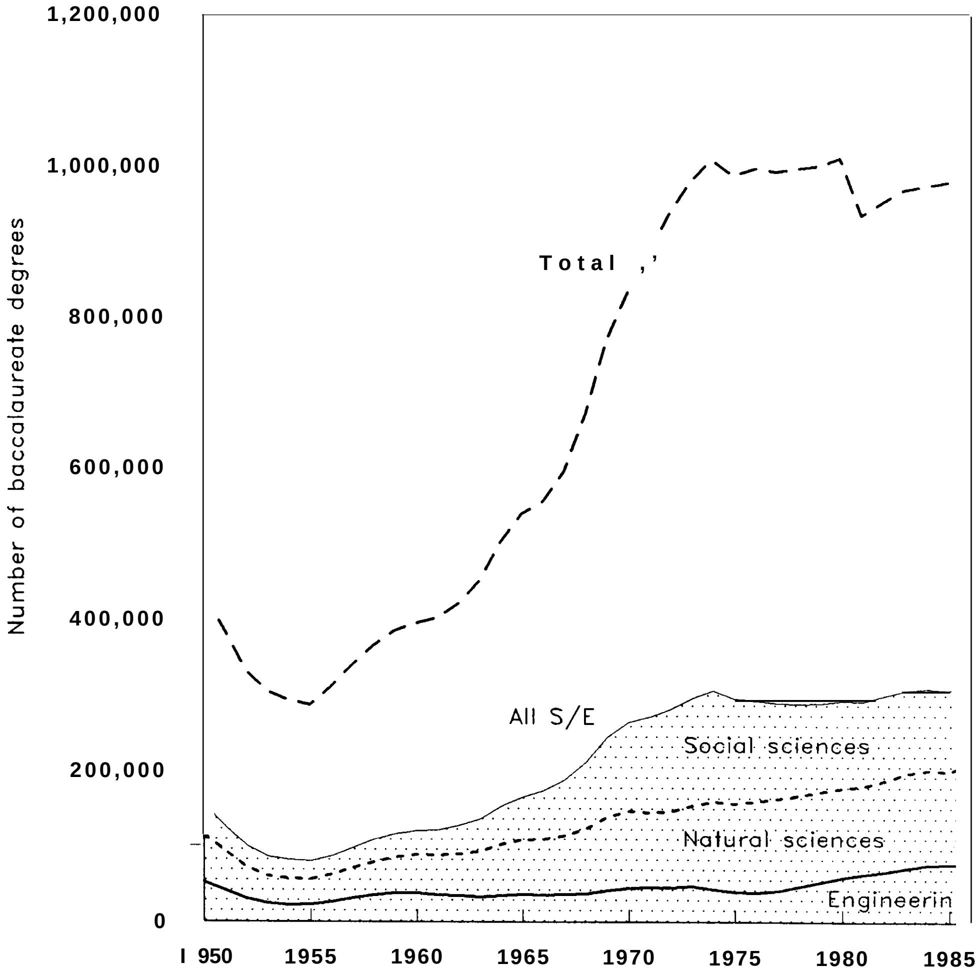
Baccalaureate awards in science and engineering have tracked overall degree awards, maintaining a fairly steady 30 to 32 percent share for the past few decades. This apparent constancy, however, masks substantial changes in individual fields. Natural sciences and engineering have shown more variation, ranging from about 16 to 21 percent in the past decade, with slight increases in recent years.

Scientists and engineers work in a variety of places and use different skills. Astronomy is dominated by Ph.D.-trained basic researchers in universities, while many B.S.-trained computer scientists and engineers develop products in high-technology companies. While the sciences are broadly similar — in the kind of students they attract, the dynamics of enrollments, degree awards, and job markets — there are significant differences between fields. Analysis of education and employment patterns, and interaction of job markets and student interest, are instructive when disaggregated by field.[15] Since shortages and surpluses occur at the level of the specialty rather than for science and engineering as a whole, looking at this finer level of detail is important.

Science and engineering B.S. awards (following the pattern of all B.S. degrees) rose rapidly in the 1960s, peaked in 1974, and then plateaued with relatively slight increases in recent years (see figure 2-3). Physics degrees have been relatively steady, dropping slightly through the 1970s and increasing again since 1980. In the life sciences, degrees peaked in 1976. The social sciences went through the most rapid increases into the early 1970s, before flattening out for a decade or so. Engineering has followed a different pattern, with slow increases until the 1970s, when degree-taking took off in response to burgeoning job offers and salaries. Most chemists work in industry, and have salaries higher than most other scientists. Bachelor's degree production has been quite steady since the mid-1960s, with slight declines in recent years.

15. For a recent review that disaggregates data on science and engineering fields, see U.S. Congress, Office of Technology Assessment, "Preparing for Science and Engineering Careers: Field-Level Profiles," Staff Paper, January 1987. The National Science Foundation prepares occasional data profiles on individual fields, for example, National Science Foundation, *Profiles — Mechanical Engineering: Human Resources and Funding*, NSF87-309 (Washington, DC: 1987).

Figure 2-3.-Baccalaureate Degrees, 1950-86



KEY: S/E = science/engineering.

SOURCE: Betty M. Vetter and Henry Hertzfeld, "Federal Funding of Science and Engineering Education: Effect on Output of Scientists and Engineers, 1945- 1985," OTA contractor report, 1987, based on U.S. Department of Education data.

Geological science degrees are closely tied to industrial indicators such as the world market price of oil. This determines the health, i.e., the hiring and R&D posture, of principal employers. In the concentrated and cyclical world of natural resources, there is a surplus of bachelor's- and master's-level earth scientists who started college just before the current downturn in the petroleum and mining industries curtailed exploration and research. As a result, undergraduate enrollments plummeted. B.S. awards, which had doubled between 1974 and 1984, declined over 20 percent from 1985 to 1986, and 25 percent from 1986 to 1987.[16]

It is important to look at mathematical and computer sciences degree data together, since the rapid drop in mathematics degrees during the late 1970s was accompanied by a boom in computer science degrees (in response to burgeoning industry demand for computer specialists). By 1983, bachelor% degrees in mathematics had started rising again. The boom years of computer sciences testify to the ability of students and universities to respond to market demand; the growth rate in baccalaureate awards in the late 1970s and early 1980s was 20 and even 35 percent per year (although many argue this rapid growth stemmed merely from the redesignation of courses, faculty, and students as "computer science" with little change in actual course content, faculty expertise, and student preparation).

In the life sciences, the market for physicians influences biological and medical science undergraduates, since many of them are planning medical rather than scientific careers. In some sense, medicine and research biology compete for students; when the market for graduate students is down, more life science graduates go to medical school. There is a large supply of life scientists, and extended graduate study is necessary to find a job above the level of technician. But degree awards in the life sciences have been declining steadily for the past decade and represent a shrinking proportion of science degrees.

SCIENCE AND ENGINEERING STUDENTS

Although science and engineering students differ from the average college student — they tend to be higher achieving academically and are much more likely to be white and male — changes in the size and composition of the college student population

16. Earth sciences degree data based on surveys conducted by the American Geological Institute, cited in *Manpower Comments,* vol. 23, No. 5, June 1986, p. 18.

trickle through to science and engineering. Policies that affect higher education in general also affect the science and engineering pool, albeit adjusted for the particular students, universities, and job markets that dominate science and engineering.

Black, Hispanics, and Native Americans

Minorities' college enrollment and retention to degree in science and engineering reflects the generally lagging educational success of minorities (see table 2-5).[17] The continuing social barriers that set minorities apart — language and cultural differences, poverty, political powerlessness, prejudice, and discrimination— are in many cases exacerbated by the traditional white male dominance of the science and engineering professions.[18]

There are relatively few Blacks, Hispanics, and Native Americans in science and engineering. Asians prefer science and engineering to other majors (see figure 2-4). Among high-achieving students, according to Cooperative Institutional Research Program (CIRP), Blacks and Hispanics, as well as Asians, are more interested in NSE than in other majors.

Blacks have made substantial gains in higher education, but their inroads into science and engineering have been modest, and increases have slowed in recent years. Those Blacks who do well academically and take many high school mathematics and science courses are about as likely as their white peers to be interested in science majors.[19] Blacks earn about 3 percent of science and engineering baccalaureates, and 6 percent of all baccalaureates. Only in the social sciences do Blacks earn more than 5 percent of the B.S. degrees conferred. Interest in the social sciences was inspired by early Black leaders in education, sociology, and political change; in the rest of the sciences and engineering, there are few role models and little cultural tradition which promote research careers. And in science and engineering more so than in other majors,

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17. Linda S. Dix (cd.), Minorities: *Their Underrepresentation and Career Differentials in Science and Engineering*, **Proceedings of a Workshop, Office of Scientific and** Engineering Personnel, National Research Council (Washington, DC: National Academy **Press, 1987); and James R. Mingle,** *Focus on Minorities: Trends in Higher Education Participation and Success* (Denver, CO: Education Commission of the States and the State Higher Education Executive Officers, July 1987).
18. Lisbeth B. **Schorr,** *Within Our Reach: Breaking the Cycle of Disadvantage* (New York, NY: Anchor Doubleday Press, 1988).
19. Valerie Lee, "**Identifying** potential Scientists and Engineers: An Analysis of the High School-College Transition," OTA contractor report, 1987.

Table 2-5. — B.S. Degrees in Science and Engineering, by Race/Ethnicity, 1984

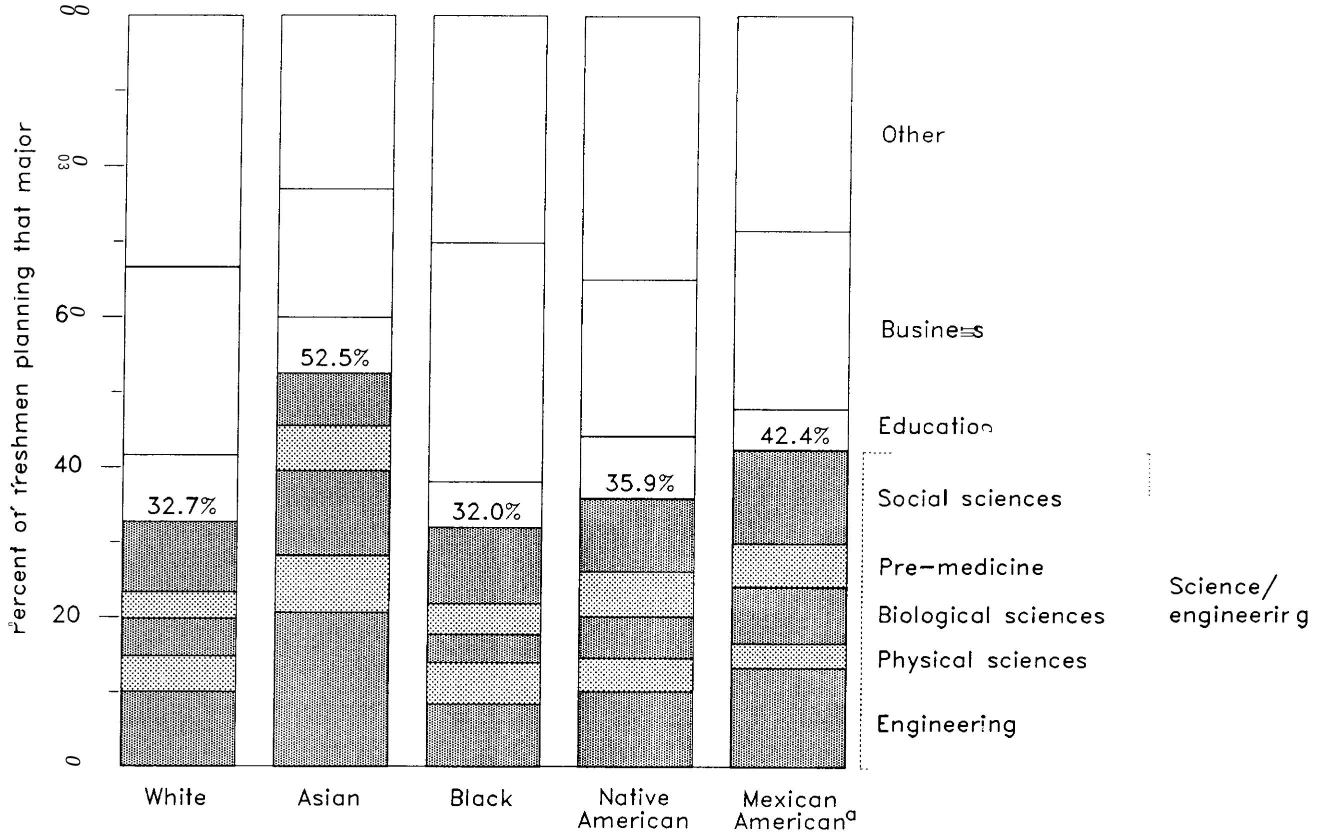
	Total[a]	Percent minority[b]	Black	Hispanic	Native American
All science/ engineering	293,200	7.5	9,400	12,300	400
Physical sciences/ computer sciences/ mathematics	62,700	5.3	1,500	1,700	100
Life/environmental sciences	54,000	6.3	1,300	2,000	100
Social sciences/ psychology	96,600	11.4	5,000	6,000	(c)
Engineering	79,800	5.6	1,700	2,700	100

[a]Includes "other" and no report.
[b]"Percent minority" includes only Black, Hispanic, and Native American.
[c]Too few cases to report.

NOTE: Rounded numbers reported in original source.

SOURCE: National Science Foundation, *Characteristics of Recent Science and Engineering Graduates: 1986*, NSF 87-321 (Washington, DC: 1987), pp. 13-14.

Figure 2-4.–Planned Freshmen Majors, by Field and Race/Ethnicity, Fall 1987



[a]Includes freshmen who categorized themselves as Mexican/American or Chicano; does not includes Puerto Rican-Americans.

NOTE: First-time, full-time freshmen in 4-year institutions only. Physical sciences include mathematics and computer science.

SOURCE: Cooperative Institutional Research Program, The American Freshman (Los Angeles, CA: University of California, Los Angeles, annually).

Blacks are much more likely to drop out than than whites. Blacks are the only group where women have a stronger showing in science, and particularly in engineering, than men.[20]

Hispanics are the Nation% fastest growing minority group in the college-age population. They are only 4.5 percent of undergraduates, and more than one-half of these students attend community colleges. The Hispanic population — two-thirds Mexican-American, 12 percent Puerto Rican, 12 percent Central and South American, and 5 percent Cuban — is concentrated in California, Texas, Florida, and New York.[21] Hispanics! success in education varies with socioeconomic status and values across these subcultures, and fares better in some States than in others. Their educational difficulties are complicated because many of them are recent immigrants with little formal education. High-achieving Hispanic freshman (with an equivalent of "A" or "A-" high school grade point average (GPA)) are less likely to be interested in science and engineering majors, and more likely to be interested in business majors, than all Hispanic freshmen.[22] Hispanic degree-taking in science and engineering fields is low, about 3 percent of baccalaureates. They are more evenly spread among science and engineering fields than Blacks, with a strong showing in the life sciences.

Native Americans may be the most disadvantaged minority group in the United States, as measured by their low socioeconomic status and educational and occupational attainment. They are 0.8 percent of the college-age population, but only 0.2 percent of

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20. Another factor is that the armed services compete for minority high school graduates. The armed forces are attracting a greater share of high school graduates. By 1985, over 90 percent of Blacks who enlisted were high school graduates, a 25 percent increase in enlistment from 1980. Solomon Arbeiter, "Black Enrollments: The Case of the Missing Students," Change, vol. 19, No. 3, May/June 1987, p. 17. Also see Holly Hexter and Elaine El-Khawas, Joining Forces: *The Militaryts Impact on College Enrollments* (Washington, DC: American Council on Education, October 1988).

21. "Hispanics: Some Basic Facts," *The Chronicle of Higher Education,* Sept. 16, 1987, p. A36. Early in 1987, the newly-founded Hispanic Association of Colleges and Universities qualified 60 U.S. institutions (mostly community colleges) for membership, based on a criterion of at least 25 percent Hispanic enrollment. By the year 2000, 100 institutions are expected to qualify. Cheryl M. Fields, "Demographic Changes Bring Large Hispanic Enrollments to Over 60 Institutions," *The Chronicle of Higher Education,* Oct. 7, 1987, p. A40.

22. Green, op. cit., footnote 6.

science and engineering baccalaureates. There is little cause for optimism about increasing their participation in science and engineering.[23]

Intentions of minorities may not be as predictive as they are for white students. Even though minorities, especially Blacks, may enter college with high (and often unrealistic) expectations, their usually poorer preparation for technical majors may pave the way for disappointment in ambitious career and degree plans.

The generally poor precollege preparation of most Blacks and Hispanics is particularly telling for science and engineering. On average, Blacks and Hispanics take fewer advanced mathematics and science courses than whites, Educators claim that low minority exposure to science and mathematics in high school and excessive reliance on standardized test scores bars many Blacks from college-level science and engineering. And the paucity of minority role models for minority children is particularly severe in science and mathematics; over one-quarter of students in public high schools are Black or Hispanic, but nearly 90 percent of all teachers and about 93 percent of mathematics and science teachers are white.[24]

What gains minorities have made in science and engineering have derived largely from broad national higher education policies and full-fledged institutional commitment to increasing minority access to higher education. Two broad policy strategies have been applied towards that goal: financial aid (student aid for individuals and institutional aid for historically Black institutions) and special social and academic intervention programs for minority students of all levels. Student aid has been particularly important in helping minorities attend college. Well-organized intervention programs can attract students to science and engineering careers and significantly increase their likelihood of completing an undergraduate degree in science or engineering (see appendix A and box 2-B).

