Nurturing Science and Engineering Talent: A Discussion Paper (1987)

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Nurturing Science and Engineering Talent:

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EXECUTIVE SUMMARY

Introduction

The Government-University-Industry Research Roundtable was created to provide a forum where scientists, engineers, administrators, and policy makers from government, universities, and industry can come together on an ongoing basis to explore ways to improve the productivity of the nation's research enterprise.

Since it first met in the fall of 1984, Roundtable Working Group One, which deals with issues relating to the development, identification, recruitment, and retention of science and engineering talent, has been examining the broad outlook for science and engineering talent. Three themes dominated the group's deliberations: the status of the science and engineering talent pool (Status), factors affecting decisions of students to pursue science and engineering careers (Career Choice), and the effectiveness of special programs to nurture science and engineering talent (Interventions and Options).

The Group compiled much of what it examined into a volume of background material, and organized a regional symposium to discuss the implications of that material. The symposium, cosponsored with the Franklin Institute in Philadelphia, was held on September 29, 1986 at the Franklin Institute.

On the basis of its deliberations, the Working Group concludes that there is cause for concern about the future adequacy of the science and engineering talent pool. Potential exists for problems with the quality and quantity of technical personnel available early in the next century, if the nation is not far sighted enough to respond to current signals.

This paper was drafted as a vehicle for discussions with organizations and individuals that have (or can have) a direct role in the policies and operation of the educational system. Through such discussion, the Working Group hopes to stimulate actions that will enhance the quality and quantity of students electing to pursue science and engineering careers. The specific actions will vary by target audience and by sponsoring group. The Working Group hopes that the sections of this paper on Career Choice and on Interventions will provide a starting point for the design of appropriate strategies for action.

A great deal of the Working Group's discussion has focused on issues at the precollege level. This is, in part, because stepping back to look at the question of the supply of science and engineering talent leads directly to early factors that influence the career choices of students. The Working Group expects its continuing deliberations to shift toward later stages of the educational pipeline.

Context

The advance of science and technology is essential to the health of the nation—essential to quality of life, to economic stability, and national security.

Human resources are key to advancing science and technology, yet the U.S. is losing its edge in the cultivation of scientific and engineering personnel.

Status

Assuming the current growth in demand in industry continues, and that demand in academe increases toward the end of this century as many current faculty retire, the demand for scientists and engineers will remain strong into the next decade.

At the same time that demand will be growing, the number of Americans qualified for science and engineering careers may be declining. A number of trends are disturbing.

The following concerns are evident regarding the supply of baccalaureates:

- The number of 22-year olds is projected to drop more than 25 percent before the end of this century. Assuming the sciences and engineering continue to attract the same proportion of youngsters as they do today, the demographic change means that, as a nation, we will graduate many fewer baccalaureates in science and engineering fields.
- A steady and significant increase in the proportion of 22-year olds that attain natural science and engineering degrees is needed if we are to maintain the current level of supply. To maintain the 1985 level in the mid 1990s, the degree award rate would have to increase by 30 percent.
- Increasing the degree award rate so far above historic levels will undoubtedly be exceedingly difficult.
    - If male degree attainment can be brought above past rates, and if female participation continues to increase, this will help.
    - Increased minority participation could raise overall degree attainment rates. However, the extent of difficulty here should not be underestimated. A very large increase in minority participation is needed if now underrepresented race/ethnic groups are to comprise more than a small percent of the total.
- The need to increase the rate at which young men and women of all backgrounds attain science and engineering degrees coincides with indications of shortages of competent science and mathematics teachers in secondary schools and with disturbing evidence of the lack of achievement of U.S. students in mathematics—a core skill for science and engineering.

For doctoral supply, the concern is primarily the declining interest of U.S. students. Foreign graduates of U.S. institutions have been able to fill the gap, but they are an unreliable resource.

- Awards of Ph.D.s over the last two decades are up in the life and computer sciences. Engineering has fluctuated—after a downturn the number of degrees is up. Mathematics and the physical sciences see fewer Ph.D.s.
    - Those recent increases that are seen are due to higher numbers of women and foreign citizens. U.S. males show declining interest in science and engineering Ph.D.s.
- Fewer U.S. students with bachelors degrees in the natural sciences and engineering are electing to continue on for Ph.D.s.
- Foreign citizens on temporary visas now earn more Ph.D.s in engineering in the U.S. than U.S. citizens. In the natural sciences, the dependence is less dramatic but also substantial—20 percent of Ph.D.s are earned by temporary visa holders.

The reliability of manpower projections is open to question. There is enough evidence, however, to cause concern about the future adequacy of the science and engineering talent pool—concern that warrants increased attention to nurturing science and engineering talent.

Career Choice

Efforts to nurture science and engineering talent should be guided by an understanding of how young people choose careers and a sense of the factors that come into play at various developmental and educational stages—in other words: Who makes what decisions, when, and why? While some factors affect the career choices of all students, other factors have special importance for underrepresented groups.

All students. Throughout a person's education and development, the expectations and encouragement of significant others, be it parents and family or other influential figures, are key.

The early years (prior to 9th grade) are critical in recruiting students to the sciences. Socioeconomic status (parental educational attainment, occupation, and income) is a strong influence at this stage affecting values and formal and informal educational activities that have a major impact on the development of children's interests and abilities.

The importance of secondary school must also be stressed. The influence of aptitude and sense of competence are critical at this stage. Particularly crucial are the decisions students make regarding enrollment in advanced mathematics courses.

Major losses to the science and engineering talent pool occur during the college years. This signals the need to pay more attention to the quality of undergraduate programs—the extent of interaction between students and senior faculty, the balance between curricula designed to weed students out and curricula designed to nurture students along, and the availability of undergraduate research experiences.

The transition from undergraduate to graduate school is another big loss point—from the educational pipeline if not from the S/E talent pool. Students' perceptions of opportunity are key here. The availability of jobs, income potential, job security, and occupational status all come into play.

Women. Early socialization that limits opportunities for girls to engage in activities that develop their scientific interest and competence is a key factor underlying women's underrepresentation in science and engineering. The remains of historic exclusion, now expressed in covert job discrimination, and conflicts between professional achievement and family responsibilities also effect women's career choices. The impact of these interrelated factors is evident in data showing that, in high school, fewer female than male students take advanced mathematics and science courses that are critical to technical careers.

Minorities. The underrepresentation of minorities is rooted in factors that add up to inadequate school achievement evident as early as elementary school. Low socioeconomic status has a major impact on the quality of schooling received and the type of educational and occupational expectations set by significant others. The limited options and opportunities perceived by many minority high school students is also significant. Provision of financial aid and attendance at predominately black institutions have a positive influence on minority access to and success in higher education.

Conclusion. Every educational and developmental stage is a potential point of intervention, and a comprehensive approach to nurturing science and engineering talent must address the whole pipeline.

INTRODUCTION

Roundtable Working Group One

The Government-University-Industry-Research Roundtable was created to provide a forum where scientists, engineers, administrators, and policy makers from government, universities, and industry can come together on an ongoing basis to explore ways to improve the productivity of the nation's research enterprise. The object is to try to understand issues, to inject imaginative thought into the system, and to provide a setting for seeking common ground. The Roundtable does not make recommendations, nor offer specific advice. It develops options and brings all interested parties together. Early on, the Roundtable Council, the group that sets the Roundtable agenda, singled out the future adequacy of the nation's science and engineering talent pool as one of the most important topics to be addressed by the organization.

Since it first met in the fall of 1984, Roundtable Working Group One, which deals with issues relating to the identification, recruitment, and retention of science and engineering talent, has been examining the broad outlook for science and engineering (S/E) talent. (Appendix I lists the members of the Working Group.) There has been special focus on particular topics, e.g., foreign students and the participation of underrepresented groups, but on the whole, three themes dominated the Group's deliberations: the status of the S/E talent pool (Status), factors affecting decisions of students to pursue science and engineering careers (Career Choice), and the effectiveness of special programs to nurture science and engineering talent (Interventions and Options).

Status of the Science and Engineering Talent Pool. The Working Group has been trying to better understand the implications of the myriad reports and predictions about the future health of the S/E talent pool. Rather than manpower forecasting, the effort has been to make a general and long range assessment of whether there is cause for concern about the quality and quantity of S/E talent. The assessment has looked at trends by broad field, but no effort has been made to examine phenomena discipline by discipline.

Career Choice. The Group focused its attention on learning more about the dynamics of the flows in and out of the talent pool and understanding the forces influencing individual's decisions to pursue or not to pursue scientific or technical careers. In other words: Who makes what decisions, when, and why?

Interventions. Many programs and activities have been undertaken by a variety of institutions and groups in the various sectors to promote the development of S/E talent. Working Group One wanted to learn more about these interventions—their range, scope, effectiveness, and what makes them work.

A great deal of the Working Group's discussion has focused on issues at the precollege level. This is, in part, because stepping back to look at the question of the supply of science and engineering talent leads directly to early factors that influence the career choices of students. The Working Group expects its continuing deliberations to shift toward later stages of the educational pipeline.

Symposium

The Group compiled much of what it examined into a volume of background material, and organized a regional symposium to discuss the implications of that material. The symposium, cosponsored with the Franklin Institute in Philadelphia, was held on

September 29, 1986 at the Franklin Institute. (A copy of the agenda is provided in Appendix II). The audience, drawn from Delaware, New Jersey, and Pennsylvania, was a diverse group of professionals and policymakers.

The key questions for the symposium were:

- Do trends indicate a need for increased efforts to develop, attract, and retain science and engineering talent?
- If so, how can current efforts be improved and expanded? What new efforts need to be undertaken?

On the basis of its deliberations and the discussion at the symposium, the Working Group concludes that there is cause for concern about the future adequacy of the science and engineering talent pool. Potential exists for problems in the quality and quantity of technical personnel early in the next century, if the nation is not far sighted enough to respond to current signals.

SCOPE AND PURPOSE OF THIS PAPER

This discussion paper, incorporating the highlights of the background material and the insights gained during the symposium, is intended to serve two functions: (1) a report on the symposium and (2) a vehicle for provoking further discussion of the subject. This is a working document, drafted for purposes of promoting further discourse on the issues. The Working Group expects that meeting with other groups to discuss this paper will sharpen and deepen its own understanding of the issues. More importantly, the Group hopes to stimulate action on the part of the individuals and organizations it meets with—individuals and organizations that have (or can have) a direct role in policies and operation of the educational system. The specific actions to enhance the quality and quantity of students electing to pursue science and engineering careers will vary by target audience and by sponsoring group. The Working Group hopes that the sections of this paper on Career Choice and on Interventions will provide a starting point for the design of appropriate strategies for action.

This paper, like the background material and the agenda of the symposium in Philadelphia, is organized around the three themes cited above—Status, Career Choice, and Interventions.

THE IMPORTANCE OF SCIENCE AND ENGINEERING TALENT TO THE NATION

Drawing on the Working Group One deliberations, and the presentations of Morris Tanenbaum and Erich Bloch during the symposium, two themes emerge with regard to the importance of science and engineering talent to the nation: the advance of science and technology and international competitiveness.

Advance of Science and Technology

The possibilities in science and technology challenge the imagination in many fields. Materials, microelectronics, photonics, software, and the control of genetically based and infectious diseases are just a few examples. The developments in these fields will promote not only our business enterprise but almost all our other activities as well, including education, health care, the home, the environment, and recreation. Moreover, beyond quality of life, the advance of science and technology is critical to national security.

International Competitiveness

We are part of a global economy, and we face challenges from other parts of the world. To meet those challenges we must use our material and human resources more effectively. The competition in the economic sphere is paralleled by competition in research itself. Our scientific and technical leadership rests on the availability, and on the quality, of our science and engineering personnel.

Historically, the United States has enjoyed a significantly more R&D intensive work force than other developed countries. But the gap is closing. As Figure 1 shows, other countries are catching up with us with respect to the proportion of their labor forces that are engaged in R&D.

A look at international comparisons of fields in which students receive their advanced degrees helps explain how these countries have narrowed the differential. While there are problems with international comparisons of degrees (there are significant international differences in the proportions of various populations that receive advanced degrees and differences in structures and qualities of educational systems) the contrasts are telling as a gauge of priorities. Figure 2 shows that among five industrialized countries, although it generally leads in absolute numbers, the United States awards the smallest proportion of first university degrees in science and engineering. (Japan runs very close to the U.S. in the number of engineers it graduates.) The picture for doctoral degrees is more complex. As shown in Figure 3, both the United Kingdom and France award higher proportions of doctoral degrees in the natural sciences; both the United Kingdom and Japan award higher proportions of doctoral degrees in engineering.

THE STATUS OF THE SCIENCE AND ENGINEERING (S/E) TALENT POOL[1,2]

Demand

As shown in Figure 4, demand for scientists and engineers has far outstripped the average increase in U.S. employment. Despite that, current employment patterns of scientists and engineers do not indicate a supply problem except perhaps in engineering[3] and computer science. Figure 5 shows the underutilization rate (unemployed plus underemployed) for different fields of science and engineering.

The important question, however, is what will happen into the next century, and the signs point to significantly higher demand. The number of white collar jobs will soon exceed the number of blue collar jobs. This implies increasing competition among professions for educated personnel.[4] Moreover, employment in science and engineering is expected to continue to rise at rates higher than the average employment rate. **The Bureau of Labor Statistics forecasts that over the next decade, civilian employment of scientists and engineers may grow by 40 percent.**

If current trends continue, a large proportion of that growth will be in industry. As shown in Figure 6, the number of scientists and engineers employed in industry increased by 60 percent in not much more than one decade.

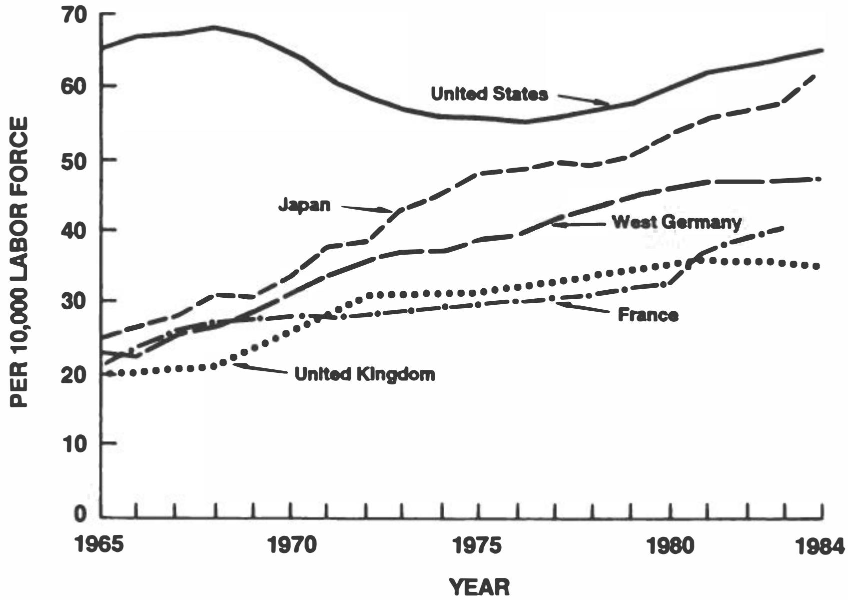


FIGURE 1 – Scientists and Engineers Engaged in Research and Development per 1000 Labor Force by Country. Source: Figure taken from presentation by Erich Bloch at the symposium "Nurturing Science and Engineering Talent," September 29, 1986, The Franklin Institute, Philadelphia; source cited is the National Science Foundation, Division of Science Resources Studies.

Other countries are rapidly catching up with the United States in the proportion of their labor forces devoted to R&D.

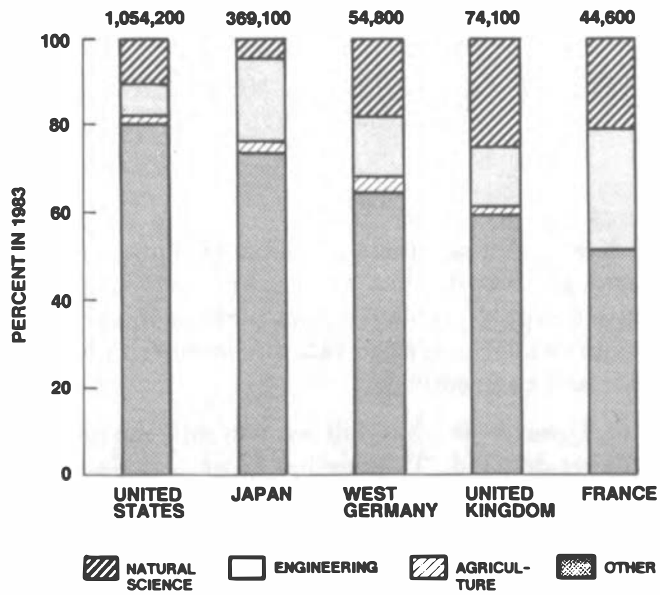


FIGURE 2 – International Comparisons of First University Degrees by Field. Source: Figure taken from presentation by Erich Bloch at the symposium "Nurturing Science and Engineering Talent," September 29, 1986, The Franklin Institute, Philadelphia; source cited is the National Science Foundation.