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23. Judith E. Fries, *The American Indian in Higher Education, 1975-76 to 1984-85* (Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement, Center for Education Statistics, March 1987). The term "American Indians" is also used for this group. The small number of Native Americans has precluded formal national analysis.

24. See Office of Technology Assessment, op. cit., footnote 4, ch. 3; data from Iris R. Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education*, (Research Triangle Park, NC: Research Triangle Institute, November 1987), table 35.

Asians

Recent waves of immigrants to the United States, Asians, have spawned a generation of educational "superachievers” who are especially prominent in science and engineering at the undergraduate level. Predominantly Chinese, Korean, and Indochinese, these children of refugees and of the affluent alike distinguish themselves in mathematics, as reflected by SAT scores, and by other measures, including high school grades and time spent on homework.[25] Dedication, family support, and hard work drive many Asian students toward the elite research universities for their undergraduate education. The 1987 freshman classes at the Massachusetts Institute of Technology (MIT), the California Institute of Technology (Caltech), and the University of California, Berkeley, for example, were over 20 percent Asian. They generally have very high educational aspirations.

Asians are the group most interested in NSE. They also are the only group who consistently enter science and engineering majors while in college. Like any ethnic group, however, Asians are diverse. While many have done well, the newest wave of Asian immigrants include many refugees from different cultures, often with little education and few portable skills, and these children have fared more poorly in U.S. schools.[26]

Women

Among freshmen, the proportion of women planning to pursue NSE majors increased slightly between 1978 and 1986, from 31 to 33.[27] However, women are more likely to drop out of science and engineering majors, and women% degree-taking in science and engineering overall has plateaued. Although more women start out interested in scientific majors and careers, their limited career opportunities may be stifling that interest.

Women planning NSE majors have better high school grades than men. In 1986, 55 percent of these women had "A” to “A-" high school GPAs, compared to 51 percent of the

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25. David Brand, “The New Whiz Kids,” *Time,* Aug. 31, 1987, pp. 42-51.
26. In short, the "superachiever" or "model minority" image *is overstated*. See Office of Technology Assessment, op. cit., footnote 3, pp. 55-56. Also see *Manpower Comments*, vol. 25, October 1988, pp. 19-20.
27. Green, op. cit., footnote 6. The proportional increase masks a fall in absolute numbers.

men. However, freshmen men planning NSE majors are more likely to rate themselves as "above average" than are the women planning these majors. Reports from college educators are that women students, particularly those in traditionally male majors such as engineering and the physical sciences, tend to have less self-confidence and drop out of a course or major much more easily than do men, even though they are just as capable, performing just as well, and getting the same grades.[28]

Among NSE majors, females are more interested in research or medical careers than their male counterparts, and less interested in engineering; women tend toward biology, and less towards mathematics-based science and engineering majors (see table 2-6).[29]

Although women have made inroads the last two decades into science and engineering, there are still broad gaps in participation (see box 2-C). Women have higher unemployment rates than men in every field of science, at every degree level, and at all levels of experience. They also earn less in every employment sector. So although women% share of degrees in science has increased markedly in the last 15 years, their opportunities for advancement still lag.[30] Since 1983, the proportion earning degrees in computer science, biological science, and the physical sciences in general have leveled off. A "chilly climate" for women still prevails in many college classrooms. Continued gains for women in science are far from assured.[31]

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28. William K. LeBold, "Women in Engineering and Science: An Undergraduate Research Perspective," *Women: Their Underrepresentation and Career Differentials in Science and Engineering*, Proceedings of a Workshop, Office of Scientific and Engineering Personnel, National Research Council, Linda Dix (ed.) (Washington, DC: National Academy Press, 1987). Also see Sheila E. Widnall, "AAAS Presidential Lecture: Voices from the Pipeline," *Science* vol. 241, Sept. 30, 1988, pp. 1740-1745.
29. A related phenomenon is computer phobia among women; even if this fear is overcome, there is evidence that women relate to the machine differently than men. See, for example, Sherry Turkle, "Computational Reticence: Why Women Fear the Intimate Machine," *Science for the People*, September/October 1988, pp. 6-11.
30. National Research Council, *Climbing the Academic Ladder: An Update on the Status of Doctoral Women Scientists and Engineers* (Washington, DC: National Academy Press, 1983).
31. Betty M. Vetter, "Women in Science," *The American Woman 1987-88: A Report in Depth*, D. Shavlik and Judith Touchton (eds.) (Washington, DC: Women% Research and Educational Institute, 1987); OTA, op. cit., footnote 3, pp. 50-53; and Barbara D. Webster, "Opening Doors for Women in Academia," *BioScience*, vol. 39, February 1989, pp. 96-98.

Table 2-6. — Planned Majors and Careers of Freshmen at 4-Year Institutions, by Sex, 1978 and 1986
(in percent)

	1978			1986		
	Total	Men	Women	Total	Men	Women
Major						
S/E pool	36.7	45.8	29.8	33.6	41.3	27.1
Engineering	10.2	18.0	2.9	10.1	17.8	3.2
Social sciences	9.2	6.8	11.8	9.4	7.0	11.9
Biological sciences	7.1	8.1	6.1	5.5	5.8	4.9
Pre-medicine	4.5	5.4	5.2	3.8	3.9	3.8
Physical sciences	4.2	5.8	2.6	2.9	4.2	2.1
Computer science	1.5	1.7	1.2	1.9	2.6	1.2
Career						
Engineer	8.9	15.7	2.5	9.0	15.6	3.0
Scientific researcher	2.8	3.4	2.2	1.8	2.2	1.4
Computer programmer	2.8	3.3	2.4	3.0	4.3	1.8

NOTE: Biological sciences includes agriculture and forestry; physical sciences includes mathematical sciences. Total is freshmen at 4-year institutions only. Total number of students in the unweighed sample was 209,627; percentages reflect weighted national norms.

SOURCE: Kenneth C. Green, University of California, Los Angeles, personal communication, 1987.

Academic Quality of Science and Engineering Undergraduates

Apart from sheer numbers, the quality of students going into science and engineering is of prime concern. Quality is difficult to measure, so analysts use proxies such as grades, test scores, and surveys of faculty opinion. By all of these measures, science and engineering have been fortunate in attracting, selecting, and keeping many of the best students.

Entering science and engineering students tend to be higher achieving academically, continue to have greater academic self-confidence, and have higher degree aspirations than conscience and engineering students. Nearly one-half of 1986 freshmen planning NSE majors reported a high school GPA in the "A" to "A-" range, compared to one-quarter of freshmen planning other majors. NSE majors generally view themselves as very talented, ranking their own academic and intellectual skills far higher than average. NSE students also have had more academic coursework coming into college, in all subjects.

NSE maintains its share of able students, despite fears that more of the best students are choosing business and other majors (see figure 2-5). "A" to "A-" students accounted for a slightly larger proportion of all freshman NSE majors in 1986 (47 percent) than in 1978 (43 percent).[32] In the fall of 1986, almost one-fifth of all freshmen planned to pursue the doctorate, twice the rate among other majors. Nearly one-quarter hoped to complete some type of medical degree. Roughly equal proportions of men and women in NSE planned to obtain a doctorate.[33] As is true with students in other major% the most academically able NSE students are less interested, as freshmen, in teaching careers.

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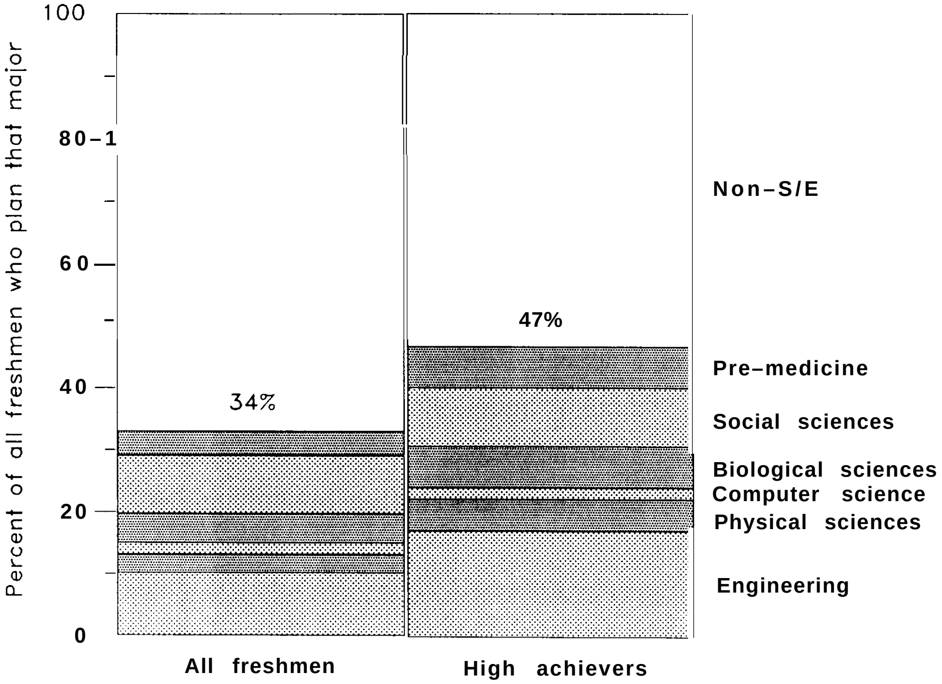
32. Although science and engineering baccalaureates tend to have about the same college grade point averages as other majors (with biological scientists having slightly higher and engineers slightly lower grade point averages), much of any difference may be due to variations in grading practices among courses for different majors. U.S. Department of Education, unpublished Recent College Graduate Survey data.

33. Although the gap in doctoral aspirations between natural science and engineering (NSE) and non-NSE fields declines among the high-talent population, academically-able NSE freshmen in 4-year institutions are still more likely to aspire to the doctorate than their peers (23 percent v. 14 percent). However, medicine is much more attractive to academically-able NSE women (38 percent for women v. 20 percent for men).

Figure 2-5.–Freshmen Choice of College Major, by Achievement, 1986



KEY: S/E = science/engineering.

[a] Freshmen who report their high school grade point average as “A” or “A-”.

NOTE: Biological sciences include agriculture and forestry. Physical sciences include mathematics.

SOURCE: Kenneth C. Green, OTA contractor report, 1987, based on data from the Cooperative Institutional Research Program, University of California, Los Angeles.

Some students enter science and engineering during college, but more than twice as many leave (see table 2-7). Some part of this field switching can be attributed to the higher academic ability of students in natural science and engineering. Attrition rates change substantially over time, reflecting changes in market conditions and corresponding student shifts in majors. One study found that NSE lost the most students; only about one-half of freshmen who planned those majors graduated in them (see figure 2-6). In comparison, about 70 percent of business majors stayed the course in business; about 65 percent of social science students stayed in their field. Among scientific majors, engineering retained the most students and physical sciences the fewest.[34]

Although most science and engineering baccalaureate recipients enter the work force upon graduation (see figure 2-7), career paths vary greatly by field. A little under one-quarter of recent natural and social science baccalaureates, and about 10 percent of engineers, have gone on to full-time graduate study.[35] Among employed baccalaureates, most natural scientists and nearly all engineers take jobs in science and engineering, compared to less than one-third of social scientists. Unlike liberal arts majors, 80 to 90 percent of B.S. recipients in mathematics, computer science, and other physical sciences feel that their first job out of college was related to their major.[36]

FEDERAL ROLES IN UNDERGRADUATE SCIENCE EDUCATION

Federal influence on science and engineering undergraduate education is most clear in general Federal higher education policies. The large Federal education aid and access programs, with rare exceptions, are not targeted to particular subjects. Student financial aid and civil rights legislation make college possible for many young people, shaping the size and makeup of the entire college student population, regardless of

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34. Green, op. cit., footnote 6.
35. National Science Foundation, Characteristics *of Recent Science/Engineering Graduates: 1986,* NSF 87-321 (Washington, DC: 1987).
36. Roslyn A. Korb, Occupational and Educational Consequences *of* a Baccalaureate Degree (Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement, Center for Education Statistics, March 1987), pp. 1, 7. Estimates are based on the Department of Education% Recent College Graduate Survey of 1983-84, which surveys students about 1 year after their B.S. A liberal arts major may reflect indecision, or a hedging of one's bets, over career directions.

Table 2-7. — College Student Retention, Entry, and Exit From Natural Science and Engineering Majors, by Field, 1981 Freshmen Through 1985 Baccalaureates

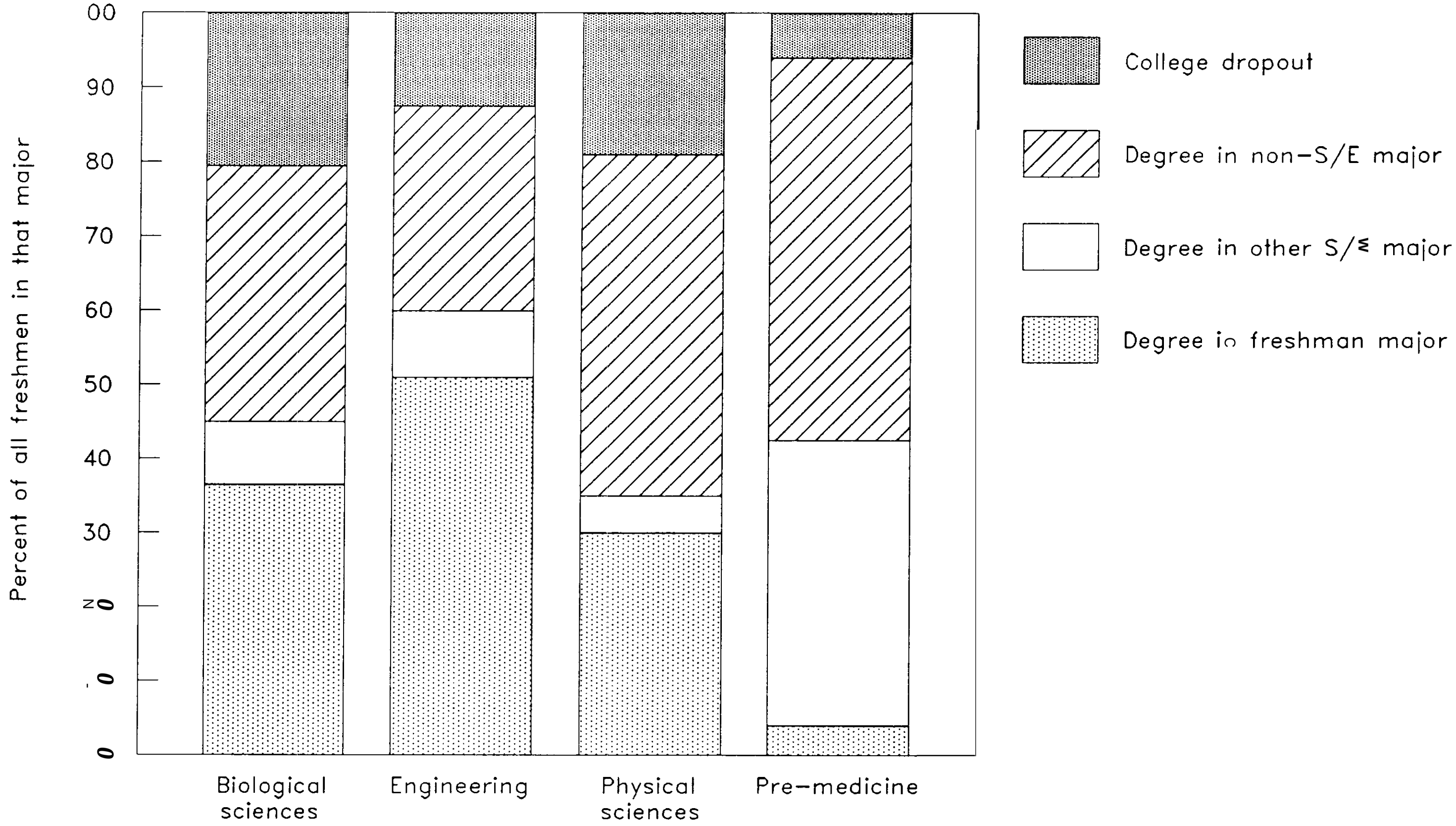
	Ratio of defectors to recruits in that major[a]	Percent who stayed with their original major
Biological sciences	1.2	24
Engineering	2.5	61
Computer science	1.6	17
Physical sciences	0.7	35
NSE	1.5	49
Non-NSE	0.8	57

[a]A ratio greater than one indicates that more students “defected" from, or left, that major during college than entered during college.

KEY: NSE = natural science and engineering.

SOURCE: Lewis C. Solmon, "Factors Determining and Limiting the Supply of New Natural Science and Engineering Baccalaureates: Past Experiences and Future Prospects," draft paper presented at the National Science Foundation, July 8, 1986, p. 41, based on data from the Cooperative Institutional Research Program, University of California, Los Angeles. Note that attrition is reported as a percent of total students at a particular time, and therefore does not reflect the overall loss of students from college.

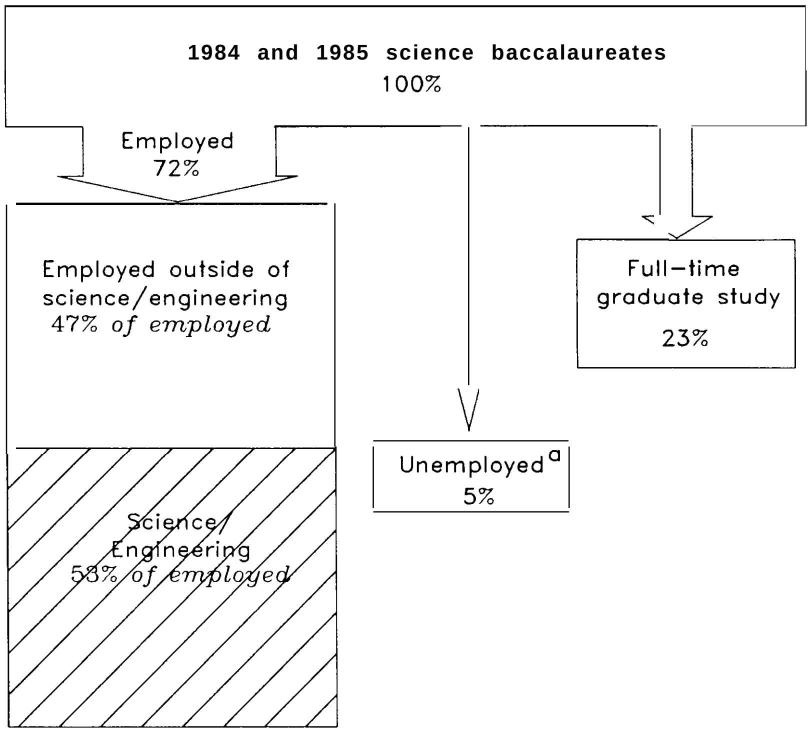
Figure 2-6.–Retention in College, by Freshman Major, 1982 Freshmen in 1986



KEY: S/E = science/engineering.

SOURCE: Kenneth C. Green, OTA contractor report, 1987, based on data from the Cooperative Institutional Research Program, University of California, Los Angeles.

Figure 2-7.-Career Paths of 1984 and 1985 Science Baccalaureates in 1986



a Includes those not in labor force.

NOTE: Total baccalaureates = 454,000 (100%)
Part-time graduate study = 36,900 (8%)

SOURCE: National Science Foundation, Characteristics of Recent Science and Engineering Graduates: 1986, NSF 87-321 (Washington, DC: 1987), pp. 20-22, 50-51, 54.

major. Institutional aid, particularly for historically Black and land-grant institutions, improves the ability of institutions to deliver a quality education.

Within this context, R&D policies have spawned some much smaller but potent science and engineering education programs to address the special needs of undergraduate science and engineering instruction. Such programs-student research apprenticeships, faculty development, and equipment and facilities support— enrich undergraduate education for a few. These supplementary programs are most often associated with specific R&D goals, and only secondarily affect educational outcomes.

The different goals of education and R&D policies have led to conflicts in developing and administering the respective programs. Higher education policies embody broad social goals of improving educational opportunities, particularly for the underprivileged. Leading-edge R&D has traditionally been a profession of a few high-achieving people and institutions, and Federal science education has targeted this elite.

The Effects of Federal R&D Policies on Undergraduate Education

Federal R&D programs affect undergraduate science and engineering education in four major ways, from indirect to direct:

- Federal R&D spending (defense and civilian) shapes the research agenda and national demand for scientists and engineers, which strongly influences undergraduates' choices of fields and careers;
- academic R&D grants develop infrastructure for science and engineering research and education, including institutions, conferences, facilities, equipment, libraries, faculty, and technicians;
- academic research grants and contracts help support and train a very few undergraduate research assistants (the training component of research grants, mostly targeted to research universities, focuses on graduate students); and
- research agencies fund a few special programs for undergraduate instruction, such as research participation, faculty enrichment, and equipment.

The effects of these research-oriented programs are concentrated at the major research universities. National R&D spending is a major determinant of the supply of baccalaureate scientists and engineers.[37]

Federal influence varies greatly by field. In engineering, where most students can plan on working in industry with a baccalaureate or master's degree, the health of the economy and perceptions of the job market shape students' educational choices. In scientific fields oriented to basic research, the job outlook for undergraduates is more sensitive to Federal programs that dominate university research agendas and Ph.D. training.

While demand for scientists and engineers depends fundamentally on R&D spending, it is also affected by economic, industrial, environmental, regulatory, energy, defense, and other policies that shape the national need for technological goods, services, and workers. The Federal Government also creates incentives, such as tax policies favoring nonprofit educational institutions, tax-free bond issues, and donations to universities and colleges. Such indirect incentives are difficult to quantify, but they clearly invigorate higher education. The government plays a symbolic role, too, in reflecting and reinforcing social attitudes toward education and science.

The National Science Board estimates total national spending for undergraduate science and engineering education is about $20 billion annually, encompassing student and institutional aid as well as special science-related programs. From this pool of money, science and engineering instruction draws about one-half of all spending on undergraduate education.[38]

Trends in the Federal Role

The Federal Government provides about one-third of all revenues of colleges and universities, and nearly two-thirds of aid to undergraduates (including guaranteed

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37. Lewis C. Solmon, "Factors Determining and Limiting the Supply of New Natural Science and Engineering Baccalaureates: Past Experiences and Future Prospects," presented at a National Science Foundation workshop, July 24, 1986. Solmon found national R&D spending and natural science and engineering salary advantage to be the top two demand factors that correlate with the supply of new baccalaureate natural scientists and engineers.

38. National Science Board, Task Committee on Undergraduate Science and Engineering Education, *Undergraduate Science, Mathematics and Engineering Education*, NSB 86-100 (Washington, DC: National Science Foundation, March 1986).

loans).[39] Through the early-1960s and early-1970s, Federal support of higher education has been increasing and shifting toward direct support of students. Recently, however, institutional and research-related support has been growing faster than student aid. In 1967, 65 percent of Federal higher education expenditures were for institutional support (largely R&D-related), with the rest allocated to student aid. By 1975, growing student aid accounted for 72 percent, and institutional support only 28 percent. In 1987, student aid has dropped to less than one-half of Federal aid for higher education.[40]

Federal policy influence in undergraduate education has been secondary to all-purpose financial support, even where Federal financial support has increased. The Federal role has been stronger in graduate education, where the links are closest to the labor market, and weaker in elementary and secondary education, where primary responsibility remains with the States and localities. States have provided most institutional "mortar and brick" support, which the Federal Government has adorned with smaller, targeted "carrot and stick" programs. In science, however, the Federal Government has had a stronger policy role than in other areas, because of its extensive support of graduate training and university development in science and engineering.

Early Federal science and engineering education policies were linked to other Federal concerns: agriculture and other practical trades (the Merrill Act of 1863 and Hatch Act of 1887); health manpower (the National Cancer Institute Act of 1937 and the Public Health Service Act of 1944); veterans' benefits (the G.I. Bill of 1944); postwar scientific development (the National Science Foundation in 1950); national defense (the National Defense Education Act of 1958); and economic opportunities (the Economic Opportunity Act of 1964).[41] With the increasing Federal involvement in higher

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39. National Center for Education Statistics, *Undergraduate Financing of Postsecondary Education: A Report of the 1987 National Postsecondary Aid Study* (Washington, DC: U.S. Department of Education, June 1988), pp. 23-27. The total Federal contribution to higher education revenues includes direct support (about 12 percent of higher education revenues), and indirect support through student aid and federally guaranteed loans (about 13 percent of revenues) and intergovernmental transfers through State and local governments (about 10 percent of revenues). These estimates are based on Lawrence E. Gladieux and Gwendolyn L. Lewis, *The Federal Government and Higher Education: Tradition, Trends, Stakes, and Issues* (New York, NY: College Entrance Examination Board, October 1987), pp. 2-3; U.S. Department of Education, Office of Educational Research and Improvement, *Digest of Education Statistics 1987* (Washington, DC: 1987), p. 229. Also see Gwendolyn L. Lewis and Jamie P. Merisotis, Trends in Student Aid: *1980 to 1987* (New York, NY: College Entrance Examination Board, 1987).
40. Gladieux and Lewis, op. cit., footnote 39.
41. Kenneth Green, 'Government Responsibility for Quality and Equality in Higher

education, targeted science and engineering education programs have dwindled in magnitude and political prominence compared to Federal student aid programs.

Financial Aid for Science and Engineering Students

Student aid is the centerpiece of Federal higher education policy. (States, by keeping tuition low at public institutions, also subsidize access to higher education.) The Department of Education administers various grant and loan programs, of which science and engineering students receive a proportionate share.[42]

Federal financial aid for college students was about $15 billion in the 1986-87 academic year; nearly $6 billion in grants, veterans aid, and work-study funds, and over $9 billion in federally financed and guaranteed loans.[43] Federal aid totals about three-quarters of all student aid. The pattern of Federal aid has changed, with loans increasing in importance (as shown in figure 2-8), and the value of Federal awards relative to college costs has dropped.[44]

Periodically there has been discussion of special Federal scholarships for undergraduates majoring in science and engineering, or in other majors where there is national need.[45] Such aid could be awarded on merit as well as (or in lieu of) financial need. In the past, the need for such scholarships was not perceived as pressing, given the large and then-expanding number of college students, and was seen by some as contrary to the Federal policy of awarding aid based on need. Precedent exists for special Federal aid for undergraduates planning to teach in areas of national need (and merit-based

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Education," *Policy Controversies in Higher Education*, Samuel K. Gove and Thomas M. Stauffer (eds.) (New York, NY: Greenwood Press, 1986), p. 88.

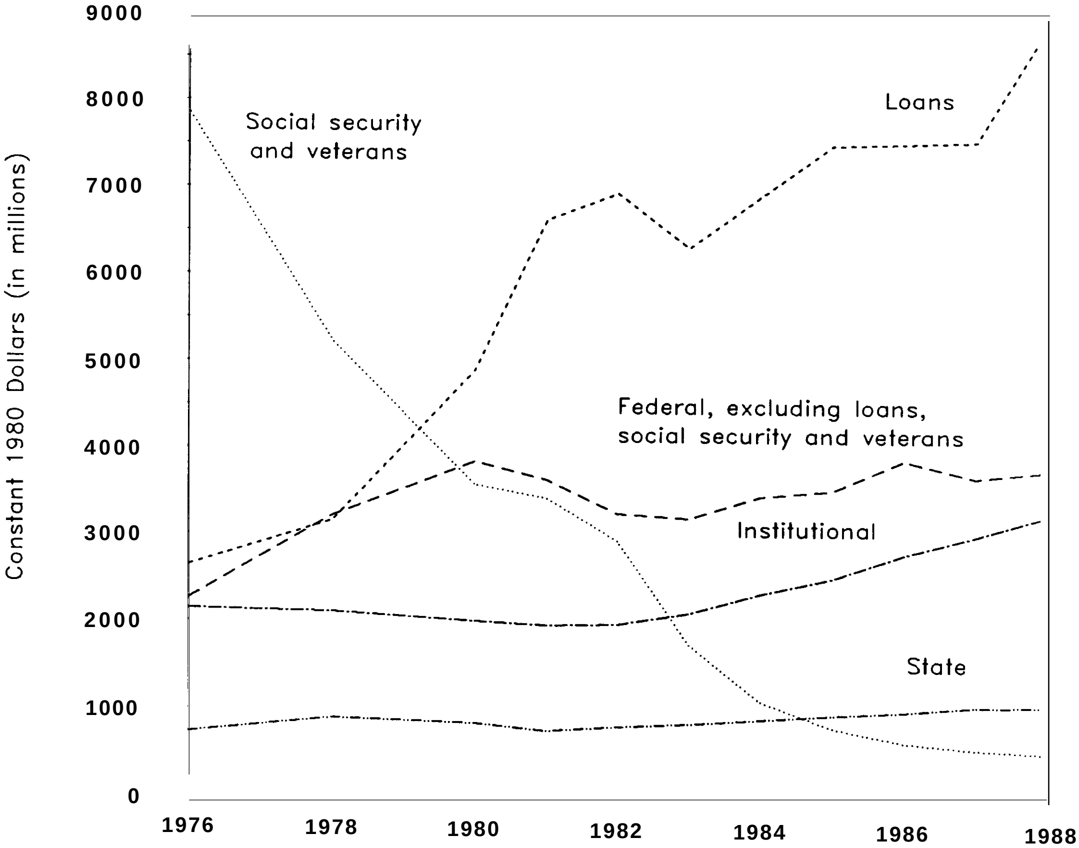
42. The major research agencies' smaller, targeted undergraduate and graduate programs for science and engineering students are discussed separately, and are not part of the "student aid" package.

43. Arthur M. Hauptman and Charles J. Andersen, "Background Paper on American Higher Education: Report to the Commission on National Challenges in Higher Education," prepared for the Commission on National Challenges in Higher Education, Washington, DC, Dec. 16, 1987, p. 12.

44. For example, James B. Stedman, *Financing Postsecondary Education Attendance: Current Issues Involving Access and Choice*, 88-315 EPW (Washington, DC: Congressional Research Service, Apr. 22, 1988).

45. Task Force on Women, Minorities, and the Handicapped in Science and Technology, *Changing America: The New Face of Science and Engineering*, Interim Report (Washington, DC: June 16, 1988). During the early years of the National Science Foundation, an undergraduate research scholars program was discussed but never implemented.

Figure 2-8.–Sources of Student Aid, in Constant 1980 Dollars, 1976–86



NOTE: Data for 1977 and 1979 are interpolated.
Data for 1988 are estimated.

SOURCE: Donald A. Gillespie and Nancy Carlson, Trends in Student Aid: 1963 to 1983 (Washington, DC: The Washington Office of the College Board, December 1983), p. 33; and The Washington Office of the College Board, "Update From Washington" (Washington, DC: The Washington Office of the College Board, February 1989), p. 7.

Federal aid has long been awarded at the graduate level for science and engineering students). The interest in subsidizing science and engineering graduates may become more pressing as the college-age population drops.[46]

The Effects of Financial Aid

Research on financial aid[47] indicates that:

- aid increases students' access to college, enrollments, their choice among institutions, and their likelihood of graduating;
- aid helps low-income students much more than it does middle-income or high-income students;
- low-achieving students (most often measured by GPA) are more influenced to pursue undergraduate study by the availability of financial aid than are higher-achieving students; and
- grants (from any source) are slightly more effective than loans and other forms of tuition reduction in increasing access, choice, and persistence. College students are more likely to stay in school when they receive substantial grants or scholarships. Students who receive grants totaling more than one-half of their tuition are less likely to drop out than those who receive no grants or Pell grants at all.[48]

The existence of aid, more than the amount, seems to be the crucial factor in expanding access and enrollments. The <u>amount</u> of aid offered becomes more significant

46. An undergraduate research scholars program could be administered by the Department of Education, the National Science Foundation, or jointly among mission research agencies, and could be leveraged through matching requirements with institutions or private sponsors.
47. Larry L. Leslie and Paul T. Brinkman, *The Economic Value of Higher Education*, (*New* York, NY: Macmillan, 1988), ch. 8; Julia A. Heath and Howard P. Tuckman, "The Effects of Tuition Level and Financial Aid on the Demand for the Advanced Terminal Degree," Economics of Education Review, vol. 6, No. 3, summer 1987, pp. 227-238. This literature review indicates that other factors affecting college attendance include student ability, cost, family income, and parental education. In one study comparing public and private sources of aid, only public grants were found to be a significant influence on college attendance, especially for lower income groups.
48. U.S. Department of Education, Office of Educational Research and Improvement data, cited in *Manpower Comments*, June 1987, p. 30; Dennis Martin, "Long-Term Implications of Student Borrowing," in College Scholarship Service, *Proceedings: Colloquium on Student Loan Counseling & Debt Management, Denver, CO, Dec. 2-4, 1985 (New* York, NY: College Entrance Examination Board, 1986), p. 59.

in students' choice among institutions, and in keeping them in college through a degree. Financial aid is becoming more important in students' decision to go to college, and where to go.

Concerns over the rising costs of education, the ability of families to pay (parents and students together pay roughly three-quarters of the total bill for college), and rising dependence on loans relative to grants (loans represent more than half the total financial assistance to college students), affects all students. Minorities show no clearcut differences from whites in how their decisions are affected by financial aid, when socioeconomic status and ability are statistically controlled. (Because minorities are much more likely to be low-income, college aid is particularly important for them.)[49]

Increasing Enrollments

The college population has expanded and diversified with the help of Federal aid, and science and engineering have shared in this expansion. Federal policies that encourage college enrollments or fuel the job market increase the number of college-educated workers, thus expanding the science and engineering talent pool. Programs specifically aimed at science and engineering training (such as the National Defense Education Act) or employment (such as the Apollo program) draw students into science and engineering, although their greatest effect is reallocating talent among some science and engineering fields.