Among industrialized countries, the United States awards the smallest proportion of degrees in S/E fields.

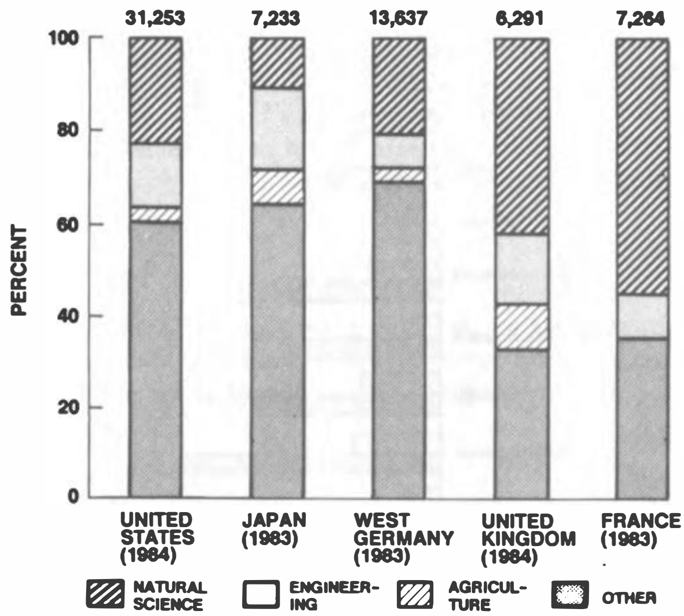


FIGURE 3 – International Comparisons of Doctoral Degrees by Field. Source: Figure taken from presentation by Erich Bloch at the symposium "Nurturing Science and Engineering Talent," September 29, 1986, The Franklin Institute, Philadelphia; source cited is the National Science Foundation.

The United Kingdom and France award higher proportions of doctoral degrees in the natural sciences; the United Kingdom and Japan award higher proportions of doctoral degrees in engineering.

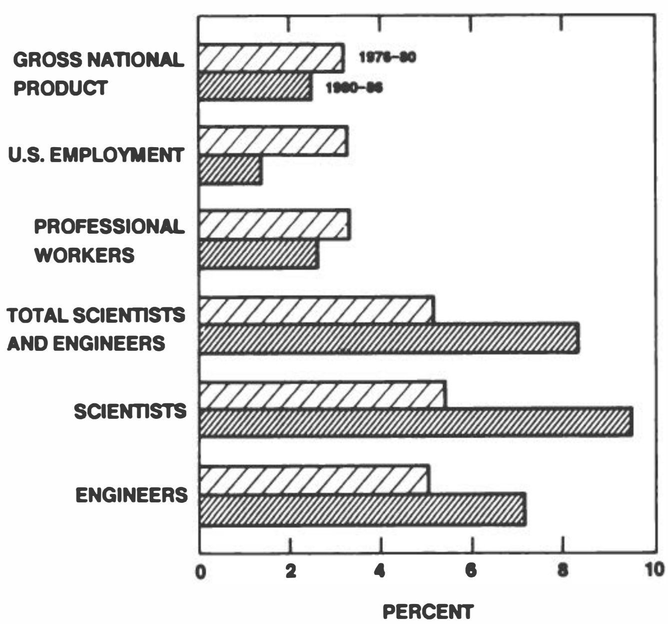


FIGURE 4 – Average Annual Growth in Science and Engineering Employment and other Manpower and Economic Variables. Source: Division of Science Resources Studies, National Science Foundation.

The rise in the demand for scientists and engineers has far outstripped the average increase in U.S. employment.

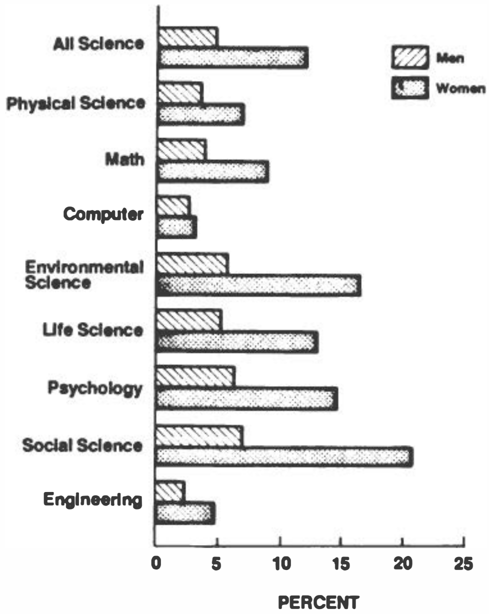


FIGURE 5 – Underutilisation Rate for Scientists and Engineers, by Sex, 1984. Source: *U.S. Scientists and Engineers: 1984*, National Science Foundation, Table B-15, pp. 146-152.

***Current* employment patterns indicate few supply problems.**

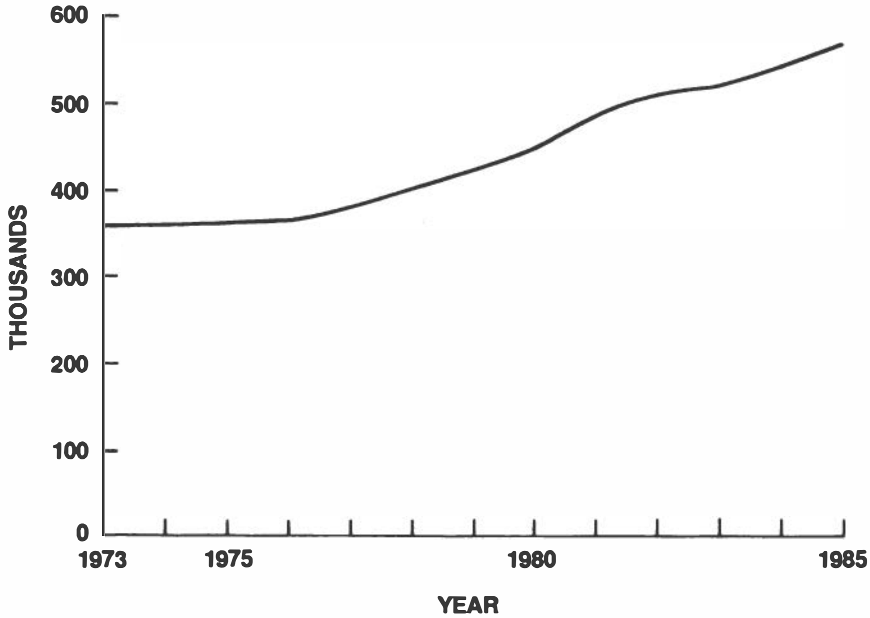


FIGURE 6 – R&D Scientists and Engineers in Industry. Source: Figure taken from presentation by Erich Bloch at the symposium "Nurturing Science and Engineering Talent," September 29, 1986, The Franklin Institute, Philadelphia; source cited is the National Science Foundation, Division of Science Resources Studies.

The number of scientists and engineers employed in industry increased by 60 percent in not much more than one decade.

In the academic area, a combination of faculty and student demographics will lead to a weak academic market for new Ph.D.s over the next decade. After the mid to late 1990s, however, increases in enrollments and faculty retirements are expected to lead to a significant increase in academic demand in science and engineering.[5] Figure 7, showing the high proportion of full-time faculty with tenure and the falling proportion of faculty with recent Ph.D.s, suggests an aging faculty and points to the projected strong increase.

Supply

At the same time as we are faced with growing demand, we are potentially faced with declining numbers of Americans qualified for S/E careers. A number of trends are disturbing. The potential impact of trends on baccalaureate and on doctorate production will be discussed separately.

Baccalaureates

The major factors affecting the production of natural science and engineering (NS&E) baccalaureates appear to be: (1) demographics, i.e., the falling number of students in the college-going age group, (2) participation rates, i.e., until quite recently, the relatively static percentage of 22-year olds attaining degrees in the natural sciences and engineering, and (3) precollege concerns, i.e. indications of some shortages of science and mathematics teachers in the secondary schools and discouraging performance by U.S. students relative to students in other countries. As background, it is helpful to look first at the trends in degree acquisition.

Degree Acquisition Trends. Degree acquisition trends are presented by field and by sex, race, and citizenship. Figure 8 shows the patterns of baccalaureate attainment in six major fields over the last two decades. As indicated:

- Fewer students are getting degrees in the social sciences, the life sciences, and mathematics.[6]
- Degrees in the physical sciences have held fairly steady.
- Engineering and the computer sciences alone see an increase.

Figures 9, 10, and 11 lump engineering and the natural sciences together to look at trends by sex, race, and citizenship. They show that:

- Women are increasing their participation but remain significantly underrepresented;
- The increase in the participation of underrepresented minorities is noticeable, but it is over such a small base that the significance of the increase dims.
- Foreign citizens do not earn a large share of NS&E degrees at the baccalaureate level (note, engineering has the highest foreign participation rate at the baccalaureate level—eight percent).

Demographics. The decline in the the college-going age group is the most significant trend at the baccalaureate level. As shown in Figure 12, the number of 22-year olds is projected to drop more than 25 percent before the end of this century. Assuming the sciences and engineering will continue to attract the same proportion of youngsters as they do today, the demographic change means that, as a nation, we will graduate fewer baccalaureates in these fields. Figure 13 provides a sense of the dimensions of the shift.

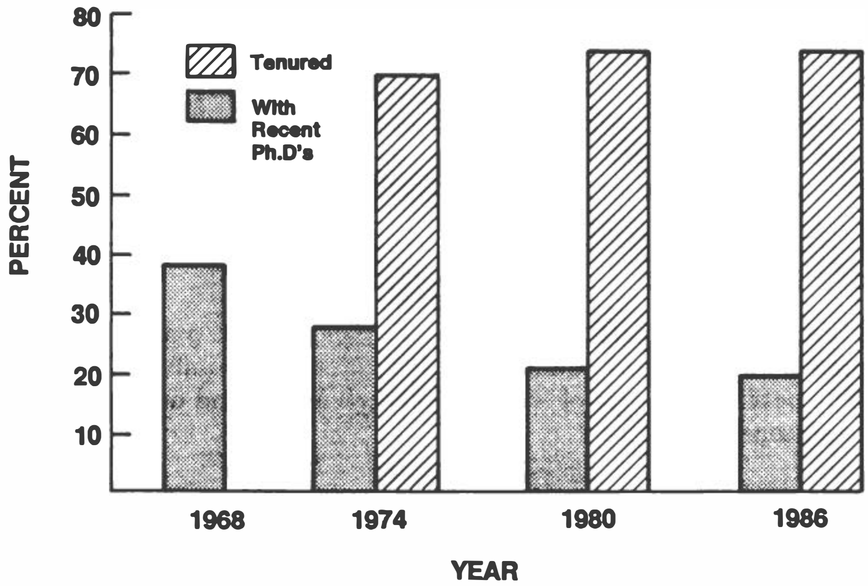


FIGURE 7 – Full-Time Faculty at Doctorate-Granting Institutions. Source: Figure taken from presentation by Erich Bloch at the symposium "Nurturing Science and Engineering Talent," September 29, 1986, The Franklin Institute, Philadelphia; source cited is the National Science Foundation, Division of Science Resources Studies.

The high proportion of full-time faculty with tenure and the falling proportion of faculty with recent Ph.D.s suggests an aging faculty.

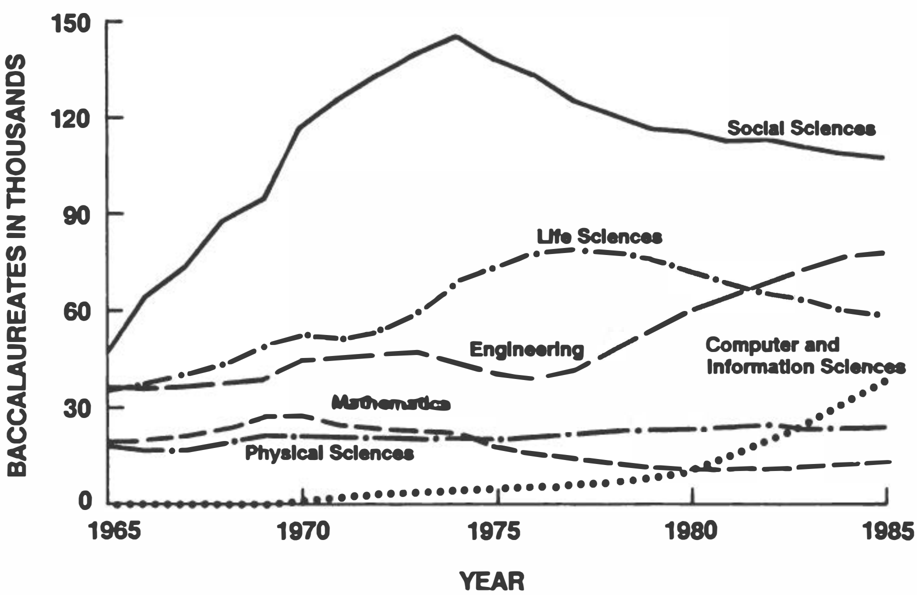


FIGURE 8 – Science and Engineering Bachelor's Degrees by Major Field Group. Source: Data provided by the Division of Science Resources Studies, National Science Foundation, source cited is the National Center for Education Statistics, Department of Education.

Fewer students are getting degrees in the social sciences, the life sciences, and mathematics. The physical sciences are fairly static. Engineering and the computer sciences see increases.

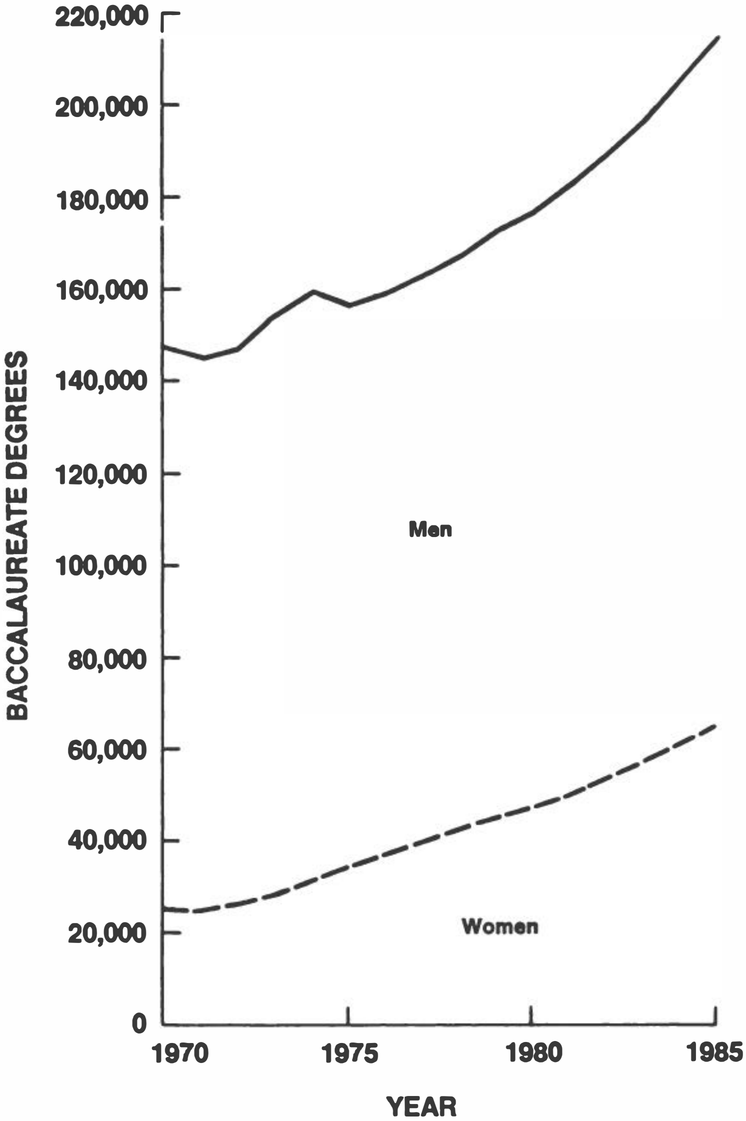


FIGURE 9 – Natural Science and Engineering Baccalaureates by Sex, 1970-1985. Sources: Data taken from *Women and Minorities in Science and Engineering*, National Science Foundation, January 1986, Table 48, pages 167-168; sources cited are National Center for Education Statistics and National Science Foundation. Data for 1984 and 1985 obtained directly from the Science Resources Studies Division, NSF.

Women are increasing their participation but remain significantly underrepresented.