The Federal program that boosted college attendance the most was the G.I. Bill for veterans. It increased the number of Americans with college degrees, and as a result increased the number of those with science and engineering bachelor% degrees. The education deferment of the draft, legislated in 1951, was also a boon for science and engineering, again, by increasing enrollments overall. The Vietnam draft gave a much smaller boost to the male high school graduates entering college during the mid- to late-1960s, with small derivative benefits for science and engineering.[50] (The majority

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49. A general discussion of college financing is beyond the scope of this report. See Michael S. McPherson, *How Can We Tell If Federal Student Aid is Working?* (New York, NY: College Entrance Examination Board, May 1988); Hauptman and Andersen, op. cit., footnote 43; Cynthia L. Brown et al., "High School and Beyond: Student Financial Assistance, Student Loans," prepared for MPR Associates, Inc., June 1987; and Roger Thompson, "Student Aid: Year of Uncertainty," *Editorial Research Reports,* vol. 1, No. 19, May 23, 1986, pp. 371-388.

50. U.S. Department of Corn merce, Bureau of the Census, "School Enrollment — Social and Economic Characteristics of Students: October 1976," *Current Population Reports,*

attended 2-year and vocational schools, an option that did not exist for World War II veterans.) The sharp dropoff in Vietnam veterans after 1976 coincides with a slight dropoff in the number of male science and engineering graduates.

However, attempting to increase the number of scientists and engineers by simply increasing enrollments may be a policy of the past. America has the highest participation rate in higher education in the world; more than 60 percent of high school graduates attend some college. Women attend college at the same rate as men. Minorities (except for Asians) attend at lower rates than Whites, for financial and other reasons, especially their relatively poorer preparation before college. Such factors suggest that further expansion of enrollments may be more difficult than in the past. The bottleneck may now be the preparation children get in the schools rather than college-level assistance; the need for colleges to do more and more remediation is evidence of this new problem.

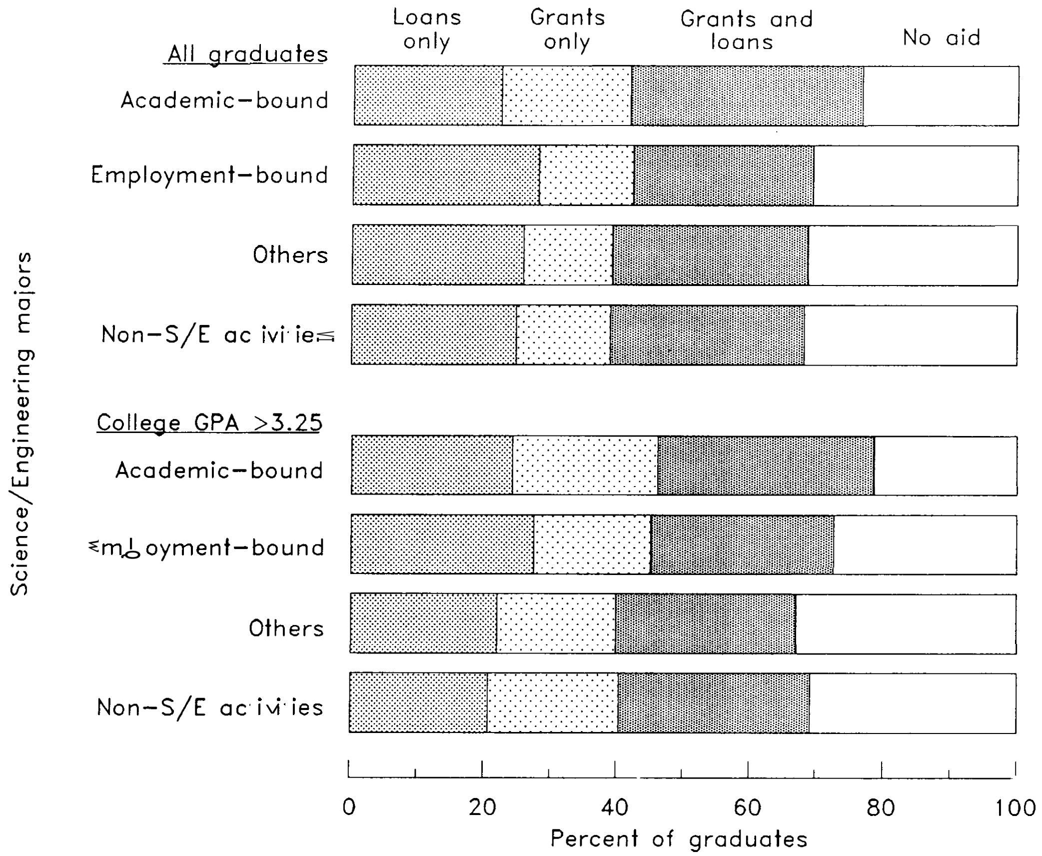
Financial Aid and Field Choice

Does availability or use of financial aid vary by major, and have changing patterns of financial aid affected students choice of major or career plans? There seems to be no strong, direct correlation. Availability of aid, and reliance on that aid, generally is unrelated to undergraduates' choice of major or career.[51] Science and engineering students are more likely to receive grants of all sorts and other campus-based aid (see figure 2-9). In part this is due to their higher than average academic ability, since much of this aid is awarded on the basis of merit. However, even when compared with students of equivalent achievement, science students are still slightly more likely to receive grants.

Series P-20, No. 319, Feb. 1978, p. 4.

51. Consortium on Financing Higher Education, *Beyond the Baccalaureate: A Study of Seniors' Post-College Plans* (Cambridge, MA: March 1983), p. i; and Applied Systems Institute, Inc., "Financial Assistance, Education Debt and Starting Salaries of Science and Engineering Graduates: Evidence From the 1985 Survey of Recent College Graduates," OTA contractor report, 1987, based on Recent College Graduate Survey data. Financial aid information reported by incoming freshmen in the University of California, Los Angeles' Cooperative Institutional Research Program survey, while not especially reliable, indicates that natural science and engineering (NSE) students are more likely than students in other majors to receive institutional aid. This is probably due to their above-average academic performance in high school (as measured by self-reported grade point average). In general, NSE majors have the same financial aid profile as their peers in other majors.

Figure 2-9.—Type of Aid Used in College by Science/Engineering Baccalaureates, by Immediate Postcollege Career Path and College GPA, 1984



KEY: GPA = grade point average.
S/E = science/engineering.

NOTE: Academic-bound are those S/E baccalaureates who go on to full-time graduate study in S/E.
Employment-bound are those S/E baccalaureates who go on to full-time employment in S/E.
Others are part-time students or part-time employees in S/E.

SOURCE: Applied Systems Institute, Inc., "Financial Assistance, Education Debt and Starting Salaries of Science and Engineering Graduates: Evidence From the 1985 Survey of Recent College Graduates," OTA contractor report, 1987.

There have been recent charges that rising student debt may be steering students inappropriately towards majors leading to more assured jobs and higher-paying careers.[52] For example, since engineers' salaries are higher than average, their ability to repay their debts is also greater; this might encourage some students to major in engineering or make them more willing to undertake debt. However, there is no analytical support for these arguments. Certainly, students' preferences in recent years have shifted towards such majors — business, prelaw, and engineering in particular. But a survey of students who were repaying loans revealed that few of them thought that their loan debt affected their choice of major.[53] And amount of educational debt and loan status are not strongly related to students' areas of study or to their average achievement.[54] Science majors have about the same average loan debt as do other undergraduates. Students of applied science (mostly engineering and computer science) are slightly more likely than humanities students to take out loans and more likely to have higher debt (see figure 2-10).[55]

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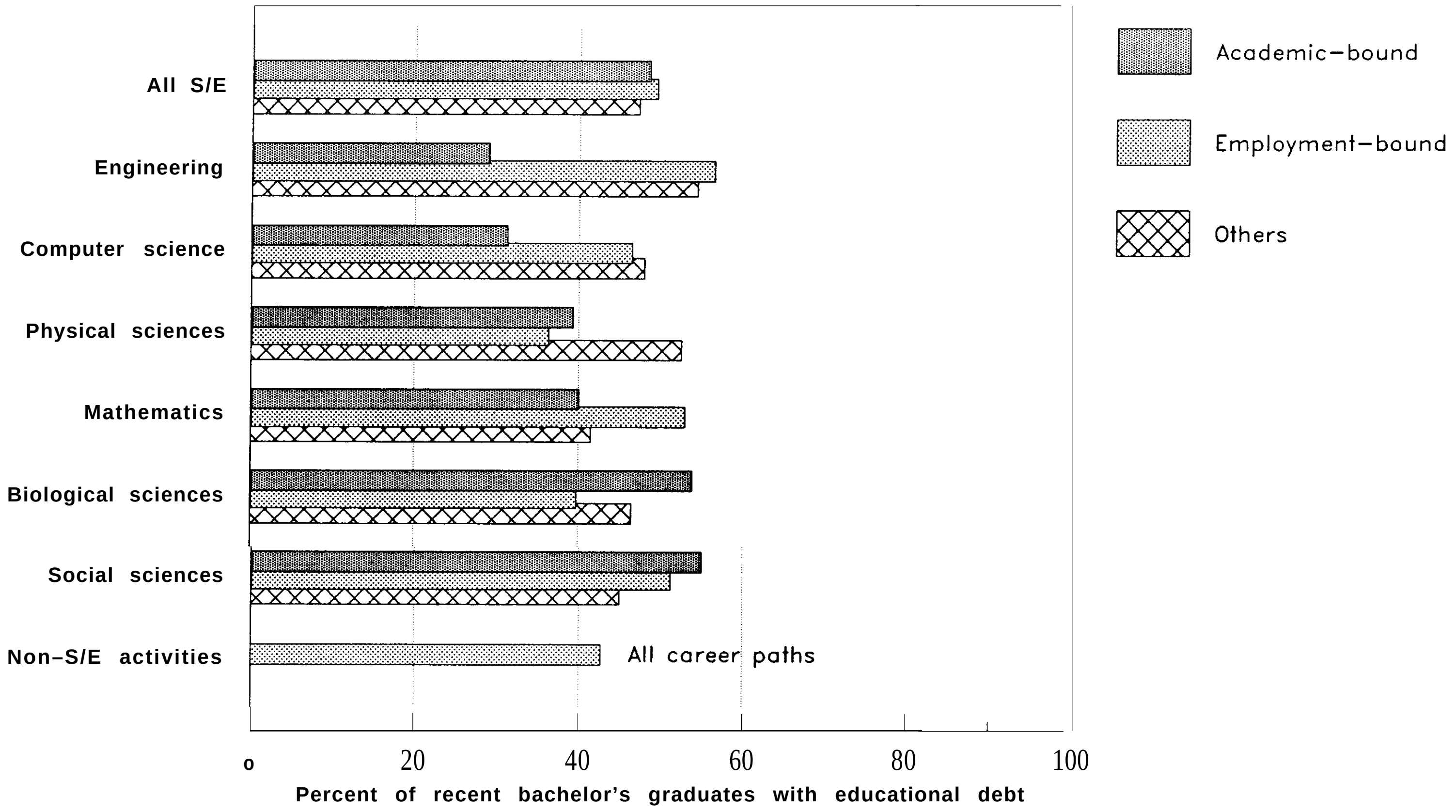
52. Kathryn Mohrman, "Unintended Consequences of Federal Student Aid Policies," *The Brookings* Review, vol. 5, No. 4, fall 1987, pp. 26-28; American Council on Education, "Student Borrowing Has Implications for Career Choice," *Fact Sheet* (Washington, DC: August 1985); and Carnegie Foundation for the Advancement of Teaching, "The Price of College Shaping Students' Choices," Change, May/June 1986, pp. 27-30.

53* National Association of Student Financial Aid Administrators, *The Characteristics of GSL Borrowers and the Impact of Educational Debt,* survey of 600 students repaying Guaranteed Student Loans in the spring of 1985, reported in Mohrman, op. cit., footnote 52, pp. 27-28; and Martin, op. cit., footnote 48, pp. 45-72.

54. Edward P. St. John and Jay Noell, "Student Loans and Higher Education Opportunities: Evidence on Access, Persistence, and Choice of Major," prepared for the NASSGP/NCHELP Research Network Conference, Washington University, June 3, 1987, pp. 17-19, based on High School and Beyond Class of 1980 data; Applied Systems Institute, op. cit., footnote 51; and Consortium on Financing Higher Education, op. cit., footnote 51, pp. i, vii. The Department of Education% National Postsecondary Student Aid Study, completed in 1988, includes extensive aid data by field of study, but field-level data have not been analyzed.

55. Consortium on Financing Higher Education, op. cit., footnote 51, p. 8; and Applied Systems Institute, Inc., op. cit., footnote 51 (based on data from the Department of Education% 1985 Recent College Graduate Survey, or RCG). The RCG results are not controlled for field differences in socioeconomic status, educational costs, etc. A 1984 Carnegie survey of undergraduate students found differences by field in the use of loans: social sciences, 42 percent; biological sciences, 42 percent; physical sciences, 33 percent; and engineering, 26 percent. About 35 percent of 1980 college graduates had some debt at graduation, with a median debt of $2,500. Thetopquartile hada debt of $3,600 at public institutions, and $5,000 at independent colleges and universities. See National Center for Education Statistics data cited in National Commission on Student Financial Assistance, *Signs of Trouble and Erosion: A* Report on Graduate Education *in America (New* York, NY: 1983).

Figure 2-10.– Education Debt of Recent Baccalaureates. by Field and Career Path, 1984



KEY: S/E = science/engineering.

NOTE: Academic-bound are those S/E baccalaureates who go on to full-time graduate study in S/E.
Employment-bound are those S/E baccalaureates who go on to full-time employment in S/E.
Other's are part-time students or part-time employees in S/E.

SOURCE: Applied Systems Institute, Inc., "Financial Assistance, Education Debt and Starting Salariesof Science and Engineering Graduates: Evidence From the 1985 Survey of Recent College Graduates, " OTA contractor report, 1987.

Students do not have to repay loans while they continue in school. Consequently, more widespread and higher debts might encourage students to go to graduate school —a desirable outcome from the point of view of science policy. There seems to be some indication, but no good evidence, that this is happening.[56] Whether high anticipated debt is a factor in students' shift towards higher-paying majors and occupations is impossible to tell. Many factors are involved in changing student preferences, not only college financing.[57]

Apart from student aid, other Federal education and human resources policies increase general access and enrollment (e.g., Title IX of the 1972 Education Amendments) by targeting special populations (women, minorities, the learning disabled, the foreign-born, or the handicapped). Although these policies have broadened the base of women and minorities in higher education, their penetration into undergraduate science and engineering has lagged their entry to the undergraduate population as a whole.

Non-Federal Support of Higher Education

Government appropriations are much more important to public institutions of higher education than to private institutions. State and local appropriations supply about 60 percent of public institutions' revenues, but only about 2 percent of private institutions', which rely much more on tuition and somewhat more on private grants and gifts. Both public and private institutions rely on Federal contracts for 15 to 20 percent of their revenue.

By far the most important actor in science and engineering higher education is the university or college itself. For undergraduates, however, institutional aid accounts for under 20 percent of aid from all sources.[58] Almost all institutional aid is based on financial need. Student aid comes out of the institution's total revenues, and generally is untraceable to its original source.

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56. Jerry S. Davis, Pennsylvania Higher Education Agency, personal communication, April 1988.

57* Blacks and Hispanics are more likely than whites to report loans as a major source of funds, but they do not report high levels of debt. The amount of debt is not related to gender, though women have less support of other types and therefore are more likely to borrow. Heath and Tuckman, op. cit., footnote 47, pp. 25, 27-28.

58. Gladieux and Lewis, op. cit., footnote 39; and Jacob O. Stampen, Student Aid and Public Higher Education (Washington, DC: American Association of State Colleges and Universities, March 1985), p. 82.

States

With State and other support, public institutions have had the fastest growing enrollments, and many have pushed into the top tier of research universities. Their substantial and rapidly growing enrollments have been the bulwark of the enrollment base for undergraduate science and engineering. State-subsidized tuition has made education available to more students, and institutional and other aid has improved the quality of education.

Much State support for higher education is subsumed under general instructional budgets.[59] Direct State support targeting science and engineering education is relatively minor and emphasizes engineering and high technology economic development. Only a handful of need and/or non-need-based programs target science and engineering; non-need-based aid includes tuition equalization, scholarships for meritorious students, and aid for particular fields such as mathematics and science or to particular groups such as veterans, medical students, or police officers (see table 2-8).

Private Support

Voluntary private support, such as grants and gifts from alumni and other individual donors, foundations, and corporations ($8.5 billion in 1987), accounts for about 7 percent of institutional expenditures. Doctorate-granting universities receive about two-thirds of all gifts (mostly private institutions), and private liberal arts colleges about 20 percent; there are no striking differences in who gives to what kind of institution. Gifts from individuals are about one-half of all voluntary support; corporations provide for roughly another one-quarter, and foundations a little less. Voluntary support of higher education has been increasing (in constant dollars).[60] Tax policies have been instrumental in encouraging private contributions and product and property donations to universities and colleges.

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59. National Commission on Student Financial Assistance, op. cit., footnote 55, p. 67; and Kenneth R. Reeher and Jerry S. Davis, '18th Annual Survey Report, 1986-87 Academic Year," prepared for the National Association of State Scholarship and Grant Programs, January 1987.