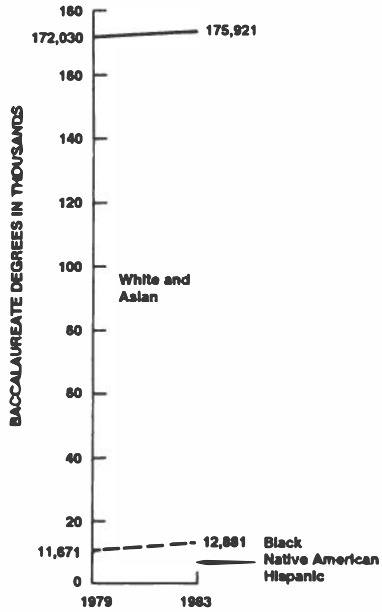


FIGURE 10 – Natural Science and Engineering Baccalaureates to U.S. Citizens and Permanent Residents Reporting Race/Ethnic Status, 1979 and 1983. Source: Data taken from *Women and Minorities in Science and Engineering*, National Science Foundation, January 1986, Table 52, pp. 175-177; source cited is National Center for Education Statistics.

The increase in the participation of underrepresented minorities is noticeable, but it is over such a small base that the significance of the increase dims.

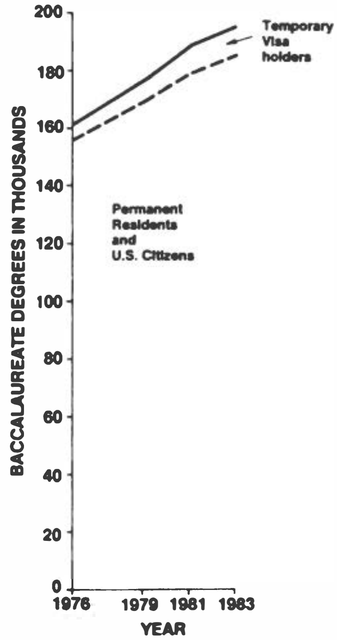


FIGURE 11 – Natural Science and Engineering Baccalaureates by Citizenship, 1976 to 1983. Data taken from *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook*, Division of Science Resources Studies, National Science Foundation, 1985, table B.7, page 133; source cited is National Center for Education Statistics, Department of Education.

Foreign citizens do not earn a large share of NS&E degrees at the baccalaureate level.

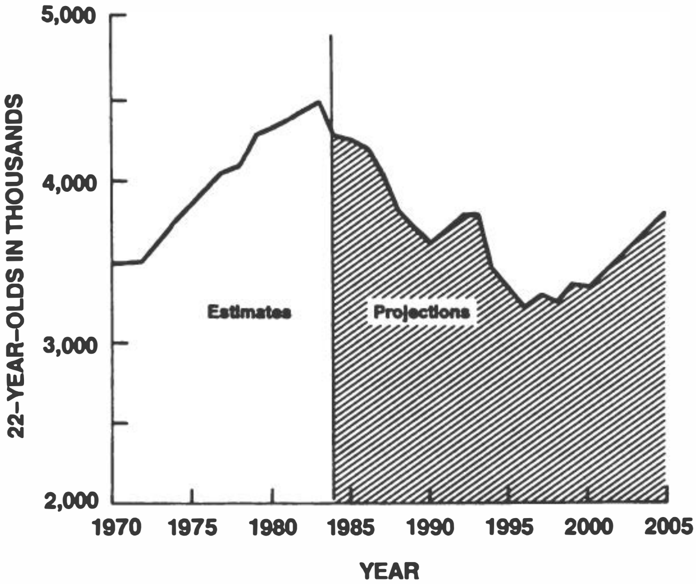


FIGURE 12 – 22-Year Olds in U.S. Population, Estimates and Projections, 1970-2005. Source: Department of Commerce, Bureau of the Census, *Projections of the Population of the United States by Age, Sex, and Race, 1983 to 2080*; Current Population Reports Series P-25. No. 952 and *Preliminary Estimates of the Population by Age, Sex, and Race, 1970 to 1981*; Current Population Reports Series P-25, No. 917.

The number of 22-year olds is projected to drop more than 25 percent before the end of this century.

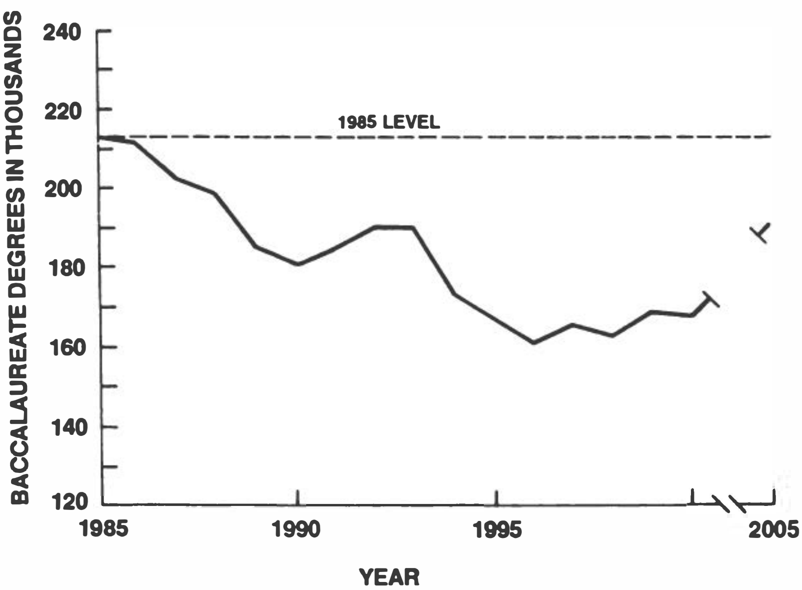


FIGURE 13 – Future Natural Science and Engineering Baccalaureates Assuming Continuation of Current (1985) Degree Attainment Rates. Source: Bureau of the Census, Department of Commerce; National Science Foundation; and National Center for Education Statistics, Department of Education.

Unless a greater proportion of the undergraduate population is attracted to NS&E fields, the number of NS&E degrees will decline.

Participation Rates. **A significant steady increase in the rate at which 22-year olds attain natural science and engineering degrees is needed if we are to maintain the current level of supply.** (While the 1985 level of degree attainment is used somewhat arbitrarily, as the most recent year for which data are readily available, it serves as a convenient point of contrast for making projections.) Is such an increase likely? Past rates give some clues. As shown in Figure 14, the average rate at which 22-year olds have earned natural science and engineering degrees has increased significantly in recent years, after being fairly static for over a decade. The current upturn in the trend is due to larger numbers of engineering and computer science graduates. There is no reason to think the average rate was artificially low during the 1970s. In fact, if the post-Sputnik flurry of science education materials had an impact, the rate would be above average during the period shown. To maintain the 1985 volume, the participation rate would have to increase to about 65 per thousand 22-year olds after running between 40 and 50 per thousand for the last 15 years. Increased demand will put added pressure on the supply of talent.

Looking at the rates for women and men separately (again in Figure 14) provides some, albeit limited, hope for improvement. For men we see a very recent return to past participation rates after a long decline; for women we see a fairly steady increase. If the progress in integrating women into science and engineering continues, and if male participation can be brought up over past rates, the number of baccalaureates graduated in the natural sciences and engineering will be higher than that projected by straight extrapolation of current rates. Nonetheless, increasing participation rates so far above historic levels will undoubtedly be exceedingly difficult.

Minorities represent a significant, growing, and largely untapped pool of science and engineering talent. Figure 15 shows the notable increase that is expected in the population of minority 22-year olds in the thirty years between 1975 and 2005—up from 14 percent of the population to 20 percent. Currently, (1983 data) only 1.6 percent of minority youths (black, Hispanic, and Native American 22-year olds) earn baccalaureate degrees in natural science or engineering compared to 5 percent of white and Asian 22-year olds. As shown in Figure 16, if currently underrepresented minorities attain baccalaureate degrees in natural science and engineering fields at the same rate as whites and Asians do now, the number of such degrees awarded in 1995 will increase by over 26,000 or almost 20 percent. Clearly, increased participation of minorities in science and engineering could significantly raise overall degree attainment rates.

However, the degree of difficulty here should not be underestimated. Vigorous efforts are needed if NS&E is to attract a higher fraction of minority talent. As was shown in Figure 10, in the few years for which data are available (1979 - 1983), not much progress was made in minority participation. We know that baccalaureate degrees to under-represented minorities increased slightly in engineering and the physical sciences, but actually decreased in the life sciences. While the academic disciplines and the educational system in general bear a good deal of responsibility for improving minority participation, the depth and societal nature of the problem cannot be ignored. The extensive poverty in minority populations is a prime factor. **Poverty typically impedes educational achievement, and trends in this indicator continue to be negative.** As indicated in Figure 17, half of black children under 5-years old are poor, almost ten percent more than a decade earlier. The situation for children of Spanish origin appears to be improving, but is still above the percent of white children in poverty.

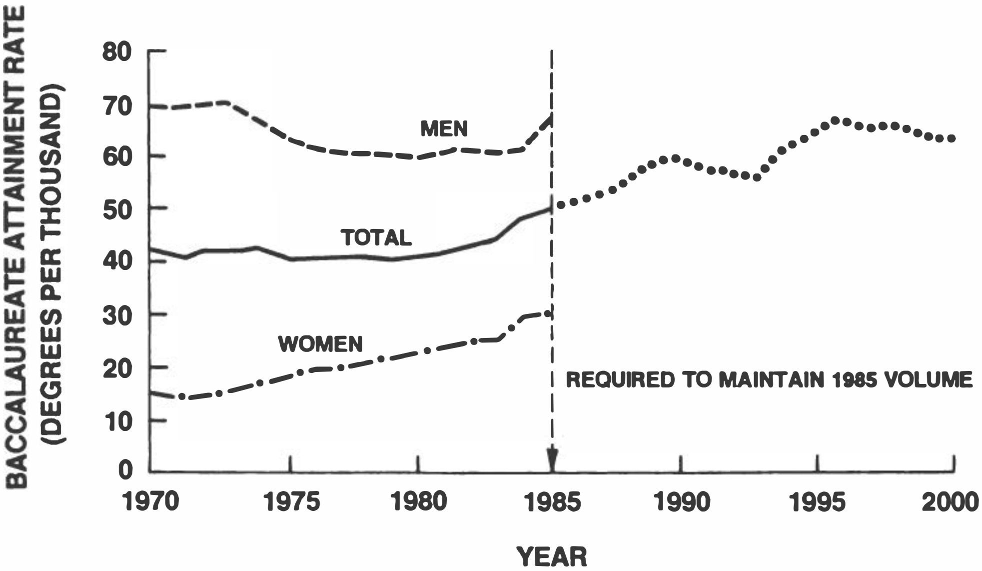


FIGURE 14 – Natural Science and Engineering Participation: Baccalaureate Degree Attainment Rates, by Sex and Total, 1970 to 1985; and Rates Required to Maintain 1985 Degree Levels, 1986 to 2000. Source: Bureau of the Census, Department of Commerce; National Science Foundation; and National Center for Education Statistics, Department of Education.

A steady increase in participation rates for both men and women (rates higher than those achieved at any time in the last decade-and-a-half) will be needed to sustain the present volume of NS&E baccalaureates.

Percent of the 22 Year-Old Population
Composed of Racial Minorities

1975	14%
1985	17%
1995	19%
2005	20%

FIGURE 15 – Percent of the 22-Year Old U.S. Population Composed of Racial Minorities. Source: Department of Commerce, Bureau of the Census, *Projections of the Population of the United States by Age, Sex, and Race, 1983 to 2080*; Current Population Reports Series P-25. No. 952.

Minorities are a growing proportion of the U.S. population.

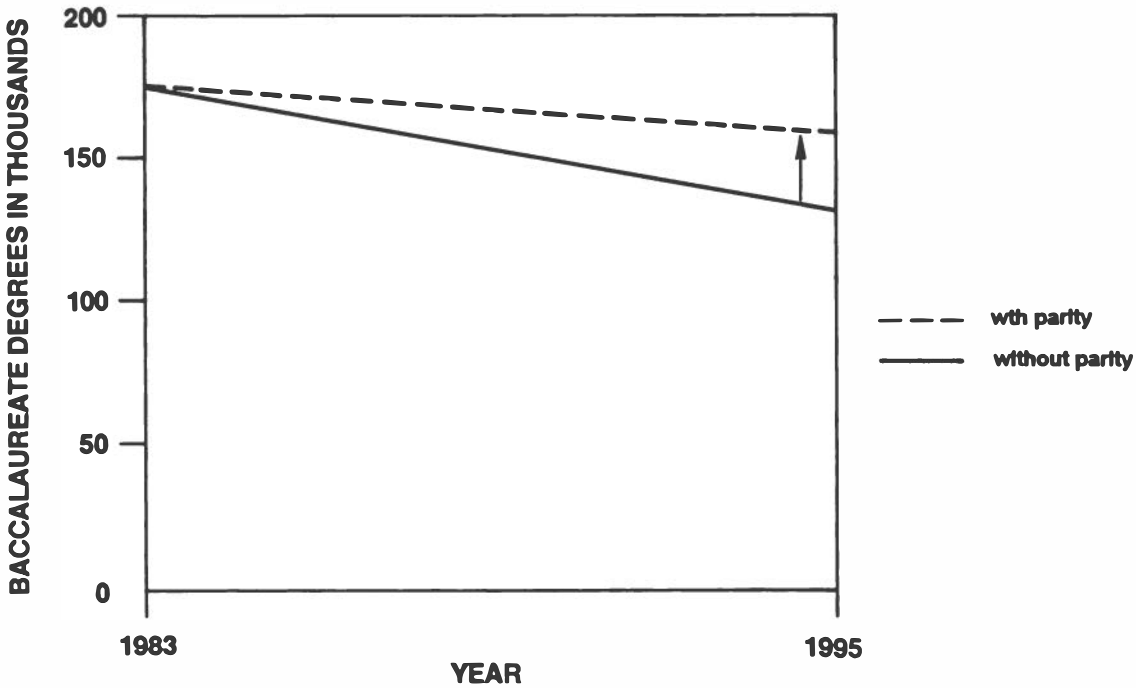


FIGURE 16 – Baccalaureate Degrees in Natural Science and Engineering with and without Parity for Underrepresented Race and Ethnic Minorities. Sources: population data taken from unpublished National Science Foundation estimates based on Census data; degree data taken from *Women and Minorities in Science and Engineering*, National Science Foundation, January 1986, Table 52, pp. 175-177; source cited is National Center for Education Statistics.

If currently underrepresented minorities attain baccalaureate degrees at the same rate that whites and Asians do now, the number of such degrees awarded will increase by almost 20 percent.

Children Under 5 Years
Percent Below Poverty Level by Race

	1970	1982
All races	16.0%	23.5%
White	11.5	18.3
Black	42.0	50.2
Spanish origin	28.2	21.9

FIGURE 17 – Percent of Children Under 5 Years Below Poverty Level, by Race. Source: *Cheating Our Children: Why We Need School Reform*, National Center for Education Information, 1985, pages 36-37; source cited is U.S. Bureau of the Census.

Poverty is a significant problem for minorities underrepresented in science and engineering fields.

Precollege Concerns. **The need to increase the rate at which young men and women of all races attain degrees in science and engineering coincides with indications of shortages of competent science and mathematics teachers in secondary schools and with disturbing evidence of the lack of achievement of U.S. students in mathematics—a core skill for science and engineering.**

The most severe teacher shortages are in mathematics, physics, and chemistry.[7] On a more general plane, Figure 18 gives high and low estimates of the annual shortage of secondary school science and math teachers. The high estimate—8,000 for science and 9,200 for mathematics—is based on replacing unqualified teachers at a rate of 5 percent per year. The authors of this study caution that these aggregates mask big variations by region, and that there is a lack of information about the quality of teachers responsible for teaching science and math.

Discussion during the Philadelphia symposium reinforced concern about an adequate teaching work force. Participants cited the inferior reward structure in science and math teaching as an impediment to the ability of school systems to attract qualified teachers. Participants also indicated that the large number of retirements expected over the next few years represents a serious problem.

International comparisons of student achievement in mathematics are further cause for concern. As stated in the U.S. report on the Second International Mathematics Study in reference to twelfth grade college-preparatory mathematics:

> "In the U.S., the achievement of the Calculus classes, the nation's best mathematics students, was at or near the average achievement of the advanced secondary school mathematics students in other countries. (In most countries all advanced mathematics students take calculus. In the U.S., only about one-fifth do.) The achievement of the U.S. Precalculus student (the majority of twelfth grade college-preparatory mathematics students) was substantially below the international average. In some cases the U.S. ranked with the lower one-fourth of all countries in the Study, and was the lowest of the advanced industrialised countries.[8]

Again, these international comparisons mask differences in the proportions of students attending high school in various countries. However, a basis for concern remains.