60. Liz McMillen, '28-Percent Surge in Alumni Contributions Lifts Givingto Colleges to $8.5 Billion,M *The Chronicle of Higher Education*, Apr. 13, 1988, pp. 1, A34-A36, reporting data from the Council for Aidto Education. National estimates are basedon a Council survey of a sample of 1,174 colleges and universities, together accounting for about 85 percent of voluntary support to higher education institutions.

Table 2-8. — State Scholarship Programs, 1986-87

	Undergraduate	Graduate/professional
Need-based		
No. of States:	52	22
No. of programs:	101	37
No. of awards:	1,353,166	26,100
Amt. of awards:	$1,399 million	$27.4 million
Non-need-based (merit)		
No. of States:	27	16
No. of programs:	76	29
No. of awards:	220,000	5,241
Amt. of awards:	$144 million	$11.8 million
Total amount:	$1,543 million	$39.2 million
Other[a]	42 States	unknown
	lots of awards	6,200 awards
	$500 million (est.)	$8.9 million[b]

a This combines National Association of State Scholarship & Grant programs (NASSGP) tables 6 and 7, which are partial reporting. In table 6, NASSGP programs listed include loans (Guaranteed Student Loan (GSL), PLUS, loan forgiveness for prospective teachers and health services professionals); teacher fellowships; tuition waivers; work-study; and minority programs. Table 7 lists programs administered by non-NASSGP agencies, such as loans and scholarships to aid veterans, health services students, and tuition waivers to special groups (e.g., minorities).

b This figure represents only programs that are exclusively for graduate-level students. Almost all monies are reserved for medical and dental students.

NOTE: Undergraduate, combined undergraduate/graduate, and unknown eligibility programs are combined under undergraduate for this table. The “other” heading is an underestimate, since there are additional programs listed that are funded by, for example, bond financing of unreported amounts, and there are several large (e.g., GSL loan) programs for which amounts are not reported.

SOURCE: Kenneth R. Reeher and Jerry S. Davis, *National Association of State Scholarship & Grant Programs 18th Annual Survey Report, 1986-87 Academic Year* (Harrisburg, PA: NASSGP, January 1987), pp. 11-33.

Corporations. Corporations provide more than 20 percent of the support received by colleges and universities, in 1985-86 giving about $1.7 billion to higher education.[61] Most is geared toward departmental and research grants, augmented by unrestricted gifts and a relatively small amount of direct support of students (see table 2-9). Corporate giving is concentrated in the largest companies, in manufacturing and R&D-intensive industries such as chemicals, computers, petroleum, transportation, telecommunications, and pharmaceuticals, and insurance companies and banks. Corporate gifts, like research contracts, are concentrated in the top research universities. Corporate giving has been rising steadily, accounting for about 25 percent of all private gifts to education.[62]

Direct corporate support of individual science and engineering students with scholarships is sparse, focused rather on graduate students and on select applied fields such as engineering, computer science, chemistry, and materials science. Indirect support of universities and colleges includes:

- jobs for students (most at the graduate level) working on industry research grants and contracts awarded to individual professors, departments, and joint university-industry research teams;
- employing students for credit or wages in co-op programs (mostly undergraduate engineering students) and industry-based joint research projects (mostly graduate students);
- science and engineering education projects (e.g., precollege teacher training, curricula and software development, equipment trials);
- employee's continuing education and training;
- surplus products donated as gifts, or access to corporate research or computing facilities; and
- that portion of unrestricted industry contributions used by the institution for science and engineering education.

Company-established foundations, which manage and distribute contributions for most large corporations, have been valuable in insulating the flow of charitable

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61. Council for Aid to Education, *Corporate Support of Education 1986* (New York, NY: February 1988); and ibid., p. A34. National estimates are based on a survey sample of 372 large companies, mostly Fortune 500 companies, which together account for about 37 percent of all corporate charitable contributions.
62. Paul R. Miller, Jr., Council for Aid to Education, *Business Week* (Special Advertising Section), June 22, 1987, p. 104.

Table 2-9. — Corporate Grants to Higher Education, 1986

Form of corporate support	% of total (in millions)		Amt. of support[a]	
Colleges/universities	83		$499.1	
Departmental grants		18		110.4
Unrestricted operating grants		12		70.0
Project/research grants		15		88.2
Capital grants		15		87.2[b]
Employee matching gifts		16		98.7
Student financial aid		4		25.6
Grants via consortia		3		19.0
Individuals				
Scholarships/fellowships	6		37.1	
Other[c]	10		62.7	
Total, 370 companies	99[d]		$599.0	
National Total (estimate)			$1,600.0 ($ 1.6 billion)	

aAt this level of detail, Council for Aid to Education reports data only for the comPanies actually surveyed, and does not make national estimates. These 370 companies together encompass about 40 percent of all corporate giving.

bIncludes single gift of property valued at $40 million.

cOther includes the Council for Aid to Educaton categories of grants to education-related organizations, and "other." Precollege education and economic education (mostly precollege) are not included (together just over $50 million). Unallocated funds are not included.

dDoes not total 100 percent due to rounding error.

NOTE: The data above include charitable gifts and grants only, and do not include substantial corporate contracts for research and other services. Noncash product and property gifts account for 25 to 30 percent of the total.

SOURCE: Council for Aid to Education, *Corporate Support of Higher Education **1986*** *(New* York, NY: February 1988), p. 5.

contributions from the ups and down of profits and business cycles. Tax-encouraged donations of equipment from computer companies have been invaluable in helping campuses computerize.

Foundations. Foundations gave about $1.5 billion to colleges and universities in 1986-87.[63] Foundation support for science and engineering education is mostly indirect; such support comes from various sources, including other foundations. They typically target their support by field or level of interest, e.g., Andrew W. Mellon in the humanities, Rockefeller in biology, Giles Whiting and Charlotte Newcomb for dissertations.

Foundations contributed about $280 million for natural and social sciences at colleges and universities in 1985-86, and about $150 million for research institutes (see table 2-10 and table 2-11).[64] Graduate and undergraduate student fellowships were $37 million, about 6 percent of total foundation spending in the sciences. Much of the other money went to develop programs and support research. Although foundations play a small funding role, they can have an impact in specialized areas. The Howard Hughes Medical Institute in 1987 launched a large program which includes $30 million in awards to selected undergraduate colleges for programs to attract students, particularly women and minorities, to scientific research careers.[65]

Targeted Federal Undergraduate Science and Engineering Education Programs

The National Science Foundation (NSF) has spearheaded Federal undergraduate science and engineering education activity, as the only agency with this formal responsibility, under its broader mission in science and engineering education. Several mission agencies have small programs, usually linked to their research and laboratories. The Department of Education strongly supports general undergraduate education but plays little direct part in science and engineering education.

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63. McMillen, op. cit., footnote 60, p. A35.
64. The Foundation Center, *The Foundation Directory* (New York, NY: 1986).
65. Liz McMillen, "44 Colleges to Share $30-Million to Improve Education in Biology," *The Chronicle of Higher Education*, May 25, 1988, p. A32. The spending is part of a result of a settlement of a Federal tax dispute. Other Howard Hughes Medical Institute (HHMI) spending will support postdoctoral fellowships, research experience for medical students, and a study of high school science education. A second wave of 5-year HHMI awards, to public and private universities, ranging from $500,000 to $2 million will be made in spring 1989. See *Manpower Comments*, vol. 25, October 1988, p. 26.

Table 2-10. — Foundation Support for Science, by Type of Support, 1985-86

	Social sciences (in millions)	Natural sciences (in millions)
Program development	$167.4	$125.1
Capital support	16.5	92.8
Research	103.5	77.2
Continuing support	90.9	78.9
General/operating support	50.7	17.3
Matching/challenge grant	21.8	19.4
Fellowship/scholarship	25.5	11.4
Endowment	24.4	6.7
Unspecified	13.2	7.0
Total	$332.0	$286.0

SOURCE: The Foundation Center, 1987.

Table 2-11. — Foundation Support for Science, by Recipient, 1985-86

	Social sciences (in millions)	Natural sciences (in millions)
Higher education	$129.8	$151.5
Private coll/univ	63.4	87.7
Public coll/univ	34.0	47.2
Graduate school	32.0	15.3
Community college	0.4	1.3
School	0.7	3.1
Museum/zoo	0.8	38.9
Research institute	106.1	49.0
Professional society	53.9	25.6
Medical facility	1.2	2.4
Library	8.7	14.7
Other‡	66.2	33.8
Total	$332.0	$286.0

‡Direct service agency, church/temple, community fund, governmental unit, library, performing arts group, and not specified.

SOURCE: The Foundation Center, 1987.

Led by NSF, Federal programs have supported institutional capability (equipment, facilities instrumentation, and technology), student research, college faculty, and to a lesser extent curricula and course materials. NSF undergraduate programs, like their other activities, competitively award limited resources to a select few institutions and students. Most predominantly undergraduate institutions compete for regular NSF research grants and get most of their NSF money this way. However, NSF (and the colleges) have felt the need to create special programs for undergraduates and undergraduate institutions, designed for their needs (which differ from those of the research universities — see below).

NSF and Undergraduate Education

NSF undergraduate programs target 4-year colleges that are unlikely to have strong research infrastructures (research opportunities, equipment, and faculty). Since there are more undergraduate institutions than full-fledged research universities, this has allowed NSF to spread its money widely in making research accessible to undergraduates.

NSF spending on undergraduate science and engineering education generally has paralleled its total education budget, peaking in 1965 and dropping steadily through the early 1980s. Through the 1960s and early 1970s, NSF spent about $30 million per year (over $100 million in 1987 dollars) on undergraduate science education. There is no observed correlation between spending and the number or proportion of undergraduate scientists and engineers produced. However, this is not surprising, as NSF programs have emphasized quality rather than quantity. Some past and current NSF undergraduate programs are listed in table 2-12.

In addition to NSF'S undergraduate education programs, a portion of its regular research funds supports undergraduate research assistants. Of particular relevance to undergraduate education are research funds that go to nondoctoral institutions; in 1987, $40 million from regular research programs, $14 million under Research in Undergraduate Institutions, and $1.6 million from Research Opportunity Awards.[66]

The National Science Board in 1985-86 charged a committee with reviewing needs and priorities in undergraduate science and engineering education. The committee

66. Richard Quinn and Lola Rogers, National Science Foundation, personal communications, June 1988.

Table 2-12. — Current and Past National Science Foundation Undergraduate Programs

CURRENT PROGRAMS

(coordinated by the
Undergraduate Science, Engineering, and Mathematics Education Division,
Science and Engineering Education Directorate,
National Science Foundation (NSF))

This list includes NSF programs that provide significant resources to predominantly undergraduate institutions, the undergraduate components of other institutions, and/or undergraduate students. It should be noted that undergraduate institutions and faculty get most of their NSF money by competing for funds under general NSF research and other programs. Regular research support awarded $40 million in 1987 to undergraduate institutions, and $1.5 million for research opportunity awards.

Equipment

College Science Instrumentation Program (CSIP, 1985→)
- (1 987 awards were $9.5 million)
- 2-year, matching grants for instructional instrumentation.

Instructional and Laboratory Improvement
- The umbrella under which CSIP is included, this effort also contains a component to support lab equipment for large doctorate-granting institutions to use in their undergraduate programs.

Research

Research in Undergraduate Institutions (RUI, 1982→)
- (1987 was $14.3 million)
- Research and research equipment funds for investigators at predominantly undergraduate institutions. About three-quarters goes to bachelor's and master's level institutions, the rest to Ph.D.-level institutions that offer 10 or less Ph.D.s a year.

Faculty

Undergraduate Faculty Enhancement Program (UFEP, 1988→)
- (1988 budget was $3 million)
- Supports seminars, workshops, etc., to keep current undergraduate faculty current in their field of instruction.

Student research experience

Research Experiences for Undergraduates (REU, 1987→)
- (1 987 was $11.9 million)
- ongoing grant supplements for one or two undergraduate research assistants, and site awards for developing a research program for 5-10 undergraduates.
- Open to all institutions; about 10%, or approximately $2 million, went to undergraduate institutions; the rest went to Ph.D.-granting universities.

Curriculum

Undergraduate Curriculum Development Program (1988→)
- Supports efforts to stimulate significant changes in the content and structure of undergraduate instruction in engineering and calculus. Future plans include extending the program to other disciplines.

Institutional Development

ACCESS - Career Access Program for Women, Minorities, and the Disabled
- Supports comprehensive regional centers to cover undergraduate and precollege educational activities for women and minority students.

Table 2-12 (continued)

PAST PROGRAMS

Equipment

College Research Instrumentation Program (1983-1985)

Forerunner to the CSIP (see above).

Instructional Scientific Equipment Program (ISEP, 1961-1981)

- Provided matching funds for instruments for instructional laboratories. Open to all institutions.

Faculty

College Teacher Workshops and Seminars (1956-1975)

- Supported summer conferences for undergraduate faculty.

Research Participation for College Teachers (1959-1970, and thereafter)

- Supported summer research for college faculty from small colleges.

Science Faculty Fellowships (1957-1981)

- Provided awards to faculty for sabbatical leave-type activity, for study and for research.

Student research participation

Undergraduate Research Participation Program (URP, 1959-1981)

- Provided full-time summer support plus part-time academic year support for undergraduates to work with faculty on specially designed research projects.
- At its peak in 1966 URP, supported 6,500 students with $6.8 million ($23 million in 1987 dollars).

Curriculum

Science Curriculum Improvement Program (SCIP, 1958-1972, and thereafter)

Local Course Improvement (LOCI)

- Supported development of specific courses by individual faculty.

Institutional development and planning

College Science Improvement Program (COSIP, 1967-1973)

- Provided institutional planning for predominantly undergraduate colleges and consortia; one component for consortia of 2-year colleges and universities, another for minority institutions.

Comprehensive Assistance to Undergraduate Science Education (CAUSE, 1976-1981)

- Institutional planning; open to all institutions.

Resource Centers for Science and Engineering (1978-1981)

- Four large $2.8 million awards aimed at minorities at all educational levels.

Restructuring Undergraduate Learning Environments (RULE)

SOURCE: National Science Foundation, *Undergraduate Science, Mathematics, and Engineering Education*, NSB-86-100 (Washington, DC: National Science Board, March 1986), pp. 10-12; Lola Rogers and Richard Quinn, National Science Foundation, personal communication, May 1988; and Robert Watson, National Science Foundation, personal communication, February 1989.

reviewed NSF'S history in this area, and made specific program and budget recommendations for NSF and other actors.67 The Neal Report was well received by scientists, employers, and universities, and NSF has taken up many of these recommendations (see box 2-C).

Since publication of the Neal Report, NSF has created a Division of Undergraduate Science, Mathematics, and Engineering Education (USEME) in the Science and Engineering Education Directorate, to manage its own and coordinate other undergraduate-level activities across NSF's research directorates. This initiative should increase the attention and money spent on undergraduate education; since the revival of NSF education activities in 1982-83, most of the spending has been on precollege and graduate education, with undergraduate education becoming noticeable only in 1987.[68]

Although programs have come, gone, and changed frequently, undergraduate-level spending since NSF's inception has supported three major activities: undergraduate e research; faculty research, seminars, and other professional enhancement; and instrumental ion and institutional development at predominantly undergraduate institutions. Smaller amounts have been spent on curriculum development, educational technologies, and educational research.

Student Experiences: Undergraduate Research and Cooperative Education

Undergraduate research experience provides students with invaluable first-hand appreciation of the skills and interests required to be a researcher — socialization that cannot be gained from classroom lectures. Such experience improves education and career preparation, and stimulates interest in science and graduate work.

The schools that are most productive of scientists share an emphasis on individual attention to students and to undergraduate participation in research: Caltech, Harvey Mudd, MIT, and the private liberal arts colleges. Close faculty-student interaction helps to compensate, in many cases, for a lack of extensive research facilities. The "five colleges" (Amherst, Hampshire, Mt. Holyoke, Smith, and the University of Massachusetts-Amherst) use their unique proximity to share and coordinate facilities.

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67. National Science Board, op. cit., footnote 38.
68. From 1982 through 1984, very little money was spent on undergraduate education by the National Science Foundation; since 1985, a growing amount has been spent on programs for undergraduate student research, and for faculty, research, curriculum development, and instrumentation.

This provides students (and faculty) at any one college access to a much broader array of faculty, classes, equipment, and research opportunities than would be feasible for any one college operating independently.[69]

The Federal Government also has a role in making undergraduate research possible, directly through NSF and mission agency programs, and indirectly through avenues such as research assistantships on individual investigator grants and research assistant add-ens for minority students. Many undergraduates participate in independent research outside of regular class laboratories (see box 2-D). At MIT and Caltech, nearly every undergraduate does research and/or a senior thesis.

Another variation on the theme of undergraduate research is cooperative education, in which students work for pay and college credit. Although less than 2 percent of undergraduates do formal co-ops, this mechanism is particularly important for students in engineering and business, and to a lesser extent science. Co-op alumni are more likely to receive job offers and earn higher salaries, and say that co-op education gave them a head start on workplace skills.[70] The Federal Government helped expand co-op education with institutional support mandated by Titles IV and VIII of the Higher Education Amendments.[71]

Faculty

At all levels of education, and in all sorts of institutions, students need competent, enthusiastic, accessible teachers. Teachers include faculty and graduate teaching assistants, and even fellow undergraduate tutors.[72] The quality of teaching in large part depends on the institutional environment, whether it encourages and rewards undergraduate teaching via release time for faculty to develop curricula and course materials, tenure review on teaching as well as publications, awards and recognitions for teaching, and matching good teachers to lower level courses.