Doctorates

With respect to the supply of doctoral level talent in the natural sciences and engineering, the main concerns are:

- The declining interest in doctorates on the part of U.S. students with science or engineering bachelor's degrees, and
- A growing dependence on foreign graduates of U.S. institutions.

Again, a review of degree acquisition trends provides perspective.

Degree Acquisition Trends. Figure 19 shows the pattern of awards of Ph.D. degrees over the last two decades by broad field. As shown:

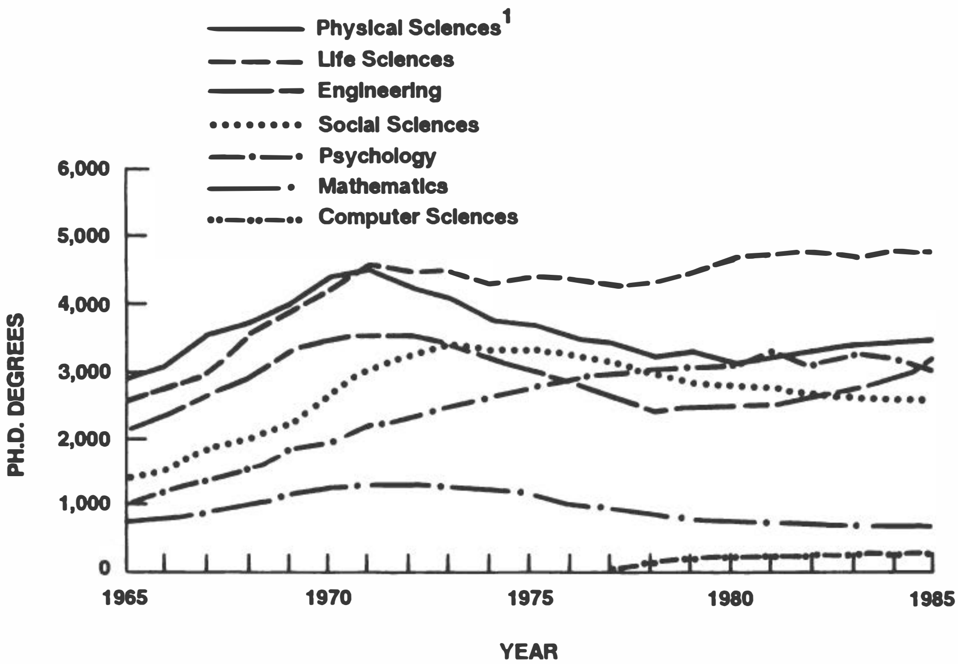
- Awards of Ph.D.s in the life and computer sciences are up.
- In engineering, there has been more fluctuation; after a downturn in the 70s, the number of degrees is back up.
- Mathematics and the physical sciences see fewer Ph.D.s—in math the number of Ph.D.s awarded has dropped by nearly half in 10 years. [Note: the fall-off in mathematics is related to the rise of computer science as a new field.]

Estimates of Teacher Shortage

	Low	High
Science	2,800	8,000
Math	3,700	9,200

FIGURE 18 – Estimates of Annual Teacher Shortage. Source: *Indicators of Precollege Education in Science and Mathematics: A Preliminary Review*, National Research Council, 1985, National Academy Press, Washington, D.C., pages 12-15.

Annual shortages of secondary school teachers are expected in science and mathematics.



[1]INCLUDES EARTH AND ENVIRONMENTAL SCIENCES.

FIGURE 19 – Doctorates Awarded in Science and Engineering Fields, 1965 to 1985. Sources: National Science Foundation and National Research Council.

Several S/E fields show increases in doctorates awarded. The most significant exception is mathematics where the number of Ph.D.s dropped by nearly half in the last decade. This is related to the rise of the new field of computer science.

As will be evident from subsequent figures, **those recent increases that are seen are largely due to higher numbers of awards to women and foreign citizens.**

Figures 20, 21, and 22 lump the natural sciences and engineering together to look at trends by sex, race, and citizenship.

- **The participation of women is up, and still increasing, albeit at a slower rate. Nonetheless, women remain underrepresented—particularly in engineering and the physical sciences.**
- **The participation of minorities has increased too; however, the change is over such a small base that it is hardly significant.**
- **The most striking trend is that for foreign citizens. Engineering and the physical sciences graduate the largest proportions of foreign Ph.D.s.**

In combination, the trends provide a picture similar to that seen until quite recently at the BA level—a decline in interest in scientific and technical education on the part of U.S. males. Figure 23 graphically displays that declining interest.

Concern. Cause for concern about the future adequacy of the supply of doctoral talent is generated by the possibility that the two major trends noted above—decreasing participation by U.S. students (specifically, white males, the traditional pool for scientists and engineers) and the over-dependence on foreign citizens—will continue in the face of the expected strong future demand forecast by the Bureau of Labor Statistics and other sources (see Figures 4, 6 and 7).

The declining interest pattern is reflected in the rate at which students with natural science and engineering baccalaureate degrees from U.S. institutions continue on and receive Ph.D.s—the continuation rate. Figure 24 displays the fall off in that rate. Since the mid 1960s, the rate at which students with natural science and engineering baccalaureates from U.S. institutions went on to earn Ph.D.s has halved. Most of the decline in the continuation rate took place in the last half of the 1960s; throughout the 1970s between 5 and 6 percent of NS&E baccalaureates continued on.

Figures 25 and 26 further document the increased importance of foreign citizens with respect to the pool of doctoral level talent. As shown in Figure 25, **there are now more foreign citizens on temporary visas earning Ph.D.s in engineering in the U.S. than there are U.S. citizens**—47 and 42.5 percent respectively. (The remainder is made up by permanent residents.) In the natural sciences (Figure 26) the dependence is much less dramatic—20 percent of Ph.D.s are earned by temporary visa holders. Note, however, that the proportions of foreign students in some of the physical sciences are particularly high. In mathematics 35 percent of students getting Ph.D.s in 1985 were on temporary visas. In physics and astronomy the comparable figure is 27 percent.[9]

The involvement of foreign students in our educational system is both a compliment to that system and a source of strength. Many foreign students stay in the U.S. after graduation and make valuable contributions to our science and engineering establishment. For temporary visa holders with 1985 doctorates, the proportion of graduates with firm plans in the U.S. ranged from 35 percent in the life sciences to 72 percent in computer science. However, it is clear that a significant portion of these graduates do not participate in the U.S. work force. Moreover, to be unable to meet demand with domestic resources is not desirable. It makes the supply of science and

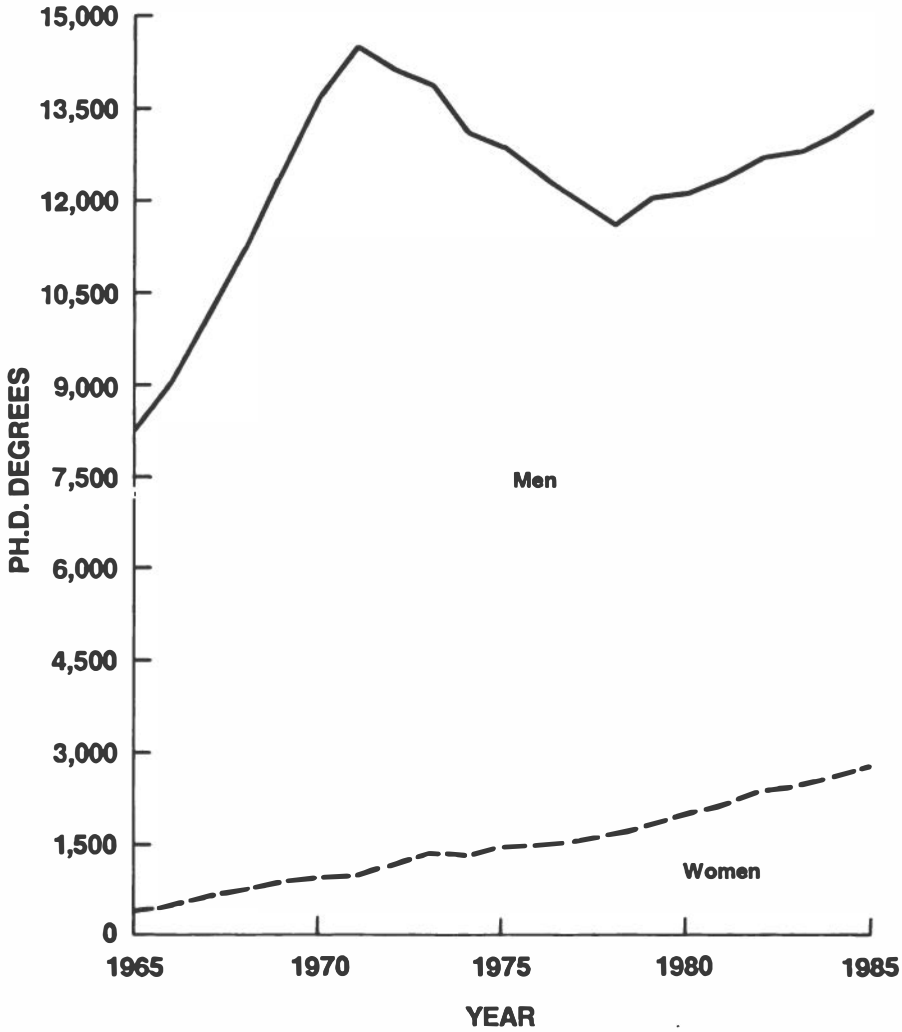


FIGURE 20 – Natural Science and Engineering Ph.D.s Awarded by U.S. Institutions, by Sex, 1965 to 1985. Source: National Research Council.

The participation of women is up, although women remain underrepresented.

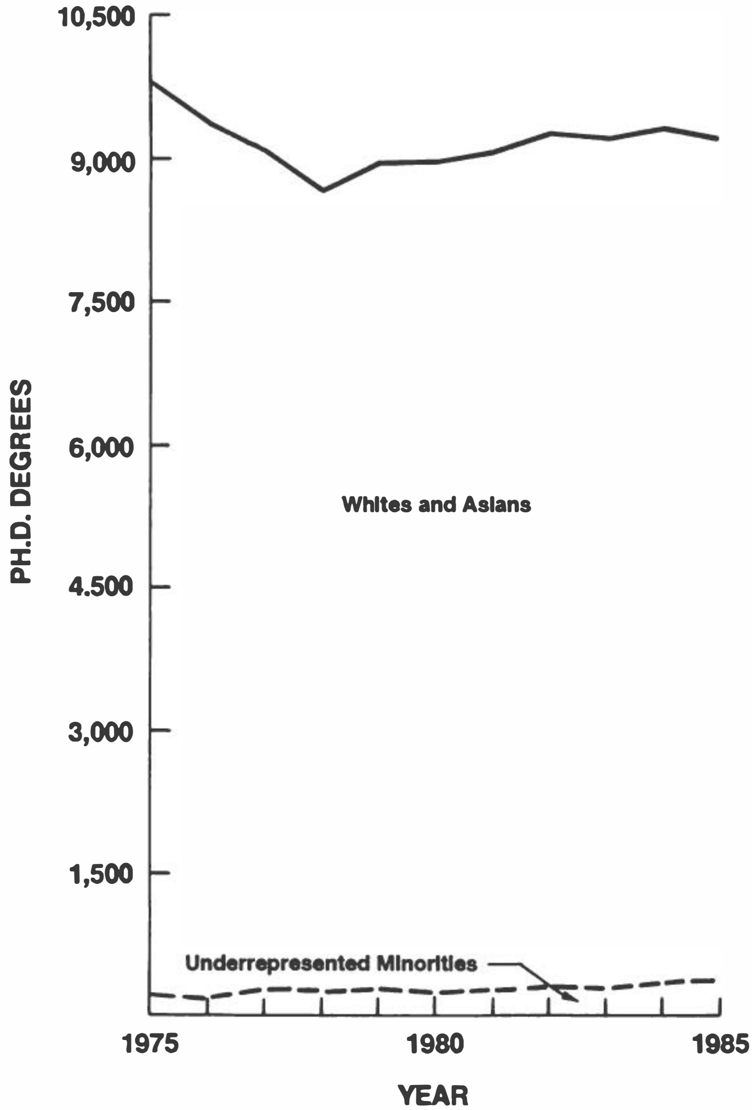


FIGURE 21 – Natural Science and Engineering Ph.D.s to U.S. Citizens and Permanent Residents Reporting Race/Ethnic Status, 1975 to 1985. Source: National Research Council.

The participation of minorities has increased, albeit over such a small base that the change is hardly significant.

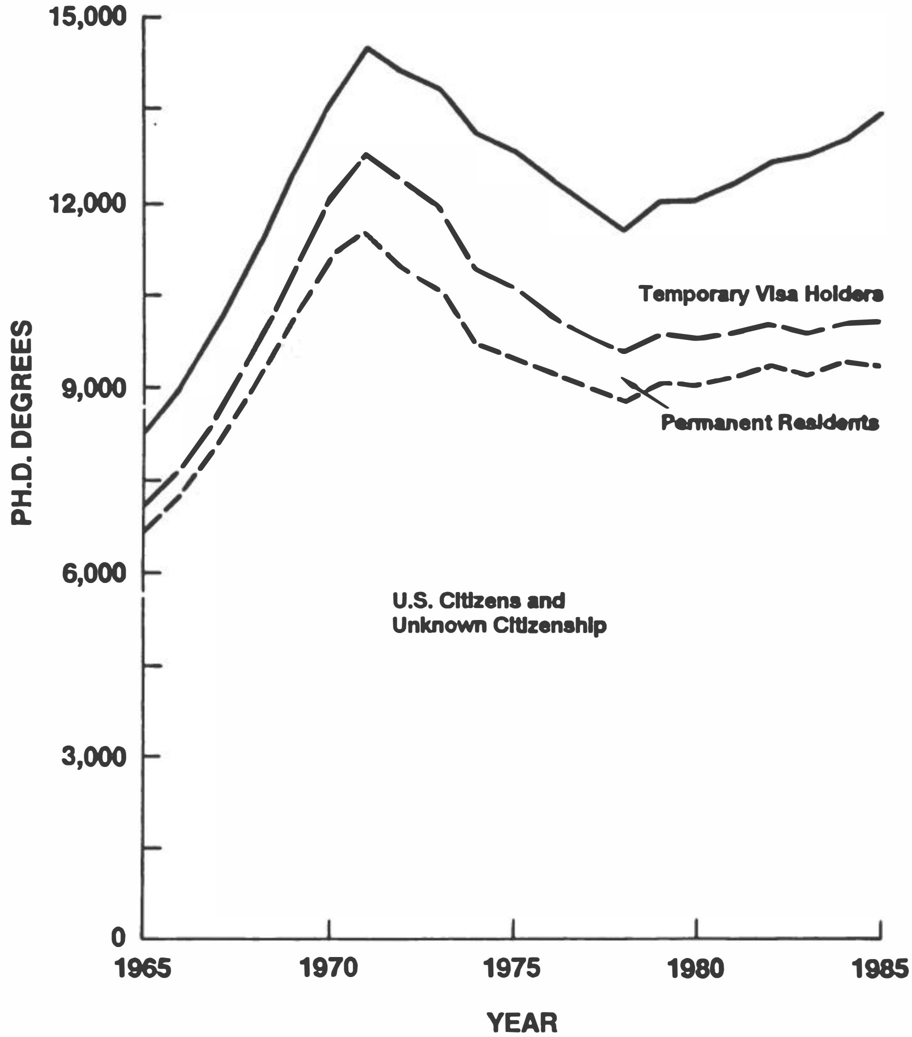


FIGURE 22 – Natural Science and Engineering Ph.D.s Awarded by U.S. Institutions, by Citizenship, 1965 to 1985. Source: National Research Council.

The increase in temporary visa-holders receiving NS&E doctorates is striking.

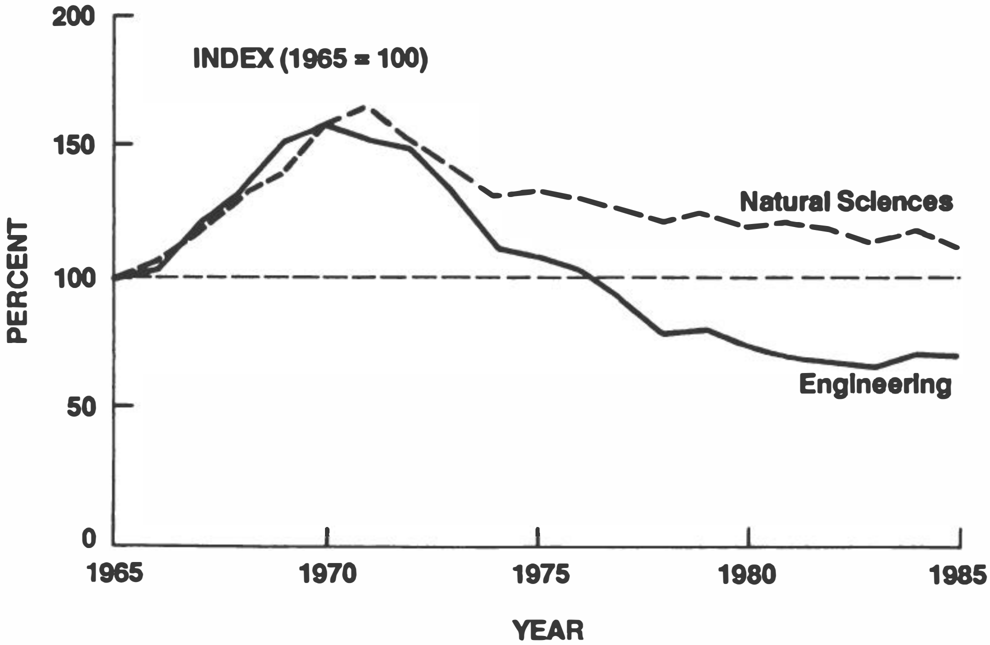


FIGURE 23 – Index of Natural Science and Engineering Ph.D.s Earned by Male U.S. Citizens. Source: National Research Council.