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69. "Five Colleges Conference on Cooperation in Undergraduate Science Education," Amherst, MA, Nov. 13-15, 1986.
70. American Chemical Society, Survey of Chemistry Co-op Alumni, winter 1985.
71. John Dromgoole et al., Change *Management in Cooperative Education: The Expansion and Development of Title VIII Comprehensive Large Scale Co-op Programs* (Weston, MA: National Commission for Cooperative Education, n.d.). Co-op engineering education is discussed in ch. 4.
72. James H. Zumberge, "From Specialist to Generalist: The Role of the Graduate School in Strengthening Undergraduate Education," *Vital Speeches of the Day,* vol. 52, No. 10, Mar. 1, 1986, pp. 300-303.

NSF's special faculty programs have concentrated on predominantly undergraduate institutions. Faculty at undergraduate institutions usually have sparse research resources in the way of equipment or graduate students to assist in research and teaching; at a small department with few colleagues, and with most of their time devoted to teaching, most have little time for research. This is not to say that undergraduate teaching at research universities is not just as vital and in need of attention, but that some parts are easier to "fix" — equipment, faculty experiences, and other tangibles — than others.

NSF's current programs offer stipends for research, conferences, short courses, and summer professional development activities: Research in Undergraduate Institutions; research and equipment support for faculty in predominantly undergraduate institutions; Research Opportunity Awards, which fund undergraduate faculty to work with NSF grant recipients; and the recently instituted Undergraduate Faculty Enhancement, which funds seminars and workshops for undergraduate faculty. Other agencies have small, more informal programs, often as part of the link between laboratories and local colleges and universities. Faculty also benefit from institutional awards.[73]

Institutional Capability

A large part of institutional awards go to equipment, facilities, and libraries. Currently, equipment and facilities refurbishing, renovation, and replacement are considered the top priority not only for institutional health, but for the health of undergraduate and graduate teaching as well. Research and instructional equipment costs are much higher for science and engineering than for other fields. NSF has had several versions of equipment programs; its current effort is the Instrumentation and Laboratory Improvement Program (College Science Instrumentation Program). Such programs are important because it is very difficult for institutions to purchase large, high-cost equipment on regular grants or through indirect cost recovery, which goes mostly to operations and some maintenance.

Many of the formal government science and engineering education programs target minority institutions, particularly historically Black colleges and universities (HBCUs)

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73. In the words of one report: "Student needs, we believe, should be addressed by NSF primarily through support for equipment and faculty needs." American Council on Education, *Towards a National Policy for Undergraduate Science Education: With the Recommendations of the National Higher Education Associations Task Force* (Washington, DC: n.d.), p. 17. Admittedly, their vested interest is institutional, not students per se.

below). Some programs target the few institutions that have mostly Hispanic enrollments. Most of these programs fund both undergraduate and graduate education, and many are reserved for HBCUs offering graduate degrees. As with many general university programs it is difficult to separate out the effects of such programs on undergraduates.

Minority institutions have needs similar to others, except in many cases the needs are more pressing. The National Science Board identified the most pressing problems as scientific equipment, followed by faculty support, development, and recruitment.[74] These institutions also have special difficulties — high dependence on government funds, relatively poor students who cannot bring in high tuition or alumni donations, and difficulty recruiting the best Black students and faculty in competition with nationally-known universities and employers trying to meet minority recruitment goals.

NSF programs include supplements for research assistants on regularly awarded grants, Research Minority Centers of Excellence, and Research Improvement in Minority Institutions. The National Institutes of Health (NIH) has a sizeable program, supporting research centers and undergraduate (and graduate) students through its Minority Access to Research Careers program. In general, mission agencies target minority institutions, even though they may not have a formal budget to do so (although much of this activity was spurred by a series of Presidential Executive Orders.) Such alliances make a unique contribution to the undergraduate and graduate education of minorities.[75]

The Future of Undergraduate Science Education

The structure of “mainstream” higher education has changed little in the past hundred years: students still congregate on a residential campus, sit in classes taking notes from lecturers and their assistants, and compete on college sports teams. However, there have been major changes in the social setting of higher education, and many have augured significant changes in the structure of universities.

Some particularly substantial changes include mass higher education and the rise of government student aid, working women and changing family structures, the vast expansion of knowledge and the questioning of traditional curricula, and new

74. The National Science Board, op. cit., footnote 38, pp. 35-36, 50.
75. National Academy of Sciences, “Alliances: An Expanded View,” Report and Recommendations, 1987 Symposium, Sept. 23-25, 1987, unpublished manuscript.

technologies, particularly computers. The rise of community colleges and proprietary institutions is a major innovation in education. Such institutions have a growing clientele and demand for the occupational skills of their graduates. Most colleges and universities have yet to act on the recognition that these 2-year institutions are a substantial pool of students for whom they must compete: the labor market is a powerful magnet.

Computer and information technologies have already made an indelible mark on campus. Powerful multipurpose workstations, stand-alone computers, data networks, remote access supercomputers, and computerized recording and analysis equipment pervade classrooms, dormitories, offices, libraries, and laboratories. In the past 10 years, computers have evolved from novelty to a vital part of university life, relied on by faculty, administrators, and students.[76] Employers expect newly-graduated scientists and engineers to be facile in modern computing.

INSTITUTIONAL SETTINGS AND INFLUENCES ON CAREERS

Colleges have a hand in turning students on or off to science. There is evidence that some institutional settings are more effective than others in selecting and preparing high-quality undergraduates for graduate study and careers in science and engineering: Factors found in most institutions that graduate large numbers of future scientists and engineers include: dedicated teaching; a challenging technical curriculum; the availability of professional apprenticeships as researchers, teaching assistants, or co-op students; easy access to high-quality instructional and laboratory facilities; and strong personal and academic support from faculty and other students (see table 2-13). These characteristics can be replicated at other institutions, and effective institutions that provide quality education and encourage students to enter research can be supported and enhanced.[77]

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76. For example, see Sara B. Kiesler and Lee S. Sproull (eds.), *Computing and Change on Campus* (New York, NY: Cambridge University Press, 1987), esp. ch. 12, on the experiences of Carnegie-Mellon University, which did early and extensive computerization of campus, curricula, administration, and student dorms and activities.
77. For example, the legacy of the National Science Foundationfs Engineering Research Centers and the brand-new Science and Technology Centers may be their socialization of students into the culture of team research. This would be a positive educational effect in the guise of "research" and “innovation. ”

Table 2-13. — Factors Affecting the Quality of Undergraduate Science and Engineering Education

Factors	Lead actors[a]
Teaching	
• Good faculty	C/U, NSF
• Good teaching assistants	c / u
• Curriculum and materials	C/U, NSF
Professional apprenticeship	
• Research participation (includes conference presentation, etc.)	C/U, NSF, R&D
• Job or cooperative work experience	C/U, ED, PRV
• Teaching experience (tutoring, teaching assistantships)	C/U
Institutional setting and resources	
• Quality of equipment (including computers)	C/U, NSF, R&D
• Access to equipment	C/U, NSF, R&D
• Teaching and research facilities	C/U, NSF, PRV
• Libraries, conferences	C/U, NSF
Personal and academic support	
• Intervention programs	C/U, PRV
• Student peers	C/U
• Family	

a These organizations have the most direct influence or have had significant programs in the specified area. Colleges and universities clearly shape the kind of undergraduate education they offer, although their programs are often supported by State, foundation, or industry grants; and personnel, facilities, equipment, or other resources.

Key: (The most important actors are in boldface.)
C/U - individual college or university
NSF - National Science Foundation
R&D - mission R&D agencies
ED - U.S. Department of Education
PRV - private foundations or industry

SOURCE: Office of Technology Assessment, 1988.

A Diversity of Institutions

Policymaking is complicated by the diversity of American colleges and universities. Diversity is a strength of American higher education, reflecting the breadth of students and their career aspirations. America's 1,500 4-year institutions include small single-sex colleges, large public universities, world-renowned research universities, technical and engineering institutions, liberal arts colleges, and historically Black institutions. These vary in size; curricula; level and field of degrees awarded; emphasis on research, graduate, and undergraduate education; Federal research support; and selectivity of admissions. Over 40 percent of all students are enrolled in 2-year colleges, which are not yet a significant source of scientists and engineers (see box 2-l?).

While the top 100 research universities graduate over 70 percent of science and engineering Ph.D.s, those same institutions graduate less than one-half of the U.S. baccalaureates who go on for science and engineering Ph.D.s. There is no single model of the most effective institution for educating future scientists and engineers.

Research Colleges

The terms "research colleges" and "science intensives" have been used to describe a group of private liberal arts colleges that encourage undergraduate and faculty research in the sciences as well as a traditional emphasis on teaching. The environment at these small colleges values teaching, student research, and intimate interaction with a relatively small number of high-quality peers and faculty.

In 1985, a consortium of 50 private liberal arts colleges undertook a self-study that called attention to their special service to the Nation as a feeder of baccalaureate students to graduate programs in science.[78] These colleges issued a second report in 1986.[79] Known as the Oberlin Reports, they presented convincing evidence of these colleges' role as ". . . among the most productive centers of high quality [baccalaureate] education in the sciences."[80] Most of their alumni proceed into graduate study. The

78. David Davis-Van Atta et al., *Educating America's Scientists: The Role of the Research Colleges* (Oberlin, OH: Oberlin College, May 1985). "Research colleges" has become a recognizable category of institutions, though the term is not embraced even by member institutions. Another 50 colleges probably share the characteristics of those included in the Oberlin Reports. See Office of Technology Assessment, op. cit., footnote 3, pp. 56-58.
79. Sam C. Carrier and David Davis-Van Atta, *Maintaining America's Scientific Productivity: The Necessity of the Liberal Arts Colleges*, Report of the Second National Conference on "The Future of Science at Liberal Arts Colleges" at Oberlin College (Oberlin, OH: Oberlin College, March 1987).

research colleges, in short, are competitive with the major research universities in preparing undergraduate students for careers in science. But that is only part of the story.

The strength of the research colleges is, first, their selective student body. They sample from one end of the distribution, competing with (mostly private) research universities for "the best and the brightest." Beyond this incoming talent advantage, peers are instrumental in the quality of education and in social support. Also key is the college's small size — typically fewer than 2,500 students, with low faculty-student ratios. Third, they cultivate the attitude that education is an investment, and students pay handsomely for this type of education.

The strengths of the research colleges — small size and limited course offerings — are also weaknesses. They cannot cater to all students. For instance, while strong in the natural sciences, few liberal arts colleges offer a major in engineering (though many offer a "3+2" arrangement with affiliated engineering schools).

The teaching-oriented research colleges receive comparatively little Federal research support, depending more on private gifts and tuition for revenue. Most Federal funding for academic science is awarded as research grants to Ph.D.-granting universities with graduate students and extensive research facilities and staff. No Federal programs target the "research colleges" exclusively; a few small programs, primarily at NSF, focus on predominantly undergraduate institutions. The research colleges fare well in these programs, as do some of the larger comprehensive public universities and some of the smallest doctorate-granting institutions that are allowed to compete in this category. It should be noted, however, that research colleges (and other undergraduate institutions) receive the bulk of their Federal funding through regular competitive grants.[81]

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80. Ibid., p. 26.

81. Recent expansion of undergraduate programs at the National Science Foundation includes more faculty and institutional support targeted to predominantly undergraduate institutions, as well as support for undergraduate students and education at all kinds of institutions. One policy question is whether increased research funding at the research colleges (as opposed, for example, to honors programs at State universities) would increase the graduate student population in science and engineering. Rolf Piekarz, National Science Foundation, personal communication, December 1988. Also see Thomas E. Hassan and Jane E. Reynolds, "Working Class Students at Selective Colleges: Where Have They Gone?" College Bored Review, No. 146, winter 1987-88, pp. 4-9, 30-31.

Historically Black Institutions

Minority students tend not to be as well prepared as majority students for undergraduate study. Perhaps more than other students, they need a supportive academic and social environment to succeed in college, of the sort found at many historically Black colleges and universities (HBCUs). Many credit a caring, nonracist social environment, Black faculty role models, and a critical mass of Black students with the educational success of HBCUs.[82] Federal institutional aid also has kept tuition low and aid high.

One-third of all baccalaureates awarded to Blacks are awarded by HBCUs, although they enroll less than 20 percent of Black undergraduates. The HBCUs are particularly productive of natural science students, granting one-half of the mathematics B.S. degrees and 40 percent of the biological sciences and physical sciences B.S. degrees earned by Blacks in the United States (see table 2-14).[83] In 1987, however, only six of the HBCUs offered full engineering curricula. In 1983-84, they awarded 19 percent of engineering baccalaureates earned by Blacks.

Some argue that the best investment in minority talent is where that talent is concentrated—HBCUs. However, fewer Black college students are attending HBCUs.[84] Some universities are attempting to develop a supportive social and academic environment for Blacks within their mostly white campuses (see box 2-F).

The Federal Government extensively supports HBCUs, through general institutional support and research-related programs that target HBCU faculty, students, and departments.[85] Other Federal programs target minority students and faculty in all

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82. Howard H. Garrison, "Undergraduate Science and Engineering Education for Blacks and Native Americans," in Dix, op. cit., footnote 17, pp. 47-50, 53-54.

83. Gail E. Thomas, "Black Students in U.S. Graduate and Professional Schools in the 1980s: A National and Institutional Assessment," *Harvard Educational Review*, vol. 57, No. 3, August 1987, pp. 269-270.

84. Linda Darling-Hammond, *Equality and Excellence: The Educational Status of Black Americans* (New York, NY: College Entrance Examination Board, 1985), p. 14, states that historically Black colleges and universities enrolled more than one-half of all Black college students before 1970, but only 27 percent by 1980. Also see Colleen Cordes, "Colleges Try to Attract Women and Minority Students to the Sciences," *The Chronicle of Higher Education*, Nov. 16, 1988, pp. A33-34.

85. Executive Order 12320, Sept. 15, 1981, directed agencies (under the supervision of the Department of Education) to work to increase the participation of historically Black colleges and universities in all federally sponsored programs ". . . in order to advance the development of human potential, to strengthen the capacity of historically Black colleges

Table 2-14. — Baccalaureates Awarded to Black Students At HBCUs and All Institutions, by Field, 1980-81

	HBCUs	All institutions	Percent of degrees awarded at HBCUs
Natural sciences	2,145	4,923	44
Engineering	848	2,445	35
Social sciences[a]	3,109	11,423	26
Total S/E	6,012	18,791	32
All B.S.		60,673	34

[a]Includes history, archaeology and cultural studies.

NOTE: In the South (where all the HBCUs are located), 59% of all bachelor's degrees awarded to Blacks are from HBCUs, as are 61% of science and engineering bachelor's degrees.

Reliable data on degrees granted to minority students at predominantly minority institutions are difficult to secure. That is one reason for the age of the data presented here. This is OTA's best estimate based on data from the U.S. Department of Education. In recent years, more Blacks have been enrolling in non-HBCUs; however, their retention rates are still higher at HBCUs.

KEY: HBCUs = historically Black colleges and universities.
S/E = science/engineering.

SOURCE: OTA calculations, based on Linda Darling-Hammond, *Equality and Excellence: The Educational Status of Black Americans* (New York, NY: College Entrance Examination Board, 1985), p. 18. Also see William T. Trent, "Equity Considerations in Higher Education: Race and Sex Differences in Degree Attainment and Major Field From 1976 Through 1981," *American Journal of Education*, vol. 92, May 1984, pp. 280-305.

institutions (see table 2-15). Institutional support such as Title III of the Higher Education Act, insofar as it reduces tuition, helps bring college within the reach of lower-income students.[86]

State Colleges and Universities

State colleges and universities, more than 550 public 4-year institutions, enroll 4.8 million students and award two-thirds of the Nation's baccalaureates.[87] Most of higher education enrollment growth has been in public institutions, whose enrollments have gone from one-half to more than three-quarters of the national total.[88]

Many State universities were created in the last century as teacher training institutes or "normal" schools. The baby boom multiplied their enrollments and shifted their mission, along with State colleges and universities founded in the 1960s and 1970s, to comprehensive offerings of undergraduate majors, professional programs at the master's level, public service, and research. Some have become full-fledged research universities. These missions today do not always peacefully coexist.

Public institutions are more dependent on State funds, generally less selective, and less expensive to attend than private colleges and universities. They also tend to be larger. Some public institutions, required by State law to admit all resident high school graduates, reduce classes to manageable sizes by "washing out" large proportions of their freshman classes. This attrition wastes talent. Evidence suggests that many students, owing to the sheer size of classes, "fall through the cracks."[89] Large introductory sections of calculus and other gatekeeper courses probably remove science and

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and universities to provide quality education, and to overcome the effects of discriminatory treatment." See 46 Federal Register 180 (Sept. 17, 1981) (and Executive Order 12232 of Aug. 8, 1980).

86. James B. Stedman, "Title III of the Higher Education Act: Provisions and Funding," Congressional Research Service, Library of Congress, Mar. 31, 1987; Robin Wilson, "White House Woos Black Colleges, But Critics Question Motives," *The Chronicle of Higher Education,* Sept. 16, 1987, p. A27.

87. Meredith Ludwig et al., *Public, Four-Year Colleges and Universities: A Healthy Enrollment Environment?* (Washington, DC: American Association of State Colleges and Universities, and National Association of State Universities and Land-Grant Colleges, May 1986), p. iii.

88. Robert S. Eckley, "Liberal Arts Colleges: Can They Compete?" *The Brookings Review,* vol. 5, No. 4, fall 1987, p. 32.

89. Alexander W. Astin, *Achieving Educational Excellence: A Critical Assessment of Priorities in Higher Education* (San Francisco, CA: Jossey-Bass, 1985), p. 89.

Table 2-15. — Major Federal Science and Engineering Education Programs for Historically Black Colleges and Universities (HBCUs) and Minority Students

All agencies target HBCUs in their regular programs and have a range of special HBCU programs (research funding and collaborative research, faculty enhancement, student internships, guest lectures, equipment access and donations, institutional development funding) in response to Presidential Executive Orders. At some agencies these programs are gathered under one umbrella program, such as the Environmental Protection Agency's (EPA) Minority Institutions Assistance Program or the Department of Defense's (DoD) Historically Black Colleges (HBC) Council.

This list includes all higher education, both undergraduate and graduate. Major agencies are in boldface.

Key to type of program
- u - Undergraduate students
- G - Graduate students
- F - Faculty
- I - Institutional

Major Programs Targeting Minority Institutions

National Institutes of Health (NIH)
- Minority Biomedical Research Support
- Research Centers in Minority Institutions

DoD
- HBC Council
- Navy DANTES (Defense Activity for Non-Traditional Education Support)

National Science Foundation (NSF)
- Research Improvement in Minority Institutions
- Minority Research Centers of Excellence

U.S. Department of Agriculture
- 1890 institutions[a]

U.S. Department of Education (ED)
- Minority Institutions Science Improvement Program
- Howard University
- Strengthening Developing Institutions
  (Title III of the Higher Education Amendments of 1965)
  (not targeted to science/engineering, but a major program)

U.S. Department of Energy (DOE)
- Minority Institutions Research Travel Program F
- Nuclear Energy Training Program U,G, F

[a]The 1890 institutions are 16 predominantly Black land-grant universities, established under the 1890 Second Merrill Act to provide for land-grant institutions in States where Blacks were denied access to State land-grant institutions established by the first Merrill Act of 1862.

Table 2-15 (continued)

• Laboratory-HBCU joint programs (student internships, joint research, faculty exchange, facility access)	
EPA	
• Minority Institutions Assistance Program includes minority student fellowships	
National Institute of Standards and Technology (NIST) (formerly the National Bureau of Standards)	
• Graduate Engineering for Minorities	G

Major Federal Programs Targeting Minority Students or Faculty at All Institutions

Minority institutions also win agency support through other competitions. All Federal agencies, particularly DoD, vigorously recruit and hire at HBCUs, both on their own initiative and as part of the Federal Equal Opportunity Recruitment Program. Many regular Federal university, research, and fellowship programs make special efforts and achieve high minority participation, without formal set-asides or targets for minority institutions, students, or faculty.

Health and Human Services/NIH	
• NIH Minority Access to Research Careers	U,G,F
• National Institute of Mental Health Minority Fellowships	G
DoD	
• Office of Naval Research Minority Research Grants	G
NSF	
• Research Careers for Minority Scholars	u
• Engineering Supplements	u
• Minority Graduate Fellowships	G
• Minority Research Initiation	F
• ACCESS — Career Access Opportunities for Women, Minorities, and the Disabled	
National Aeronautics and Space Administration (NASA)	
• Graduate Student Researcher Program, minority focus	G
ED	
• Graduate Professional Opportunities Program (Javits Fellowships)	G
Agency Consortium	
National Physical Sciences Consortium for Graduate Degrees for Women and Minorities (NPSC) (DOE, NIST, NASA)	G

SOURCE: Office of Technology Assessment, 1988.

engineering students from the pipeline prematurely. While not attrition per se, such experiences dash hopes of a career in science or engineering.

Thus, while the quality of incoming students to State colleges and universities is diluted, these institutions appear to commit two kinds of errors — flunking out students who are capable of earning a baccalaureate degree and discouraging students from pursuing a science or engineering major. These errors are more visible in institutions that admit large freshman classes that include many students only marginally prepared — academically and emotionally — to succeed. Data on attrition, by type of institution and major, would go far to refine or correct such perceptions of "error" in the squandering of human talent.

Research Universities

One hundred or so research universities house the vast majority of academic science and engineering research. The superb resources of research universities —many excellent faculty, graduate students, researchers, facilities, libraries, and equipment — can be a boon to undergraduates if they have access to them, and if the university emphasizes undergraduate teaching along with graduate training. However, in many universities, the commitment to research and graduate education may divert attention from undergraduate education.[90] In a few cases, undergraduates constitute less than one-half of the students. Despite the preeminence of the top research universities in academic science and engineering and their dominance of graduate training, little evaluation has been done of undergraduate education at these elite institutions.

Undergraduate Origins of Science and Engineering Ph.D.s

One way to investigate the effect of undergraduate settings on science and engineering careers is to look at what types of undergraduate institutions produce the most people who go on to get science and engineering Ph.D.s.[91] OTA conducted an

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90. "Research Universities Urged to Upgrade Teaching," *The Chronicle of Higher Education, Nov. 4, 1987,* p. A19; and Roger L. Geiger, "Research Universities: Their Role in Undergraduate Education," *Contexts for Learning: The Major Sectors of American Higher Education* (Washington, DC: National Institute for Education, 1985), pp. 74-97.

91. Previous studies include: National Research Council, *Doctorate Recipients From United States Universities,* Summary Report *1984* (Washington, DC: National Academy Press, 1986), pp. 10-24; Todd C. Hanson, *Baccalaureate Origins of Ph.D.s, 1920-1980: A* New Study (Ashland, VA: Randolph-Macon College, 1986); Carol H. Fuller, *An Analysis of Leading Undergraduate Sources of Ph.D.'s, Adjusted for Institutional Size* (Ann Arbor,

analysis of institutions' "productivity" of science and engineering Ph.D.s, and also looked at trends in this institutional productivity over time.[92] Some highlights are Presented below; appendix A contains a fuller discussion of this analysis and various lists of the productive institutions.

As might be expected, the large degree-granting institutions graduate the largest numbers of baccalaureates that goon for science or engineering Ph.D.s. However, their success in undergraduate education fades somewhat when the size of study body is taken into account. Some small institutions send much higher proportions of their bachelor[s] graduates on for Ph.D.s. than do many of the largest institutions.[93]

MI: Great Lakes College Association, August 1986); M. Elizabeth Tidball, "Baccalaureate Origins of Recent Natural Science Doctorates,"*Journal of Higher Education,* vol. 57, No. 6, November/December 1986, pp. 606-620; Davis-Van Atta et al., op. cit., footnote 78; and James N. Spencer and Claude H. Yoder, "Baccalaureate Origins of College and University Chemistry Faculty in the United States," *Journal of Chemical Education,* vol. 61, September 1984, pp. 802-803. An essential element in any such analysis is controlling statistically for differences in incoming student quality or other relevant characteristics. Disentangling attributes that predispose individuals to academic achievement from organizational characteristics that reinforce those predispositions, however, is far easier said than done.

92. Betty Maxfield, "Institutional Productivity: The Undergraduate Origins of Science and Engineering Ph. D.s, " OTA contractor report, 1987. Baccalaureate degree data for academic years 1950-51, 1955-56, 1960-61, and 1965-66 (hereafter referred to in tables as 1950, 1955, 1960, and 1965) were extracted from the National Center for Education Statistics annual publications, U.S. Department of Health, Education, and Welfare, National Center for Education Statistics, *Earned Degrees Conferred* (Washington, DC: U*S. Government Printing Office, 1950-51, 1955-56, 1960-61, and 1965-66). (Baccalaureate reference points beyond 1975 would have been unreliable because a high percentage of graduates who pursued doctoral studies would still be in the Ph.D. pipeline.)

Two other data sources were used: the National Research Council's Doctorate Record File (DRF) and the Survey of Doctorate Recipients (SDR) file. The DRF is based on the annual Surveys of Earned Doctorate (SED). The SED is done in cooperation with the graduate departments of Ph.D.-granting institutions for the National Science Foundation. New Ph.D. recipients complete questionnaires that provide information on the new doctorate's demographic characteristics and employment plans. The SDR is a biennial survey of a sample of Ph.D.s in the sciences, engineering, and humanities. The sample has been studied longitudinally, and includes information on doctorates from 1930 to 1986. The SDR was designed to follow the employment patterns of Ph.D.s overtime. The active survey sample includes doctorates for the most recent 42-year time span. For example, the first SDR, in 1973, included a sample of doctorates from 1930 to 1972. The 1985 survey, however, includes doctorates from 1942 to 1984. The SDR questionnaire consists of questions on the Ph. D.fs field of employment, type of employment, primary work activity, and salary.

93. The unknown, of course, is the relative quality of the graduates from these different undergraduate environments. Their specialization by discipline, research area, and post-baccalaureate experiences are also of analytical interest.

Adjusting for size significantly changes the list of the most productive institutions. For instance, Harvey Mudd College, a small engineering-intensive liberal arts college in California, ranked 207th when the number of its graduates who went on to earn science and engineering Ph.D.s were compared to other baccalaureate granting institutions, yet its productivity based on the proportion of its graduates who obtained science and engineering Ph.D.s placed it second overall in rank.

Productivity ratios reflect the emphasis that undergraduate institutions put on science and engineering among their bachelor's degrees, as well as the aggregate quality of the undergraduate population. Institutions such as Harvey Mudd or Caltech, which focus on science and engineering, could be expected to send much larger proportions of their baccalaureates on for science and engineering Ph.D.s than could other high-quality institutions with more diverse curricula.

Most of the more productive baccalaureate institutions (adjusted for size) are private. Only three women's colleges and none of the traditionally Black institutions were in the top 100. Fourteen 'technical institutions" and 31 private liberal arts research colleges were in the top 100. OTA earmarked several groups of institutions for special analysis: technical institutions, liberal arts colleges, women's colleges, and historically Black colleges and universities.

Productive Institutions

Among the most productive of all institutions (adjusted for size) are technical schools with undergraduate curricula focusing on engineering and the physical sciences.[94] As might be expected from their emphasis on the physical sciences, all but 1 of a group of 15 of these selected for analysis were among the 100 undergraduate institutions most productive of students who earned science and engineering Ph.Ds. Two institutions stood out as particularly productive: Caltech and MIT. During the years

94. The institutions were: California Institute of Technology, Carnegie-Mellon, Case Western Reserve, Colorado School of Mines, Illinois Institute of Technology, Lehigh, Massachusetts Institute of Technology, New Mexico Institute of Mining and Technology, Polytechnic Institute of New York, Rensselaer Polytechnic Institute, Rose-Hulman Institute of Technology, South Dakota School of Mines and Technology, Stevens Institute of Technology, Webb Institute of Naval Architecture, and Worcester Polytechnic Institute. See Fuller, op. cit., footnote 91.

selected for analysis, 44 percent of Caltech and 21 percent of MIT baccalaureates went on to earn science and engineering Ph.D.s.

Institutions that serve special populations do not provide a large proportion of science and engineering Ph.D.s. For example, only 34 of the 120 women's colleges analyzed had more than 1 percent of baccalaureates obtain doctorates. Three (Radcliffe, Bryn Mawr, and Wellesley) were in the top 100 baccalaureate sources of science and engineering Ph.D.s. For most of these 120 colleges, an average of five graduates per year went on to earn science and engineering Ph.D.s.[95] Similarly, Black colleges and universities, in general, had very few graduates who went on to complete science and engineering Ph.D.s.[96] Two percent of the baccalaureates from the top-ranked Black colleges went on to earn Ph.D.s in these fields.

Trends in Institutional Productivity

Trends in students' propensity to complete sciences and engineering Ph.D.s indicates a link to Federal fellowship and traineeship dollars, and to Federal R&D spending. OTA analyzed trends in institutional productivity of baccalaureates (adjusted for size) for six time points between 1950 and 1975. The proportion of students going on for science and engineering Ph.D.s peaked in 1965. Although the analysis was limited to selected years, this peak generally corresponds to the rise and fall of generous Federal fellowship support for graduate students. Appendix B provides data on the productivity ratios of the top 100 undergraduate sources of science and engineering Ph.D.sever time.

During the rapid rise in productivity between 1955 and 1960, nearly 90 percent of institutions increased or remained stable in their productivity ratios. The most noteworthy change occurred from 1965 to 1970, when 89 percent of the top 100 institutions had a decrease in their productivity ratios.

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95. For comparison, see Tidball, op. cit., footnote 91.
96. While historically Black colleges enroll 20 percent of Black students, 40 percent of Blacks who pursue graduate study come from the historically Black institutions. See Willie Pearson, Jr., and LaRue C. Pearson, "Baccalaureate origins of Black American Scientists: A Cohort Analysis," *Journal* of Negro Education, vol. 54, No. 1, 1985,pp.24-34; and Willie Pearson, Jr., "The Role of Colleges and Universities in Increasing Black Representation in the Scientific Profession," *Toward Black Undergraduate Student Equality in American Higher Education*, M. Nettles and A.R. Theony (eds.) (Greenwich, CT: Greenwood Press, 1988), ch. 6.

The same pattern was exhibited by all types of institutions. However, the 10 most productive and the technical institutions exhibited the strongest rise and fall in productivity; the liberal arts, women's, and Black colleges a more modest peak. While not mirroring the pattern of distribution of Federal funds, the magnitude of differences in productivity among institutional types is not surprising. Most Federal R&D and fellowship dollars go to the elite research universities and doctorate-granting technical institutions.

Baccalaureate Origins of Research Scientists and Engineers

Only some science and engineering Ph.D.s go on to become productive researchers. What factors influence the decisions and preparation of those few who do continue in research careers? To understand the educational path for successful research scientists and engineers, it is important to look not just at Ph.D. production but to identify institutional settings that encourage students who continue beyond the Ph.D. to become active researchers.

The OTA analysis identified the undergraduate origins of Ph.D.s who join the science and engineering work force, looking at science and engineering Ph.D.s working in any science and engineering-related job, and at a more select group engaged in research.[97]

Looking beyond the Ph.D. to employment in science or engineering generates different information about productive educational environments than measures of Ph.D. productivity. Some key differences result from comparing institutions' "researcher productivity" rather than '[f]Ph.D. productivity":

- Ph.D. recipients from highly-productive undergraduate institutions are likely to stay in science and engineering.

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97. Maxfield, op. cit., footnote 92. Those surveyed in 1985 had received their Ph.D.s from 1 to more than 20 years previously. The analysis was limited to categories of undergraduate institutions (top 100, liberal arts, technical, women's, historically Black) rather than individual institutions. To identify science and engineering Ph.D.s working in research, and trace their educational history, a group of Ph.D.s was identified from the National Research Council's (NCR's) Survey of Doctorate Recipients file. These were then matched with the NRC% Doctorate Records file, which follows a weighted sample of Ph.D. recipients and contains information on work. The two surveys are based on different data sets and are not completely comparable. Methodological information is available in the contractor report.

- About 30 percent of Ph.D.s from these highly-productive undergraduate institutions stayed in basic or applied research.
- Baccalaureate graduates from technical institutions were more likely than graduates from other types of undergraduate institutions to pursue research careers after completing their Ph.D. degrees. Alumni of liberal arts colleges and the top 100 were comparable.
- Ph.D.s from women's and Black undergraduate institutions were much less likely to select research careers.

Tracing the educational paths of successful Ph.D. researchers from highly-productive undergraduate institutions reveals that active researchers come from graduate study at a small number of top research universities. These elite research universities, however, draw on a broader base— the successful graduates of highly-productive undergraduate institutions. The career decisions made by Ph.D. recipients are influenced as much by their college experiences as by their graduate schools.

Box 2-A. — Handicapped Scientists: The Invisible Minority

The physically handicapped — for example, deaf, blind, and those confined to a wheelchair — are an invisible minority in science and engineering. In 1984 they represented a work force of 92,000, or 2.2 percent of U.S. scientists and engineers.[1] In the view of some: "Progress has been made in the cases where the package is 'different,' women and minorities, but much remains to be done . . . when the package is 'faulty'."[2]

The problem of underutilized talent is also a problem of low expectations of teachers and stereotypical views of what a disabled person can and cannot do.[3]

> Individuals without any knowledge of what it means to be disabled make major decisions for us in the light of what they think a handicapped person is capable of doing. It starts in precollege education where some teachers discourage the disabled from attempting a career in science and continues and continues and continues. We, the handicapped, wind up in a box, the dimensions of which are not set by the inherent limitations in the vision and understanding of influential and not-so-influential educators. This squandering of human resources is an injustice second only to the concomitant exclusion of capable and competent individuals from full participation in the academic field of their choice.[4]

Since 1975, colleges and universities that receive Federal funding must make science and other courses available to handicapped undergraduates. Under the National Science Foundation's program on Research Experiences for Undergraduates, various campuses around the United States provide disabled students with summer introductions to research, encouraging them to pursue careers in science.