The number of male U.S. citizens earning NS&E Ph.D.s has declined markedly.

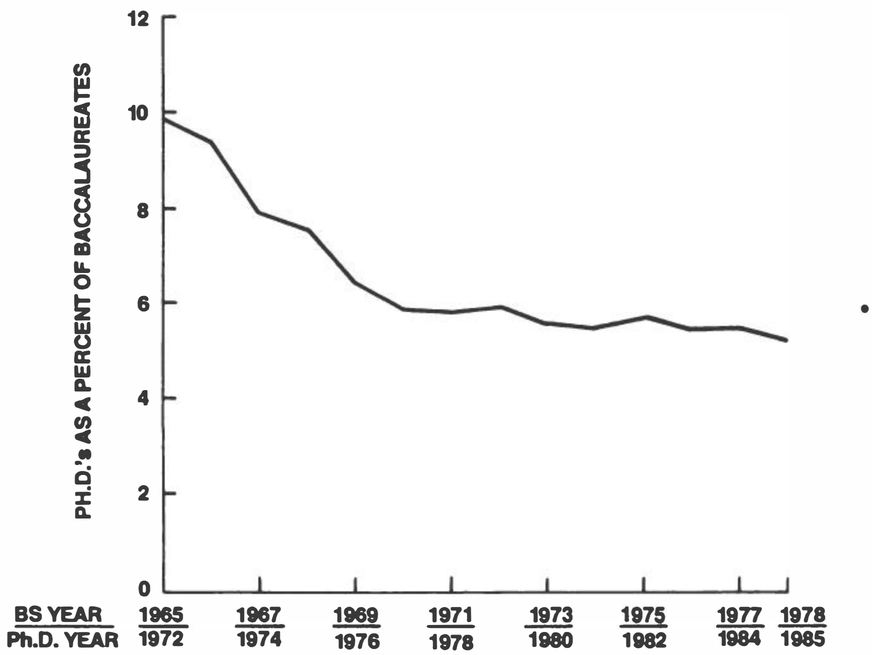


FIGURE 24 – Percent of Natural Science and Engineering Baccalaureates Attaining Ph.D.s Seven Years Later. Source: Baccalaureate data taken from National Science Foundation and National Center for Education Statistics; Doctorate data from National Research Council.

Fewer U.S. students with bachelors degrees in natural sciences and engineering are continuing on for Ph.D.s.

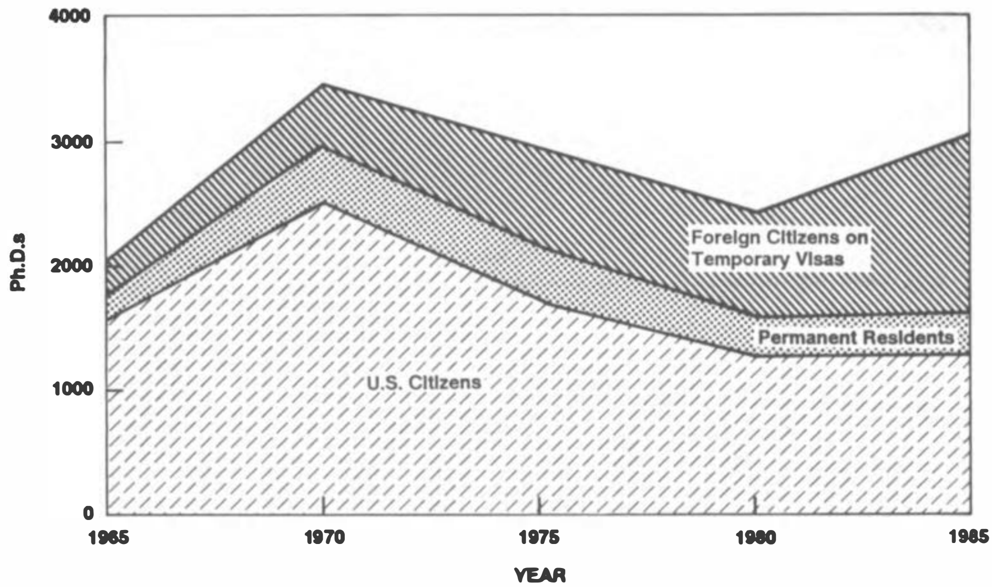


FIGURE 25 – Ph.D.s in Engineering: U.S. and Foreign Citisens. Source: figure taken from presentation by Erich Bloch at the symposium "Nurturing Science and Engineering Talent," September 29, 1986, The Franklin Institute, Philadelphia; sources cited are National Science Foundation and National Research Council.

The share of engineering Ph.D.s earned by foreign citizens on temporary visas is increasing, and there are now more foreign citizens on temporary visas earning Ph.D. awards in engineering than there are U.S. citizens.

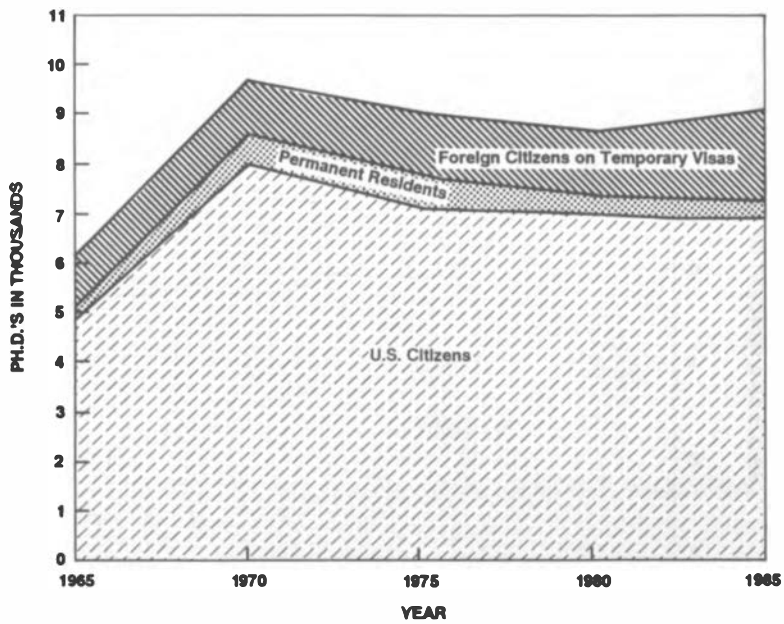


FIGURE 26 – Ph.D.s in Natural Science: U.S. and Foreign Citisens. Sources: figure taken from presentation by Erich Bloch at the symposium "Nurturing Science and Engineering Talent," September 29, 1986, The Franklin Institute, Philadelphia; sources cited are National Science Foundation and National Research Council.

Temporary visa holders are also increasingly present among natural science Ph.D.s.

engineering talent subject to rapid shifts in international relations and immigration policy—shifts not necessarily motivated by nor assessed as to their impact on the health of the U.S. research establishment.

Demographics. The projected number of 30-year olds is less an issue relative to doctoral production than the number of 22-year olds is to baccalaureate production. This is true for two reasons:

(1) The ratio of Ph.D.s to baccalaureates is so small that a slight change in the continuation rate will make a big difference in the supply of Ph.D.s. Figure 27 indicates that the number of NS&E doctorates only needs to increase from 2.1 to 2.6 per thousand 30-year olds to maintain the current (1985) volume of U.S. degree holders over the next two decades. Compensating for increased demand and for the dependence on foreign citizens would of course require much higher rates.

(2) Ph.D. supply is more highly correlated with labor market forces than it is with demographics[10]—between 1971 and 1984, the number of science Ph.D.s earned by men dropped 28 percent, yet this was a period in which the number of 30-year olds in the population increased by 65 percent.[11]

Reversing the Trends. A number of factors need to be taken into consideration in an assessment of the difficulty of reversing the decline in interest in science and engineering Ph.D.s and the resulting over-dependence on foreign citizens.[12]

The inability to precisely forecast demand for science and engineering talent and the difficulty of projecting how many baccalaureate level NS&E graduates will be available makes it difficult to estimate what proportion of baccalaureates will be needed to continue on for Ph.D.s in order to satisfy the growing demand. **Clearly, the decline in interest in NS&E Ph.D.s must be reversed,** but whether a return to past rates (see Figure 24) will be needed or even will be sufficient is not clear. The fact that the continuation rate has been much higher in the past is encouraging, however, cautions are in order. The high rates seen earlier were somewhat of an aberration—a product of an extraordinary set of incentives (plentiful research and research training support, lots of job openings, and a milieu in which the life of an academic scientist fit comfortably into then current notions of the "good life"). Recreating a parallel or higher level of incentives in the 1980s and 1990s is a formidable challenge.

Given the length of time required for doctoral training—7 to 8 years in NS&E fields[13]—the impact of any improvement in the rate of Ph.D. acquisition will not be immediately noticed. Thus, in addition to the question of whether sufficient incentives for an adequate supply of Ph.D.s will exist, a second question comes into play: **Can the trends can be turned around in time to avoid the dislocations associated with the lag time needed to generate Ph.D.s?** If we delay in reversing the decline in interest NS&E Ph.D.s, the resultant shortages will eventually stimulate demand (whether sufficiently is not clear), however, the supply will be out of phase with demand.

The increasing participation of women is encouraging. Although, the fact that the rate of increase in awards of NS&E Ph.D.s to women is slowing down causes concern about the extent to which women's participation will be a mitigating factor.

While minorities also represent an underutilized pool of talent, it is not clear whether we can marshal the forces of change to the extent required to make significant difference in the overall production of NS&E doctorates in the near term. Blacks, Hispanics, and American Indians combined earn about 4 percent of NS&E Ph.D.s despite their much

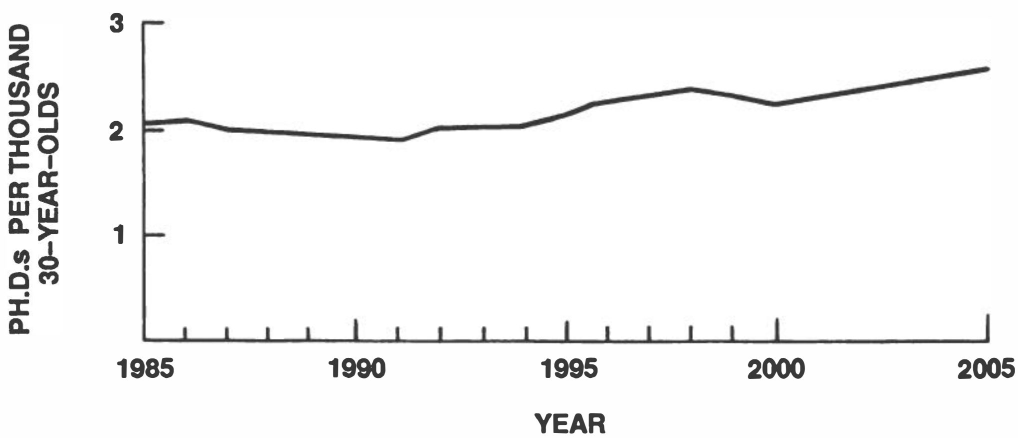


FIGURE 27 – Rate of Ph.D. Attainment by U.S. Citizens Needed to Maintain the 1985 Level of Production Through 2005. Sources: Ph.D. data taken from National Research Council; population data from the Bureau of the Census.

To maintain the current volume of U.S. citizen NS&E doctorates, the rate at which 30-year olds earn such degrees only needs to increase from 2.1 to 2.6 per thousand. Compensating for increased demand, and for the dependence on foreign citizens, would of course require much higher rates.

higher (over 20 percent) and growing representation in the population at large. Minority participation must be increased for reasons of equity and need. However, it would be unrealistic to look to underrrepresented minorities as a short term solution to any shortfall in doctorate level S/E personnel.

Conclusion

The reliability of manpower projections is certainly open to question; as a predictive tool such projections have shortcomings. Nonetheless, **the consensus of the Working Group, after more than two years of discussion, is that we face a potentially serious problem unless positive trends are accelerated and worrisome trends are turned around.** The Group is uneasy with the implications of current trends for the future adequacy of the science and engineering talent pool.

CAREER CHOICE

Efforts to nurture science and engineering talent should be guided by an understanding of how young people choose careers and a sense of the factors that come into play at various developmental and educational stages—in other words: Who makes what decisions, when, and why? While some factors affect the career choices of all students, other factors have special importance for underrepresented groups.

Throughout the Length the Pipeline

Throughout a person's education and development, the expectations and encouragement of significant others, be it parents and family or other influential figures, are key. Early in life, family members and role models set standards, place achievement expectations on children, and stimulate or discourage a range of informal and formal educational activities that influence the interests and development of the child. High school students cite parents and other relatives as the sources of information that most influence their career choices.[14] Parental expectations and encouragement continue to affect career choices even after children graduate from college, as the best predictor of enrollment in any advanced degree program (graduate or professional) is parental attitude toward further education.[15]

Participants in the symposium held at the Franklin Institute underscored what the Working Group has learned about the role of family background. Parents were identified several times as being critical to science and engineering career choice. For example, parental attitudes about mathematics were cited as an influence on the attitudes of children from the beginning.

Prior to High School

All Students. The early years are critical in recruiting students to the sciences. **By grade 10, four-fifths of students are already lost to the S/E talent pool judging by expressions of interest in mathematics, science, and engineering (MSE) careers.**[16]

Socioeconomic status (parental educational attainment, occupation, and income) is a strong influence at this stage affecting activities and values that have a major impact on the development of children's interests and abilities. A whole complex of characteristics typical of high social class families work to promote school achievement—e.g., parents' achievement expectations for a child, language models, work habits, academic guidance in the home, and intellectuality in the home, represented by the nature of toys, games, and hobbies available.[17]

Societal attitudes toward learning also affect young children. One panelist in Philadelphia noted that Americans seem to believe that math skill is a matter of innate ability (or inability), and this attitude is conveyed to children early. In other countries, Japan in particular, more stress is placed on hard work and effort as the basis for mathematical skill development.

Attitudes the public holds about occupational fields sway choices too. Limited interest in science and engineering stems to some degree from negative attitudes the public holds about these fields, according to symposium participants. Several factors contribute: agent orange as it is perceived to have been used in the Vietnam War; nuclear power problems and nuclear weapons; perceived genetic engineering threats; toxic wastes; and concerns about the use of animals in research. Some participants, however, questioned the extent to which these public perceptions hold sway. One panelist cited the attitude of school children to the Challenger disaster, noting that the students are sorry that lives were lost, but are eager to press on. They want to keep Challenger going.

Women. Early socialization that limits opportunities for girls to engage in activities that develop their scientific interest and competence is a key factor underlying women's underrepresentation in science. **By 10th grade boys are three times more likely than girls to express interest in MSE careers.**

Minorities. **Low socioeconomic status plays a major role in the under-representation of minorities.** The effect of parental education (a major component of socioeconomic status) on choice of college major provides evidence. Minority students whose parents attended college are as likely to choose quantitative majors as their white counterparts.[18] Socioeconomic status is linked to the underrepresentation of minorities through its impact on the quality of schooling received, the type of the educational and occupational expectations set for children, and the advantages their families can (or cannot) give them. These factors in turn have a role in the inadequate school achievement that Hispanics and blacks manifest. As shown in Figure 28, data from the Third National Mathematics Assessment, given in 1982, indicate that, **even in fourth grade, wide racial gaps are evident in the academic achievement of students.**

The High School Years

All Students. Not surprisingly, aptitude and sense of competence are critical factors in choices students make during the high school years. As seen in Figure 29, students of above average ability show a higher interest in MSE careers than students as a whole. Individuals with quantitative doctorates or quantitatively oriented careers usually have had scientific and mathematical career interests and high math achievement scores in grade 12.[19] And, students with aspirations of majoring in the physical and biological sciences generally have high SAT scores.[20]

The central aptitude that tends to separate the scientist from the non-scientist is mathematics knowledge.[21] This theme received a lot of play during the symposium with mathematics identified as the greatest single "ticket" to success in science and engineering careers. To succeed in science, according to symposium participants, students must be comfortable with mathematics and, because many of them are not, they opt out of the science/math curriculum as early as possible. This opting out cuts off career options.