Programs such as that hosted by the Science Institute for the Disabled at East Carolina University, in Greenville, NC, have succeeded in improving educational opportunities, access to laboratories, and employment in science and technology for

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1. This estimate is from a National Science Foundation survey, cited by John J. Gavin, Engineering and Economics Research, Inc., testimony, Subcommittee on science, Research, and Technology, Committee on Science, Space, and Technology, U.S. House of Representatives, *Women, Minorities, and the Disabled in Science and Technology* (Washington, DC: U.S. Government Printing Office, June 28, 1988), p. 131.
2. Ibid., p. 132.
3. Virginia Stern, Project on Science, Technology and Disability, Office of Opportunities in Science, American Association for the Advancement of Science, testimony, in Subcommittee on Science, Research, and Technology, op. cit., footnote 1, pp. 92-93.
4. Gavin, op. cit., footnote 1, p. 133. Later in his testimony he observes the irony that: "Many universities appear to exploit the physical abilities of athletes who may be somewhat slow academically, but not the mental capabilities of those who may be physically limited."

handicapped students. The emphasis has been on raising the awareness of teachers and counselors and linking handicapped students and educators through various networks. [a]

Out-of-school "informal" education programs based in science centers and museums augment campus-based programs of formal instruction sensitive to the needs of the handicapped. For example, the Disabled Access program of the Exploratorium in San Francisco, begun in 1986, has been expanded through partnership with the San Francisco Volunteer Center's Youth Quest Internship Program. Youth Quest is an experimental education and community service project for middle school adolescents. An internship program trains volunteers on how to make 600 Exploratorium exhibits accessible to visitors with mobility, hearing, and vision impairments. Disabled mentors and students speak with the interns, heightening their awareness that disabilities do not diminish curiosity. [6]

Programs that bring handicapped students (of all ages) together in educational settings with scientists (disabled and others) are needed to erase stereotypes and present opportunities that create and sustain interest in research careers. Such programs bring new meaning to the familiar words "recruitment" and "retention."

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5. Michael Heylin, "Hands-On Research for Disabled Students," *Chemical & Engineering News*, Aug. 15, 1988, p. 25.
6. Ellen Lieber, "Youth Quest Interns Assess Exploratorium Exhibits for Accessibility," *ASTC Newsletter*, November/December 1988, pp. 9-10.

Box 2-B. — Retaining Hispanics and Blacks in Engineering: California's Minority Engineering Program

The California Minority Engineering Program (MEP) has dramatically improved the retention of Black and Hispanic students in engineering majors in California public universities and colleges.[1] Not only are MEP students much more likely to stay with engineering than are minorities students not in MEP, but they even outperform majority engineering students (see table below). MEP began at one institution in 1973. In 1982, the State funded the expansion of MEP to most other California university campuses. In 1986-87, about 2,500 students were in MEP.

Crucial elements of MEP — and crucial to most intervention programs — are:

- peer support, tutoring, and community building among minority students;
- academic support through science and mathematics workshops; and
- professional and personal support through participation in student organizations, summer jobs, internships, and career awareness activities.

The founder of MEP, Raymond B. Landis, emphasizes the particular importance of helping students through the freshman year, usually the most difficult phase of academic and social adjustment for minorities. His relatively low-cost programs includes in-depth, formal university and academic orientation, clustering MEP students in the same classes so they can work together on the same assignments, upper-class mentors, and a 24-hour student study center. Regular classes are supplemented with both prefreshmen bridge programs and workshops. MEP also facilitates employment and career development through summer jobs, internships, and career presentations.

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1. California Postsecondary Education Commission, "Retention of Students in Engineering: A Report to the Legislature in Response to Senate Concurrent Resolution 16 (1985)," unpublished draft, December 15, 1986; Raymond B. Landis, "The Case for Minority Engineering Programs," *Engineering Education,* vol. 78, No. 8, May 1988, pp. 756-761; and Cheryl M. Fields, "What Works: California's Minority Engineering Program," *The Chronicle of Higher Education,* Sept. 30, 1987, p. A33. See also National Action Council for Minorities in Engineering, *Improving the Retention and Graduation of Minorities in Engineering (New* York, NY: 1985).

In 1984-85, 19 California public institutions enrolled over 31,000 engineering undergraduates and awarded 5,391 engineering baccalaureates, about 7 percent of national enrollments and degree awards.

Three-Year Retention Rates of Fall 1982 Engineering Freshmen, Students in and Not in the Minority Engineering Program (MEP) (as percent of entering freshmen)

	All Students	Blacks in MEP	Blacks not in MEP	Hispanics in MEP	Hispanics not in MEP
University of California	47	64	23	57	21
California State University	67	79	30	88	41

Box 2-c. — Douglass Project for Rutgers Women in Mathematics and Science

The Douglass Project at Rutgers University's Douglass College was launched in September of 1986 to increase the number of female students in mathematics and science. The project is open to all women on the New Brunswick campus.[1]

The project sponsors peer study groups, career planning workshops, and a mentor program that includes seminars with presentations by role models in academia and industry. Target audiences are high school students, teachers, and parents. Grants are also sought for an on-campus summer institute. Douglass coordinators consider this outreach component to be the most crucial of the project because of the 9th and 10th grade science and mathematics "gatekeeper" function. Director Ellen Mappan is working with Arlene Chasek at Futures Unlimited, a support program targeting female high school students interested in science and mathematics, in developing the precollege program.

Although the Douglass Project is relatively new, the response has been enthusiastic. Over 100 students participated in the first-semester activities and suggested ideas for future Douglass Project components. Thematic study groups are especially popular. The interest generated by the project literature has even resulted in the establishment of a residence house for undergraduates. The Douglass Project is funded by a 3-year, $123,500 grant from the New Jersey Department of Higher Education's Fund for the Improvement of Higher Education. Contributions have also come from the Associate Alumnae of Douglass, the Ellis and Adrienne Anderson Science Enrichment Fund, the Provost's Excellence Fund, and the Joe and Emily Lowe Foundation.

1. Doris Kulman, "DC Project Encouraging Women in Math, Science," *Rutgers Newsletter,* Dec. 5, 1986.

Box 2-D. — The Neal Report

In 1986 the National Science Board concluded an in-depth study of undergraduate science and engineering education.[1] The report of the Task Committee identified three areas of undergraduate science and engineering education needing particular attention:

- equipping laboratories and making laboratory instruction and research an important and vibrant part of undergraduate education;
- upgrading the qualifications of faculty; and
- improving courses, curricula, and the quality of instruction.

The committee called upon all major actors — universities and colleges, States, corporations and foundations, and mission agencies — to do their part in each of these three areas. The special roles and needs of 2-year and minority institutions, and the importance of institutional diversity, were also noted. The committee recommended that the National Science Foundation (NSF) spend an additional $100 million each year on laboratory instruction, faculty enhancement, curriculum development (particularly in mathematics and engineering), research participation, instructional equipment, and minority institutions.[2] These funds and programs could be highly leveraged through matching as well as by "setting examples" for universities, States, and industry. Noting that Federal agencies and corporations focused their attention and spending on research and research-linked graduate education, the committee recommended that NSF, mission agencies, and other research sponsors find new ways to involve undergraduates and undergraduate faculty in research.

1. National Science Board, Task Committee on Undergraduate Science and Engineering Education, *Undergraduate Science, Mathematics and Engineering Education,* NSB 86-100 (Washington, DC: National Science Foundation, March 1986), known as the Neal Report after the chair of the Task Committee.
2. Since the publication of the report, continuing deterioration of conditions has increased cost estimates. National Science Foundation Director Bloch secured a promise to double the budget of his Agency by 1992. While congressional appropriations in fiscal years 1988 and 1989 were disappointing, in the context of a $2.2 to $3.0 billion budget, the Task Committee's price tag attached to their recommendations seems modest.

Box 2-E.— Undergraduate Research Participation:
U.S. Department of Energy Student Research Program

The Department of Energy (DOE), as part of its mission to develop scientists and engineers in fields relevant to DOE's mission, supports undergraduate student research. The Student Research Participation program (SRP) each year provides about 1,200 talented college juniors and seniors the opportunity to do summer research at DOE laboratories. This mentored research provides students a unique opportunity for hands-on experience as part of a research team at sophisticated facilities.

The SRP program is effective; its alumni go on to higher degrees, do research, and excel in science, engineering, and medicine. Students gain not only a professional understanding of research and career paths, but self-confidence as well.[1] Some representative comments reflect the enthusiasm of SRP students for the experience, and the lasting impact it had on their careers:

> "My participation in research efforts in immunology at Argonne was pivotal in my choice of career and contributed greatly to subsequent research efforts."

> "My appointment resulted in my attending grad school rather than becoming a medical technologist — which was my original career plan."

> "To date, I still feel that my summer with Brookhaven was the most exciting, and perhaps, most important event in my professional career."

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1. Frank M. Vivio and Wayne Stevenson, U.S. Department *of Energy Student Research Participation Program: Profile and Survey of 1979-1982 Participants* (Washington, DC: U.S. Department of Energy, January 1988). In 1987 the Department of Energy (DOE) evaluated the Student Research Participation program, looking particularly at the long-term impact on students' choice of fields and decision to go on for a graduate degree and work in research. The evaluation also investigated to what extent students' choice of degrees and research areas supported DOE'S mission research. The evaluation surveyed a sample of students who had been in the program between 1979 and 1982, thus allowing 5 or more years for long-term effects to be seen, and for transitory effects to disappear. As with all such "people development" programs, it is difficult to tell how much of the success of alumni is due to their high ability and interest coming into the program, and how much is due to the additional boost the program may give them. What is clear, however, is that the whole program, from selection of students to the research experience itself, generates a cadre of research-oriented, high-caliber scientists and engineers.

Women's decisions about the attractiveness of graduate school and their degree aspirations were much more affected by SRP than were those of men. However, the SRP group still reflects national patterns: women are much less likely than their male counterparts to plan a Ph. D., and less likely to work in the physical sciences or engineering or at a university. The SRP program also has a high proportion of minority participants, particularly Blacks.

Box 2-F. — Community Colleges: An Alternate Entry Route?

The 1,300 U.S. community colleges enroll over one-half of first-time freshman — 2 million in 1985. They fill several niches in science and engineering education. First, they provide an alternate educational route into the science and engineering pipeline for some students, by preparing them for transfer to B. S.-granting colleges.[1] Second, and most important to the overall research and development effort, they train technicians and technologists. Third, a growing part of community college services is customized retraining, primarily for industry technicians. Many community colleges have a regular contract training agreement with local companies; over one-quarter of students receive employer-subsidized job-related training.[2] In some cases State funding is prorated to provide more money for students in vocational courses, in the interest of economic development and work force training. Another, smaller role of community colleges is providing high school students with courses unavailable in their schools.

One estimate is that 5 to 15 percent of all community college students transfer to 4-year institutions.[3] About 40 percent of community college graduates transfer.[4] Transfer of students into engineering from community colleges almost compensates for attrition of freshmen and sophomores at baccalaureate-granting institutions. It is unclear, however, whether students who transfer in as sophomores or juniors from community colleges are more likely to complete a B.S. than are students who entered as freshmen.

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1. G.R. Kissler, "The Decline of the Transfer Function," *Improving Articulation and Transfer Relationships,* F.C. Kintzer (cd.) (San Francisco, CA: Jossey-Bass, 1982); Western Interstate Commission for Higher Education, *Improving the Articulation/Transfer Process Between Two- and Four-Year Institutions* (Boulder, CO: 1985); and Arthur M. Cohen and Florence B. Brawer, *The Collegiate Function of Community Colleges* (San Francisco, CA: Jossey-Bass, 1987).
2. Cheryl M. Fields, "Many Aggressive Community Colleges Focusing on Training Workers for Fast-Growing Fields," *The Chronicle of Higher Education,* Feb. 25, 1987, p. 21.
3. Richard C. Richardson, Jr. and Louis W. Bender, *Students in Urban Setting: Achieving the Baccalaureate Degree,* Association for the Study of Higher Education, cited in "Vocational Focus of 2-Year Colleges in Urban Areas Helps to Perpetuate Social Inequality, Report Says," *The Chronicle of Higher Education,* Apr. 2, 1986, p. 15. (If the 30 percent rule — of all B.S. degrees earned, 30 percent are in science and engineering — holds for transfers in, a 10 percent transfer rate means that about 60,000 (20 percent) of baccalaureate scientists and engineers each year hail from community college origins. This estimate seems high, or optimistic, depending on one's perspective.
40 Daviel D. Savage, "Com munity Colleges open Door to Education," *New York Times*, Feb. 2, 1987, letter.

This transfer opportunity is particularly important for minorities, since those Blacks and Hispanics who continue their education beyond high school are much more likely than whites to enter community colleges. The disproportionately large number of minority students who begin their collegiate careers at community colleges makes the transfer function socially imperative.[5] However, in a national perspective community colleges are not "helping" the educationally disadvantaged towards 4-year degrees. Blacks and Hispanics are much less likely to transfer out of community colleges than are whites.

A key policy question is how to help make community colleges a fertile educational environment for minorities. States with large minority populations, such as California and Florida, have established student assessment and placement programs in cooperation with 4-year institutions to prepare those who wish to transfer in pursuit of the baccalaureate.[6]

Community colleges provide an alternate, "late entry" route to the main education pipeline. Given the high percentage of minority students in community colleges and the dearth of minorities in science and engineering, this alternate route to a science or engineering degree, and therefore teaching as well as research, must be explored.[7]

States and Congress in recent years have paid increasing attention to the role of community colleges in high-technology training. Congress directed the National Science Foundation (NSF) to expand eligibility for several college assistance programs to community colleges. Legislation has proposed that NSF support and guide technician training.[8] However, programs to encourage the use of community colleges as a stepping-stone to higher degrees are much rarer.

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5. J.G. Avila et al., *Petition to Increase Minority Transfer From Community Colleges to State Four-Year Schools* (San Francisco, CA: Mexican American Legal Defense and Educational Fund, Inc.; and Public Advocates, Inc., 1983).
6. See, for example, Cheryl Fields, "Community Colleges Discover They Are at the Right Place at the Right Time/' Governing, February 1988, pp. 30-35.
7. For example, see Martin Haberman, "Alliances Between 4-Year Institutions and 2-Year Colleges Can Help Recruit More Minority Students into Teaching," The *Chronicle of Higher Education,* July 27, *1988,* p. A28.
8. H.R. 2134, introduced in April 1987 by Rep. Doug Walgren, requires the directorof the National Science Foundation to carry out an advanced technician training program, making matching grants to community and technical colleges to provide training in strategic fields. The bill was referred to the House Committee on Education and Labor.

The success of transfer programs is difficult to assess, in large part because of lack of information. Data that trace the educational paths taken by community college students would be useful to determine whether funding mechanisms might be put into place to reward community colleges for transferring students to 4-year institutions.[9]

9. Jim Palmer, "Bolstering the Community College Transfer Function: An ERIC Review," Community College Review, vol. 14, No. 3, winter 1986/1987, pp. 58-60.

Box 2--G. — Why Blacks Persist to the Baccalaureate at the University of South Carolina

The University of South Carolina has the largest percentage (14 percent) of Black students of any major, predominantly white campus in the United States. [1] The University has not only successfully recruited, but more importantly, has retained and graduated Black students. [2] Although entering Blacks had lower SAT scores and predicted grade point average, the retention and graduation rates for Black students entering in 1976-78 actually exceeded the rates for white students. This contrasts starkly with the national average, where Blacks are twice as likely to drop out. While there is no surefire recipe for success in higher education, the reasons for this uncommon occurrence at this one university are instructive:

- student involvement, including holding leadership positions in campus organizations;
- Black faculty serving as advisors to organizations in which Black students participate;
- housing arrangements that put Blacks together on campus; and
- a "critical mass" of Black students, 2,500 in this case, ensuring the opportunity for a good social life.

A poll of Black students yielded the following reasons, in order of their importance, for the University's high Black student retention rates:

1. individual perserverance;
2. family pressure and support;
3. helpful Black students;
4. helpful Black faculty and staff; and
5. special programs and the superior quality of Black student academic preparation.

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1. A.W. Astin, Minorities *in American Higher Education* (San Francisco, CA: Jossey-Bass, 1982).
2. Michael F. Welch et al., University of South Carolina, "Factors Contributing to Black Student Retention at the University of South Carolina," report of research completed under a grant from the South Carolina Commission on Higher Education, August 1987. Three Black women for every two Black men enroll at the University. Total undergraduate enrollment is 18,000.

A study concluded that Blacks enjoy a campus climate of acceptance that is relatively free of racial discrimination, especially in the classroom. They also participate in a special freshman orientation course to help them adjust to campus life.[3]

3. Ibid., p. 39. This course has led to the establishment of the National Center for the Study of the Freshman Year Experience on Campus. Elizabeth Greene, "South Carolinats Gardner: Self-Appointed Spokesman for the 'Largest Educational Minority' — Freshmen," *The Chronicle of Higher Education*, Oct. *7, 1987*, pp. A41-43. For an evaluation of the course, see Mark G. Shanley, University of South Carolina, "An Exploratory Longitudinal Study of Retention, Persistence, and Graduate Rates of Freshman Seminar Course Participants and Non-Participants at the University of South Carolina During the Period 1979 -1986," doctoral dissertation, 1987.