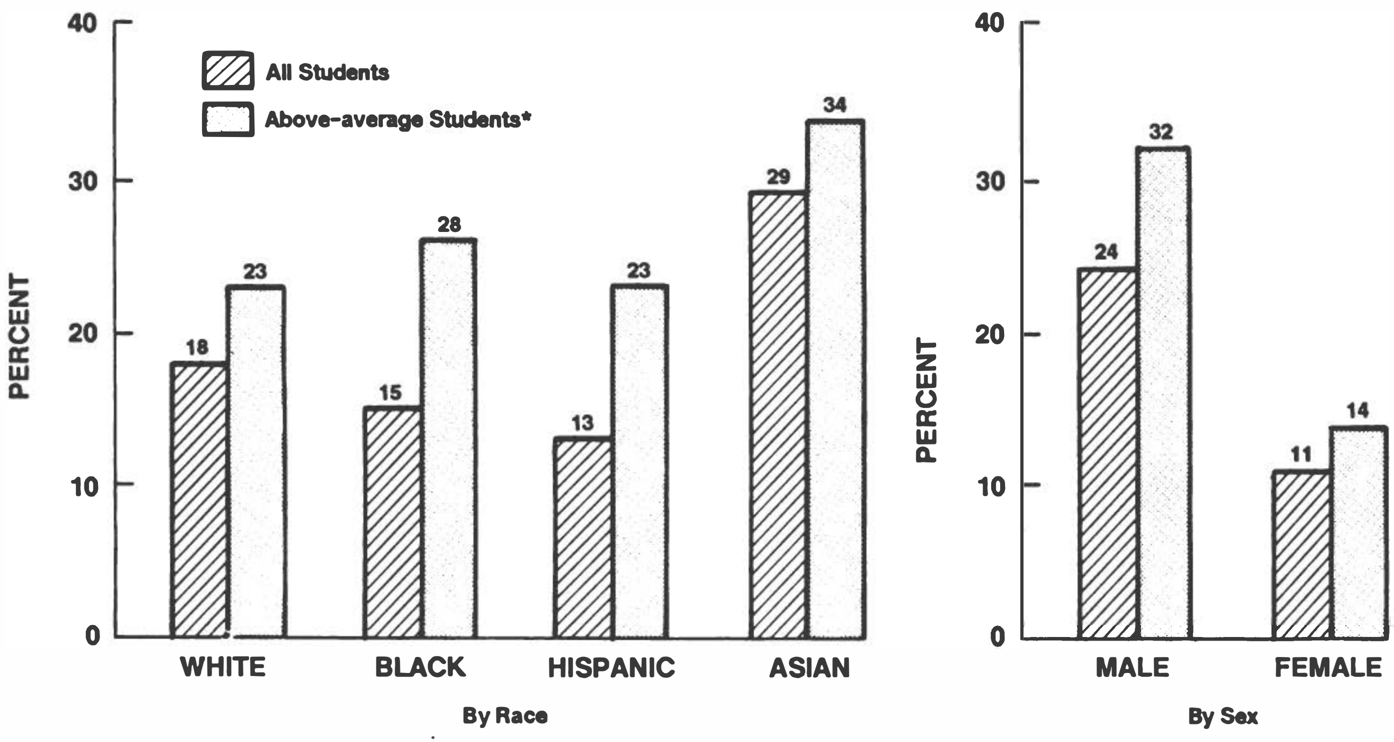
Percentage of Students Placing in the Top Quartiles* on the Third National Mathematics Assessment Test, by Racial/Ethnic Group, Sex, and Grade, 1982

Subgroup	Grade 4	Grade 8	Grade 11
White	56	57	57
Black	24	20	16
Hispanic	32	29	24
Male	26	26	29
Female	24	23	20

*Top two quartiles for racial/ethnic groups; top quartile for gender groups.

FIGURE 28 – Percentage of Students Placing in the Top Quartiles on the Third National Mathematics Assessment Test, by Race/Ethnic Group, Sex, and Grade, 1982. Source: Figure taken from "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," Office of Scientific and Engineering Personnel, National Research Council, September 1986; source cited is Education Commission of the States.

Significant differences in mathematics achievement are seen among race/ethnic groups at every grade level. Gender differences are more slight and mainly seen later in the pipeline.



*Above-average students are those who fall in the top quartiles on the High School and Beyond Cognitive Test.

FIGURE 29 – High School Seniors who were Interested in MSE majors, by Ability, Race, and Sex, 1982. Source: Figure taken from "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," Office of Scientific and Engineering Personnel, National Research Council, September 1986; source cited is First follow up to the High School and Beyond Sophomore Survey; unpublished tabulations, Thomas Hilton, Educational Testing Service.

Above average students show a higher interest in MSE careers than students as a whole. Among above-average high-school students, Asians and blacks express the most interest in majoring in math, science, or engineering. More than twice as many males as females are interested in such majors regardless of ability.

Women. Confidence in math ability is a particular problem for girls. Even for children with the same objective math ability, there are gender differences in math confidence. This, and the perceived utility of math in realizing career goals, appears to influence girls' participation in elective mathematics.[22] Only about two-thirds as many girls as boys take calculus in high school.[23] Test scores reflect the consequence of fewer females taking advanced math courses. Among 4th graders, roughly the same percent of each sex falls in the top quartile of the Third National Mathematics Assessment (given in 1982); yet, 11th grade females are somewhat underrepresented. (Again, see Figure 28).

The observed gender differences go beyond math. Fewer females than males enroll in advanced chemistry, and few females take physics at any level.[24] In general, among females and males of comparable levels of academic ability, women have lower self confidence with respect to achievement in male-dominated careers.[25] Thus, it should not be surprising that the NLS-72 data on high school seniors indicates that less than half as many female as male students are interested in MSE careers.

Minorities. Black high school seniors show about as much interest in MSE careers as do white. Hispanics show somewhat less interest. However, the data on math ability indicates problems. Looking again at the Third National Mathematics Achievement Test (Figure 28), but this time at the 11th graders, only 16 percent of blacks and 24 percent of Hispanics fell in the top two quartiles. There can be no doubt that these scores are connected to the fact that blacks and Hispanics are not adequately represented in high school academic curricula and that they are less likely to take advanced mathematics and science.[26] This is undoubtedly rooted in the socioeconomic factors addressed earlier. Additionally, the limited options and opportunities perceived by many minorities during high school is also significant.[27] The fact that black high school graduates have higher unemployment rates than white high school dropouts (16 and 13 percent, respectively)[28] must dampen the drive of black students to excel academically.

College

All Students. Major losses to the science and engineering talent pool occur during the college years. The National Longitudinal High School Study of the Senior Class of 1972 (NLS-72) provides data on the progress of a specific cohort as it moves through the pipeline.[29] As shown in Figure 30, there is still movement into the MSE pipeline during the college years. However, at each stage, the net effect of the movements in and out of the pool is loss. The cumulative impact of these losses is substantial. Over 50 percent of the high school seniors surveyed drop out of the MSE pipeline by the end of their first year in college. Some return later on, however, by college graduation, only 35 percent of the high school seniors who planned on MSE majors have stayed with their plans. This suggests that, during the college years, more attention should be paid to preventing migration out of science. Colleges and universities need to pay more attention to the quality of undergraduate programs. The Working Group feels strongly that this is an area that needs more thorough and intense attention. The balance between curricula designed to weed students out and curricula designed to nurture students along, the extent of direct interaction between students and senior faculty, and the availability of undergraduate research experiences, which are documented to encourage students to pursue scientific careers,[30,31] all need to be examined.

While ability and interest continue to be important factors as college students make their career choices, economic incentives are also influential. The long and short term earning prospects of different occupations do influence what majors students choose.[32]

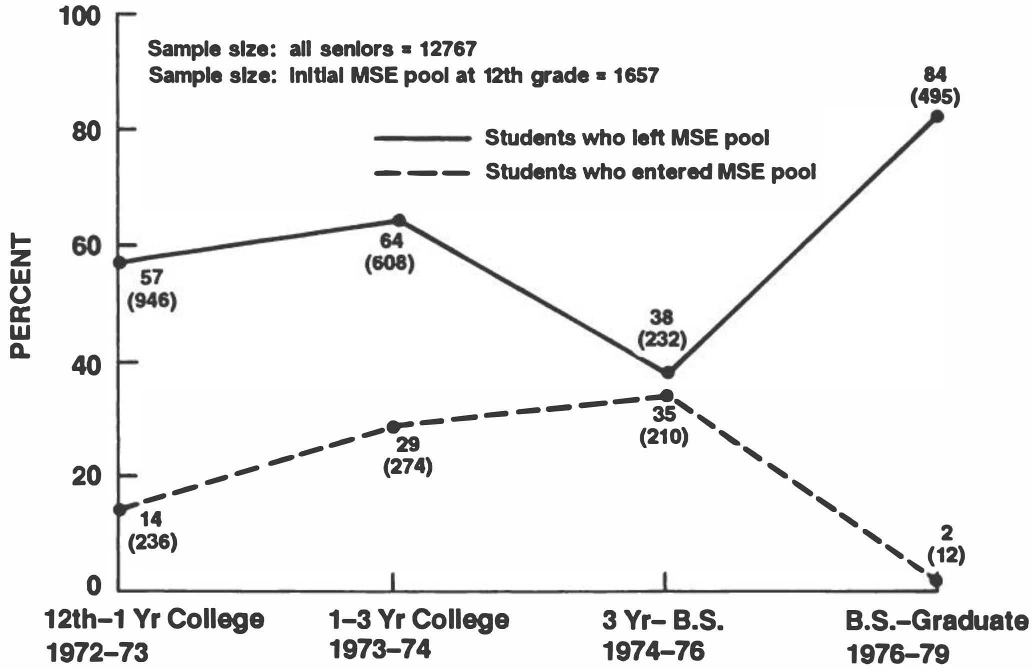


FIGURE 30 – Gross Flows to and from the MSE Pool, 1972 to 1979, by percent (sample numbers provided in parentheses). Source: Figure taken from "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," Office of Scientific and Engineering Personnel, National Research Council, September 1986; source cited is National Longitudinal High School Study of the Senior Class of 1972 (NLS-72).

While there is movement both in and out of the pipeline between the senior year of high school and graduate school, the net effect is substantial loss. By college graduation only 35 percent of the high school seniors who planned on MSE majors have stayed with their plans. Most of the loss in the first few years of college. Another big loss point is the transition to graduate school, although this is more a loss to the educational pipeline than to the talent pool.

Women. Figures 31 and 32 display the NLS-72 data disaggregated by sex. Interestingly, the patterns for men and women are quite similar. The biggest difference is that there is somewhat more movement both in and out of the MSE pool during college for women than there is for men.

Minorities. Figures 33 and 34 display the NLS-72 data for Hispanics and blacks.[33] Striking differences are seen in comparison to the total pool. Specifically, much higher than average losses. Related data show that, more than any other group, blacks leave the MSE pool during college, not by shifting majors but by leaving school. In contrast, when leaving the MSE pool during the college years, Hispanics were more likely than the other groups to stay in school but move to non-MSE majors.

Low scores on achievement tests are a significant barrier to higher education for minorities. Achievement tests are a major criterion for college admission. The fact that minorities do less well than whites on standardized tests—a barrier to higher education—is rooted in inadequate elementary and secondary school preparation, insufficient knowledge of test-taking methods, and test bias.[34]

The availability of financial aid is also particularly important for minority access to higher education. Both the type and amount of financial aid are important contingencies. Grant awards have been shown to have a more positive influence on the retention and access of minority students than loan awards.[35]

The support structures at predominately black institutions—the availability of role models, academic assistance, and tutorial programs—have a positive influence on success in higher education and in broadening the career choices of blacks. This may be a contributing factor to the fact that, in 1980, although black colleges enrolled only 27 percent of black college students, these schools accounted for more than 40 percent of all degrees for blacks in agriculture, computer science, biology, math, physical science, and social science.[36]

The presence or absence of racial balance in a field also influences the occupational choices of minorities. Studies suggest that blacks and women choose college majors and careers in which they are more likely to be represented adequately, because they perceive less discrimination and a greater opportunity for achievement and advancement.[37]

Graduate School

All Students. The transition from undergraduate to graduate school is another big loss point—from the educational pipeline if not from the MSE talent pool. Looking again at the NLS-72 data displayed in Figure 30, over 80 percent of MSE baccalaureates never started or have left graduate school within three years of college graduation. Students perceptions of opportunity are key here. The availability of jobs, income potential, job security, and occupational status all come into play. Economic incentives are a very important factor. The importance of high income, job security, and status often leads students to reject graduate study.[38] As stressed during discussions in Philadelphia, the financial rewards offered in fields such as law and business indicate that society places a higher value on these non-science and non-engineering careers.

Closely related to economic incentives are perceptions, accurate or not, of leadership opportunities. A point stressed by symposium participants is that young people do not understand the opportunities for leadership that are available through science and engineering careers. One panelist questioned whether we do an adequate job of letting

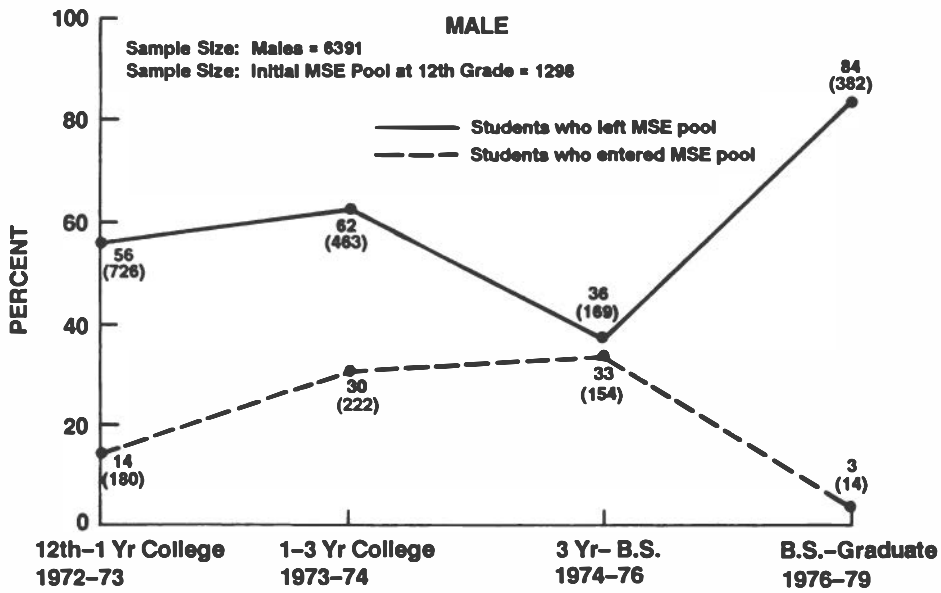


FIGURE 31 – Flows of Male Students to and from the MSE Pool, 1972 to 1979, by percent (sample numbers provided in parentheses). Source: Figure taken from "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," Office of Scientific and Engineering Personnel, National Research Council, September 1986; source cited is National Longitudinal High School Study of the Senior Class of 1972 (NLS-72).

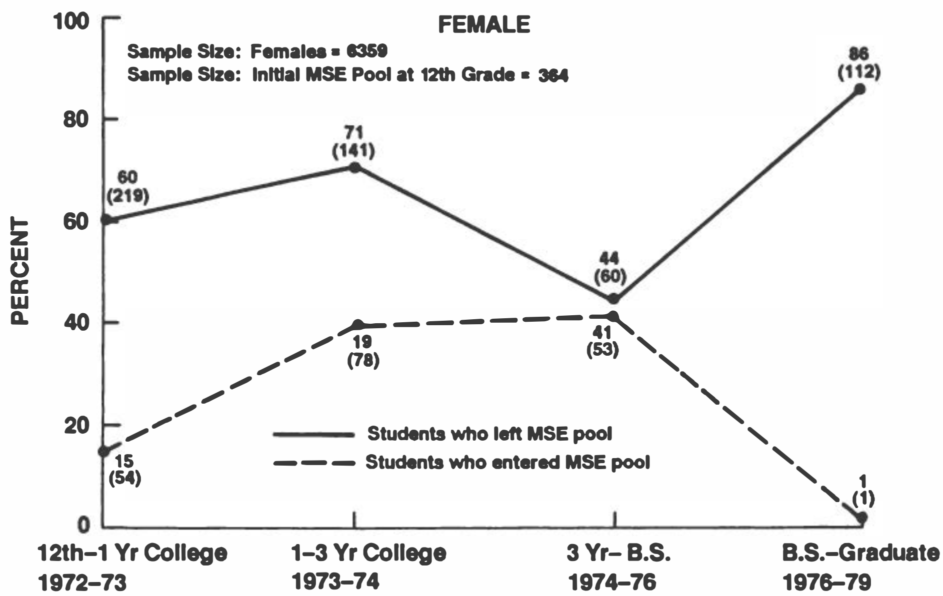


FIGURE 32 – Flows of Female Students to and from the MSE Pool, 1972 to 1979, by percent (sample numbers provided in parentheses). Source: Figure taken from "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," Office of Scientific and Engineering Personnel, National Research Council, September 1986; source cited is National Longitudinal High School Study of the Senior Class of 1972 (NLS-72).

Similar patterns are seen in the flow of male and female students in and out of the MSE pipeline; although there is somewhat more movement in both directions for females.

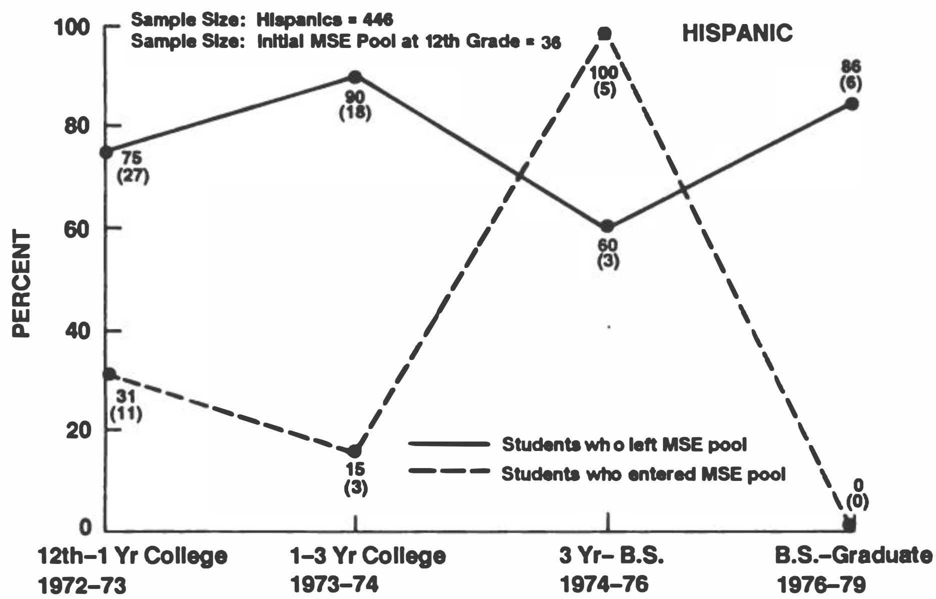


FIGURE 33 – Flows of Hispanic Students to and from the MSE Pool, 1972 to 1979, by percent (sample numbers provided in parentheses). Source: Figure taken from "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," Office of Scientific and Engineering Personnel, National Research Council, September 1986; source cited is National Longitudinal High School Study of the Senior Class of 1972 (NLS-72).

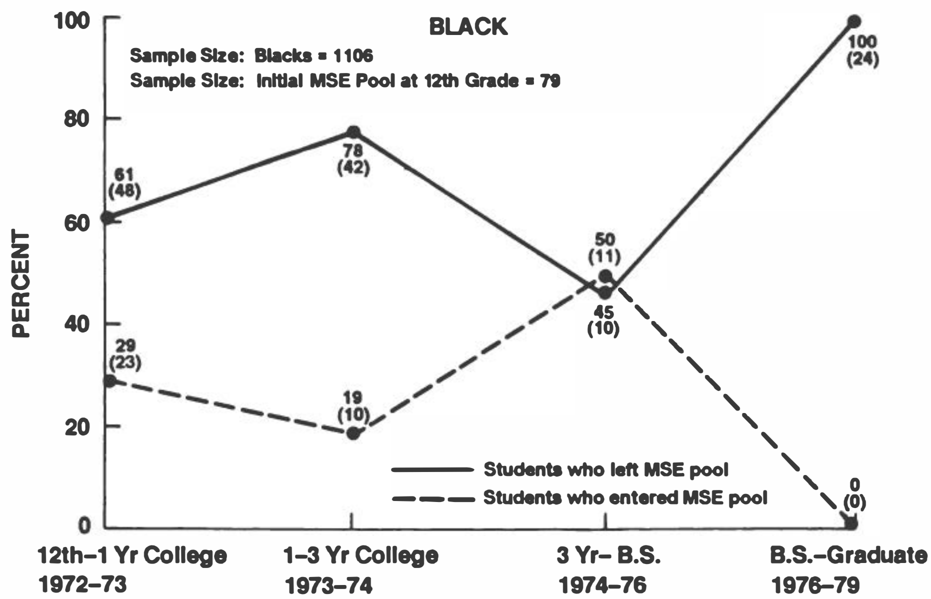


FIGURE 34 – Flows of Black Students to and from the MSE Pool, 1972 to 1979, by percent (sample numbers provided in parentheses). Source: Figure taken from "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," Office of Scientific and Engineering Personnel, National Research Council, September 1986; source cited is National Longitudinal High School Study of the Senior Class of 1972 (NLS-72).

Much higher than average losses are seen in the movement of blacks and Hispanics to and from the MSE pipeline. [Note: sample sizes are so small as to cause question about the applicability of the findings for the general populations of these groups.]

students know that a science and engineering degree is not just a route to a specialized laboratory or research job but a path into a very large spectrum of industrial employment.

Women. Many observers perceive discriminatory practices—reflected in unemployment, underemployment, salaries, and rank and tenure—to be the most serious impediment to the goal of equality of opportunity for women in science and engineering education.[39] The recent increases in the participation of women indicate that improvements in opportunity do result in improvements in participation.

Sex role expectations and the structure of work also affect women's ability to balance family life with work. This in turn shapes their career decisions. As long as females expect to assume the major child-rearing responsibilities, they will be less likely than males to choose occupations that require major educational and labor force commitments.[40] Role models are few and lack of mentoring limits the success of women in science graduate programs.[41]

Minorities. Minorities also lack access to relevant role models and mentors to help cultivate and facilitate their interest in non-traditional careers.[42] Efforts to provide such support do make a difference. The presence of black faculty in graduate and professional schools is the most significant predictor of retention of blacks in graduate school.[43] Beyond role models, other support systems also are important. Minority recruitment programs and the availability of academic assistance and tutorial programs influence access and success of minorities in graduate education.[44]

Conclusion

There are no magic one or two points in a student's life that are crucial to career choice. At every educational and developmental stage factors come into play that shape and reshape the occupational direction a student is taking. Moreover, the influences affecting different groups vary. This makes every stage a potential point of intervention, and it means that a comprehensive approach to nurturing science and engineering talent must address the whole pipeline and be sensitive to sex, race, ethnic, and class differences.

Expediency argues for giving more weight to factors that influence the choices of the significant number of students who are lost to the talent pool toward the end of their educational development. This points strongly to the impact of undergraduate and graduate education and the attractiveness of science and engineering careers. Nonetheless, the importance of early influences on career choice, while diffuse, remains significant, particularly for women and underrepresented race/ethnic groups.

INTERVENTIONS AND OPTIONS

There is a good deal of material describing interventions. More scarce are studies and analyses documenting the effectiveness of interventions and the causes of effectiveness. Working Group One gathered an assortment of assessments and evaluations as background material for the symposium, and it learned more about effective interventions in Philadelphia. The highlights of what was learned through these sources are summarized here. This is not a comprehensive review. The purposes of this summary are to provide a sketchy review of the types of outcomes that can be gained through intervention, to provide some insight into what makes some interventions particularly successful, and to present a few of the issues surrounding implementation and institutionalization of interventions.

Interventions Do Have an Impact

Evaluations and assessments of intervention programs show that such programs are effective. A few of the successful programs that have come to the attention of the Working Group are noted below.

Preschool. The Perry Preschool Program nearly doubled rates of employment and participation in college or vocational training.[45]

Television. 3-2-1 CONTACT familiarizes children with concepts, facts, vocabulary, and relationships; alters stereotypes of scientists; and improves the appeal of scientific activities.[46]

Teacher Internships in Industry. The Philadelphia Teachers in Industry program revitalizes teachers by placing them in corporate laboratories full-time for nine months.[47] The teacher internship program of the New Jersey Business/Industry/Science Education Consortium gives teachers new self-esteem, and causes students to view their teachers with more respect.[48]

Math In-service and Awareness. In school districts where teachers have been active in EQUALS math in-service training, progress can be seen in girls' enrollment in elective mathematics classes. The EQUALS career awareness conferences increase the number of math and science courses that girls plan to take during high school.[49]

Counseling/Encouragement/Support. Students in Florida A&M's Talent Search Program matriculate in post-secondary institutions at nearly twice the expected rate.[50]

Enrichment Programs for Gifted. The Duke University Talent Identification Program improves children's acceptance of themselves and their giftedness.[51] Summer Ventures in Science and Mathematics helps crystallize students' interests and increases their academic comfort.[52]

High School Enrichment Programs. The Macy Foundation high school projects provide an academically rigorous course of study for poor students enrolled in schools that cannot normally provide rigorous programs. The majority of Macy-sponsored youngsters do not start out as honors students, but by the junior year the vast majority have maintained honors grades and have achieved above the mean on nationally-normed tests. The students' achievements have had major effects on teacher attitudes, e.g., pessimism about the ability of minority youngsters to achieve academically and cynicism regarding the ability of school systems to support and respect efforts to identify and encourage minority talent.[53]

New Science Curricula. The average student exposed to the "new" science curricula generated in the late 1950s and the 1960s exceeded the performance of 63 percent of the students in traditional science courses. The greatest gains were in creativity, problem solving, techniques, spacial relations, attitude toward science, and achievement.[54]

Minorities in Engineering. Ninety-two percent of students who go all the way through the PRIME (Philadelphia Region Introduction for Minorities to Engineering) program are admitted to 4-year colleges. Over 80 percent of those will graduate four years later with a degree in math or science.[55]

Women in Engineering. An experimental course for first year women engineering students at Purdue University leads to retention, through at least the fourth semester, of 78 percent of women compared to retention rates of 62 percent for a control group of women and a 69 percent rate for all students (women and men).[56]

Undergraduate Research Apprenticeships. The University of Delaware Science and Engineering Scholars Program helps to develop a different attitude toward research among student participants. A much larger percentage of them go on to full time graduate school than the other top students.[57] Of participants in the National Institutes of Health's Minority Access to Research Careers (MARC) program, 76 percent enroll in graduate or professional training.[58]

Comprehensive Program for Minorities in Graduate Engineering. The GEM Program (Graduate Degrees for Minorities in Engineering) experiences a graduation rate of 84 percent. The national average is in the 70s.[59]

Mentoring of Minority Graduate Students. The mentoring program for minority graduate students at the University of California at Irvine increases the expectations that faculty hold for the quality and sophistication of research performed by minorities.[60]

Graduate Fellowships and Traineeships. Federal graduate education policies and programs in the 1960s contributed to the increased numbers of Ph.D.s and increased number and quality of graduate programs.[61]

Why Interventions Work

There is substantial evidence that interventions can be and are effective in accelerating the development of students generally and in meeting goals for increased participation of underrepresented groups. The question of why interventions work is less clear. Interventions may simply stimulate the "Hawthorne effect."[62] However, some general guides as to how to achieve positive outcomes can be ascertained from the assessment literature and other sources.[63] The factors linked to success that are discussed below are not ranked in order of importance.

Expectations. To be effective, those involved in an intervention must agree on clearly defined educational goals, encompassing a well-understood instructional focus, and using techniques which motivate students.[64] **"The success of intervention programs for minorities and girls may derive from the fact that the programs demonstrate that there are people who hold high expectations for these groups—expectations not shared, by and large, by the science and engineering establishment."**[65]

Commitment of Leaders and Community Support. Commitment to the concept and goals of the intervention and involvement by school leaders (principals and teachers), parents, industrial leaders, community groups, and scientists is important to successful intervention.[66] For example, one of the reasons for the success of PRIME is that the Dean of the college of engineering of every major institution in Philadelphia sits on the PRIME board. Thus, when PRIME went to the colleges, it dealt with senior faculty and picked the cream of the crop to teach PRIME youngsters in their summer programs.

The commitment of leaders and community support often derives from bottom-up program genesis (that is, programs initiated in response to local rather than federal imperatives) and is characterized by local funding sources.[67]

Collaboration. The contribution partnership makes to successful interventions must be underlined.[68] What makes PRIME work is a partnership among and between school districts, colleges and universities, businesses and industries, professional societies, governmental agencies, community groups, parents and students.[69] Collaboration is important because: "When you view science education as a dynamic process involving doing as opposed to telling, you learn very quickly that you need many resources and that these resources need to come from many sources, since no school or school district can do it alone."[70]

Commitment of Students. In addition to commitment from leaders, strong student commitment is important. The more time and effort students invest in the learning process and the more intensely they engage in their own education, the greater their growth and achievement. Interventions create more time-on-task for the students, leading to increased productivity.[71]

Role Models. The presence of role models is an important ingredient to motivate student interest.[72]

Peer Support. Peer support within an intervention program and the presence of a critical mass of like participants are crucial.[73] For example, the Graduate Degrees for Minorities in Engineering (GEM) program has observed that the program is most successful in increasing the graduation rate of minorities in places where the concentration of GEM students is high.[74] Minority student organizations and study groups can provide students the opportunity to meet their social needs within the context of a success-oriented engineering environment.[75]

Getting the Basics, Assessment, and Feedback. There are lasting benefits from preschool education evident in increased high school graduation rates and enrollment in postsecondary programs.[76] Learning the basics as early as possible prevents the formation of incorrect, even if seemingly sensible, notions about how the natural world works. These "naive" theories can interfere with later learning.[77] Moreover, mastery is itself the best motivation for sustaining further learning.[78]

Ninth grade is not too late to overcome deficiencies through a rigorous academic program. An adequate assessment program must be in place to recognize the need to combat deficiencies.[79]

Assessment and feedback serve as a way to redirect efforts, as a powerful lever for involvement, and as an aid in communicating expectations.[80] The Penn State minority engineering program checks with professors on student progress as early as the third or fourth week of a semester and uses the results to direct tutoring efforts.[81]

Enrichment. A focus on enrichment rather than remediation marks exemplary programs. Academic subjects are approached through problems and projects rather than drill.[82]

Hands-on Experience. An integrative approach to teaching incorporating all subject areas, "hands-on" experience, and computers is important.[83] Exemplary academic-based programs characteristically place heavy emphasis on the applications of science and mathematics and on careers in these fields.[84] Moreover, research shows that practical hands-on training is a more effective way for minority high school students to acquire aptitude in engineering than lecture/discussions.[85]

Minorities and Women. Programs with specific goals and initiatives for women and minorities are more successful with these groups than programs designed for all students.

Recruitment of participants from the target population, and specific attention to removing educational inequities related to gender and race are all important factors here.[86]

Financial Aid. Although both grants and loans are important for access to and success in higher education, grant awards have a more positive influence on the retention and access of black and Hispanic undergraduate and graduate students than do loan awards.[87] Low stipends may discourage minority undergraduates from participating in summer research programs.[88]

A core of highly talented individuals, with excellent graduate training, in all fields of basic science and engineering is best maintained via fellowship and training grant programs supplemented by research assistantships.[89]

Multi-year Involvement. Long-term financial support for programs is important.[90] Additionally, without discounting the place of short-term efforts, evaluations of interventions show the importance of multi-year involvement with students.[91] The tendency of intervention programs to expand into both higher and lower grades[92] is evidence of the recognition of this.

Base Programs on Research Findings. Interventions should be based on research findings and on evaluated models.[93] NACME's handbook, *Improving the Retention and Graduation of Minorities in Engineering*, edited by Raymond Landis, is a good example of how evaluated models can be used as the basis for designing successful programs.[94]

Evaluation. Program evaluation is essential.[95] Monitoring what works and what does not work and establishing a pattern of keeping successful program elements and discarding unsuccessful ones is important to the process of institutionalizing interventions.[96] Measures of pupil achievement are a good basis for evaluation.[97]

Implementation Issues

Much of the discussion at the symposium centered around implementation issues such as the need to extend, replicate, and institutionalize interventions; the stumbling blocks interventions face; and the roles of various sectors.

Continuing Need

The lively record of past and ongoing programs to nurture science and engineering talent demonstrates success, but the scale of these programs has been too limited. Significant need for such programs remains. Discussion of extension, replication, and institutionalization of interventions is played out against this background of continuing need. PRIME serves 3,000 youths—a significant number. Yet, this is a small fraction of the 130,000 minority youths in the target area. Thus, PRIME reaches only about two percent of its target population, and it is one of the largest intervention programs.[98] The New Jersey Business/Industry/Science Education Consortium received 280 applications from teachers for internships in industry during the summer of 1986—only about 10 can be supported each year.[99] Out of 25 plus million black Americans in the U.S., there are only about 110 Ph.D.s in MSE fields per year. Special intervention programs account for many of those Ph.D.s. **If nothing is done beyond the current set of intervention programs, we will continue to have only 110-115 black MSE Ph.D.s per year.**[100] The causes for concern about the future adequacy of the science and engineering talent pool—rising demand and disturbing trends in supply—coupled with the knowledge that intervention programs are reaching a very limited number of students indicate significant and continuing need for efforts to develop technical talent.

Press Every Button

The magnitude of change needed leads to the conclusion that we have to attack this problem on multiple fronts. Significant reforms are needed. Marginal interventions will not be sufficient; we need to press every button. Moreover, as long as programs are "interventions," they will address only a small fraction of the need. **To have a genuine impact, intervention techniques must be institutionalized as a part of the educational system at every stage in the educational pipeline. There is a systems problem, but, as of yet, there is no systems solution.**

If such institutionalization is unlikely to happen soon, then at minimum current interventions need to be expanded and replicated. "We see local efforts here and there, but...there are gaps...there are gaps in levels...there are gaps in target audiences... there are gaps in geographic locations."[101] Interventions must be designed so that they are exportable from one place to another, from one discipline to another, and from one target group to another.[102] Although, "preconceived solutions" should be avoided,[103] and interventions must be tailored to the target group, it is both feasible and necessary to adapt and transfer what works from one sphere to another. The family math program run by the Consortium for Educational Equity provides an example of successful transferability. This program was developed by the Lawrence Hall of Science in Berkeley and has been implemented in several locations around the country. Another example is the Museum-To-Go program of the Franklin Institute which expanded from a hands on science program for the junior high schools to a program to enrich the whole elementary school curriculum in Philadelphia.

Stumbling Blocks

There are many stumbling blocks to successful program implementation.

Funding Problems. **Lack of dollars restricts the number, scope, and size of programs, and those sources that do exist are not always reliable.** Supportive industries are subject to business conditions that can interfere with their ability to provide backing.[104] Foundations are often more interested in supporting new ideas than in sustaining ongoing programs. In addition, federal programs too often have been "on-again, off-again." The temporary shut down of science education activities at the National Science Foundation is just one example. Beyond discontinuity, funding has simply stopped for many good programs. The former NSF summer institutes for teachers are widely missed.

Local Support. Some states have better records than others of local support for education. Where the connection between support for education and low unemployment is not widely known or accepted by local taxpayers, taxpayer support may not be forthcoming. Lack of taxpayer support for education is a real hurdle to institutionalization of interventions.

Localized Control of Education. Control of education is localized in the United States. Given the need for change throughout the educational system, this decentralization presents a stumbling block. We lack mechanisms to stimulate and coordinate a systems approach to the problem. It is also recognized that many of the strongest features of our educational system result from its decentralized and diversified character.

Crisis Mentality. Our society is rarely moved by long-range needs. We would rather react to crises. Our resistance to address long range needs impedes our ability to address the issue at hand.

Risk-Taking. Another stumbling block to institutionalizing interventions is fear of making a mistake. Teachers and students are afraid to try different approaches. We need to encourage teachers and students to see mistakes as an opportunity for learning rather than as a condition that merits a punitive response.[105] We need to reward risk-taking.

Roles

Roles to be played by teachers, community colleges, universities, federal and state governments, school districts, museums, and the corporate sector, as well as partnerships among these groups, were discussed explicitly during the symposium.

Teachers. The best way to intervene during the elementary school years may be to support the teachers.[106] In the absence of families that can set expectations for students, teachers take on the role model position.[107] The teacher is also important in transmitting information on science-related career opportunities and prerequisites.[108] Thus, programs to support and "retool" teachers must be implemented so that teachers have confidence in their understanding of science and in their ability to teach from their own experience. Corporations, universities, and museums have unique contributions to make here.

Education Officials. State education agencies and school districts have roles to play not only vis à vis teachers and their qualifications, salaries, working conditions, and continuing education, but also in terms of the educational standards students are required to meet and the quality of curricula students are exposed to.

Community Colleges. The particular skills of two-year colleges in developing the talents of non-traditional students make these schools valuable recruiting grounds for MSE. For community colleges to fulfill this role successfully, better articulation of programs between two- and four-year colleges will be necessary.[109]

Universities. The proper allocation of university resources, e.g., funds and faculty time, to science education (curriculum and materials development, research on teaching and learning, and teacher training—both pre-service and in-service) is also a serious matter that needs to be addressed. Less traditional partnerships with the precollege community also need to be pursued. Moreover, improvement in the quality of undergraduate science and engineering programs could exert singularly effective leverage.

Corporations. Corporations have taken a major role in supporting interventions with funds, influence, and access to personnel and equipment. But here too, staying power is an issue.

Both universities and corporations need to examine the equity of their hiring and promotion practices.

The Federal Government. The adequacy of the science and engineering labor force is of national concern and the problems in assuring adequacy are of a national scale. The need for leadership from the highest levels of government is clear. The message needs to reach the country and an impetus must be provided to stimulate the nation into action.

While a federal solution is neither possible nor desirable in this complex area, federal agency representatives acknowledge specific responsibilities, in addition to the leadership role. There are a number of good federal programs at the college and university level, but the federal role in precollege education is more problematic. Here, the states and localities are the dominant players, and available federal appropriations are small in terms of the scope of precollege education. NSF sees its role in terms of funding model programs that direct attention to where the problems are and that demonstrate potential solutions. Leverage and matching are key concepts. Continuity in support is required to address the lack of staying power that has plagued past federal programs.

Conclusion

There is a wide range of demonstrably effective programs for nurturing science and engineering talent. This base of activity can and should serve as a platform for replication and adaptation of intervention programs and, most importantly, as a starting point for the institutionalization of effective techniques throughout the educational system. All sectors of society need to be involved.

SUMMATION

The nation faces a potentially serious problem in quality and quantity of technical personnel unless the rates at which young people earn degrees in science and engineering are increased. Every educational and developmental stage is a potential point of intervention. A systems approach to nurturing science and engineering talent that draws on demonstrably effective intervention techniques is needed. All sectors must be involved.

ENDNOTES

1. Thanks go to Erich Bloch and his staff at the National Science Foundation for their contributions to this section.
2. The data in this section are aggregated at different levels depending on their availability and their purpose. The term science and engineering (S/E) is used to refer to all fields, including the social and behavioral sciences. The term natural science and engineering (NS&E) does not include the social nor the behavioral sciences. Some figures use data presented by broad field: Physical sciences include math and computer science; social sciences include psychology; life sciences include agriculture and medical science; engineering is straightforward.
3. Only some fields of engineering are experiencing shortages. In *Engineering Graduate Education and Research*, a 1984 NSF report is cited as projecting shortages through 1987 in three fields only: aeronautical/astronautical, computer specialties, and electrical/electronic engineers. Committee on Engineering and Technical Systems, National Research Council, National Academy Press, Washington, D.C., 1985, p. 17.
4. Tanenbaum, Morris, Vice-Chairman, Board of Directors, AT&T, statement during Symposium "Nurturing Science and Engineering Talent" held at Franklin Institute, Philadelphia, 09/29/86.
5. Office of Technology Assessment (OTA), U.S. Congress, *Demographic Trends and the Scientific and Engineering Work Force: A Technical Memorandum*, U.S. Government Printing Office (Publication No. OTA-TM-SET-35), Washington, D.C., December, 1985.
6. The rise of the new field of computer science is linked to the decline of mathematics majors. These phenomena must be considered jointly.
7. Akin, James N., *10th Annual Report on Teacher Supply/Demand, Association for School, College, and University Staffing*, Madison, Wisconsin, 1986.
8. *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, Stipes Publishing Company, Champaign, Illinois, January, 1987, p. vii.
9. Office of Scientific and Engineering Personnel (OSEP), *1985 Summary Report, Doctorate Recipients from U.S. Universities*, National Research Council, National Academy Press, Washington, D.C., 1986.
10. OTA, op. cit., *Demographic Trends*, p. 22.
11. Doctorate Records Files, National Research Council, Washington, D.C.; and Bureau of the Census.
12. Ph.D. production can either be increased by a rise in the number of baccalaureates or by a rise in the continuation rate. The latter approach has a more direct impact.
13. OSEP, op. cit., *1985 Summary Report*, Table 2, p. 46-47.
14. Gilmartin, Kevin J., *Development of Scientific Careers: The High School Years*, American Institutes for Research in the Behavioral Sciences, Palo Alto, August 1976, p. 132.
15. Consortium On Financing Higher Education (COFHE), *Beyond the Baccalaureate*, Cambridge, March, 1983, p. iv.
16. Office of Scientific and Engineering Personnel, "Leaving the Pipeline: Documenting Losses in the Science Talent Pool," September, 1986.
17. Berryman, Sue E., "Minorities and Women in Mathematics and Science: Who Chooses These Fields and Why?" *New Perspectives*, U.S. Commission on Civil Rights, Washington, D.C., Winter, 1985, p. 10-13.

18. Berryman, Sue E., Testimony Before the Task Force on Science Policy, Committee on Science and Technology, U.S. House of Representatives, Washington, D.C., July 24, 1985, p. 9. Quantitative fields include the physical and biological sciences, mathematics, engineering, and medicine.
19. Berryman, op. cit., *New Perspectives*, p. 8.
20. Thomas, Gail E., *Black College Students and Factors Influencing Their Major Field Choice*, Southern Education Foundation, Atlanta, March, 1984, p. 6.
21. Rever, Philip R., *Scientific and Technical Careers: Factors Influencing Development During the Educational Years*, The American College Testing Program, Iowa City, 1973, p. 130-131.
22. Berryman, op. cit., *New Perspectives*, p. 9.
23. OSEP, op. cit., "Leaving the Pipeline," page 14. Source cited is National Center for Education Statistics.
24. Two-thirds as many girls as boys take Chemistry II; half as many take physics (11.6 v. 22.1%). OSEP, op. cit., "Leaving the Pipeline," page 14. Source cited is National Center for Education Statistics.
25. Fitzgerald, Louise F.; and Betz, Nancy E., "Issues in the Vocational Psychology of Women," *Handbook of Vocational Psychology*, edited by W. Bruce Walsh and Samuel H. Osipow, Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1983, p. 121-122.
26. Thomas, Gail E., *The Access and Success of Blacks and Hispanics in U.S. Graduate and Professional Education*, National Academy Press, Washington, D.C., 1986, p. 25.
27. Smith, Elsie J., "Issues in Racial Minorities' Career Behavior," *Handbook of Vocational Psychology*, edited by W. Bruce Walsh and Samuel H. Osipow, Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1983, p. 168.
28. Bureau of Labor Statistics, data provided by phone. Current as of March, 1986. Note that whites with 4 years of high school have an unemployment rate of only 7%.
29. Some methodological problems constrain the interpretation of these data. The findings pertain only to full-time students who provided all data at all survey points. Nonetheless, the data are suggestive of flows in and out of the pipeline.
30. Bloom, Benjamin S., *Developing Talent in Young People*, Ballantine Books, New York, January 1985, p. 386-388.
31. Oberlin College, "Executive Summary," *The Future of Science at Liberal Arts Colleges. A Conference Held at Oberlin College June 9 and 10, 1985*, Office of the Provost, May, 1985; and Oberlin College, *Maintaining America's Scientific Productivity: The Necessity of the Liberal Arts Colleges*, Office of the Provost, June, 1986, p. 33.
32. Thomas, op. cit., *Factors*, p. 4.
33. Sample sizes are so small here that, in combination with the methodological problems cited above, these findings may not accurately reflect career choice patterns of the general populations of these groups.
34. Thomas, op. cit., *Access and Success*, p. 18-20.
35. Ibid., p. 22.
36. The College Board, Educational Equality Project. *Equality and Excellence: The Educational Status of Black Americans*, Washington, D.C., 1985, p. 2.
37. Thomas, op. cit., *Factors*, p. 10.
38. COFHE, op. cit., *Beyond*, p. 39-40.
39. OTA, op. cit., *Demographic Trends*, p. 118-121.
40. Berryman, op. cit., *New Perspectives*, p. 9-10.

41. Berg, Helen M.; and Ferber, Marianne A., "Men and Women Graduate Students: Who Succeeds and Why?, *Journal of Higher Education*, Vol. 54, No. 6, Ohio State University Press, November/December 1983, p. 644-45.
42. Thomas, op. cit., *Factors*, p. 9-10.
43. Thomas, op. cit., *Access and Success*, p. 26.
44. Ibid., p. 22-23.
45. Berrueta-Clement, John R., et. al., *Changed Lives: The Effects of the Perry Preschool Program on Youths Through Age 19*, High Scope Press, Ypsilanti, Michigan, 1984.
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48. Clarke, Gertrude, Executive Director, New Jersey Business/Industry/Science Education Consortium, statement during Symposium "Nurturing Science and Engineering Talent" held at Franklin Institute, Philadelphia, 09/29/86.
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50. Franklin, Paul L., *Helping Disadvantaged Youth and Adults Enter College: An Assessment of Two Programs*, College Entrance Examination Board, Washington, D.C., 1985.
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54. Shymansky, James A.; Kyle, C. Jr.; and Alport, Jennifer M., "The Effects of New Science Curricula on Student Performance," *Journal of Research in Science Teaching*, Vol. 20, No. 5, John Wiley & Sons, Inc., 1983.
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56. Purdue University, Department of Freshman Engineering, *Putting It All Together: A Model for Women Entering Engineering*, Women's Educational Equity Act Publishing Center, Newton, Massachusetts, 1982, p. 24.
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APPENDIX I

Roundtable Working Group One: The Identification, Recruitment and Retention of Science and Engineering Talent

JAMES B. WYNGAARDEN, (Chairman), Director, National Institutes of Health
MARVIN L. COHEN, (Vice-Chairman), Professor of Physics, University of California, Berkeley
DAVID B. ASHLEY, Associate Professor, Department of Civil Engineering, University of Texas at Austin
HELEN S. ASTIN, Associate Provost, UCLA College of Letters and Science, and Professor of Higher Education, School of Education, University of California, Los Angeles
ERICH BLOCH, Director, National Science Foundation
JOEL N. BLOOM, President, The Franklin Institute Science Museum
LILLI HORNIG, Senior Consultant, Higher Education Resource Services, Wellesley College
JAMES M. JAY, Professor, Department of Biological Sciences, Wayne State University
IRVING S. JOHNSON, Vice President, Lilly Research Labs, Eli Lilly Corporate Headquarters
HENRY W. RIECKEN, Professor of Behavioral Sciences, Emeritus, University of Pennsylvania
MORRIS TANENBAUM, Vice Chairman, Board of Directors, AT&T
CLARENCE VER STEEG, Dean of the Graduate School (until 8/86) and Professor of History, Northwestern University

Staff:

DON I. PHILLIPS, Executive Director
D. ANNE SCANLEY, Program Officer
LINDA ALLEN-DAVIS, Senior Secretary

APPENDIX II

NURTURING SCIENCE AND ENGINEERING TALENT

A Symposium

September 29, 1986

Science Auditorium
FRANKLIN INSTITUTE
20th Street and The Parkway
Philadelphia, PA

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

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THE FRANKLIN INSTITUTE

AGENDA

8:30 Registration

9:00 Welcome

CHARLES L. ANDES, *Chairman, Franklin Institute*

Introductory Remarks

DALE R. CORSON, *Chairman, Research Roundtable*

Moderator

JOEL N. BLOOM,* *President, Franklin Institute Science Museum*

9:10 Keynote Address

MORRIS TANENBAUM,* *Vice-Chairman, Board of Directors, AT&T*

9:30 Session 1: The Status of the Talent Pool

--Presentation

ERICH BLOCH,* *Director, National Science Foundation*

--Panel Response

ROBERT K. ARMSTRONG, *Manager, Professional Staffing, E.I. du Pont de Nemours Co., Inc.*

FRAN S. ATCHISON, *Assistant Director for Policy and Planning, New Jersey Commission on Science and Technology*

CHARLES L. HOSLER, *Vice President for Research and Dean of the Graduate School, Pennsylvania State University*

JOHN J. LEONARD, *Manager, Oxygenates R&D, ARCO Chemical Company*

--Questions and Comments from the Audience

11:00 Break

11:15 Session 2: Career Choice

--Presentations

ALAN FECHTER, *Executive Director, Office of Scientific and Engineering Personnel, National Research Council*

HELEN S. ASTIN,* *Associate Provost, College of Letters and Science and Professor of Higher Education, University of California, Los Angeles*

--Panel Response

ANDREW BINNS, *Associate Professor, Biology Department, University of Pennsylvania*

MARGARET FETZER, *Chairperson, Guidance Department, Alexis I. du Pont High School, Greenville, Delaware*

OTTO MAUKE, *President, Camden County College*

JENNIE PATRICK, *Research Section Manager, Rohm and Haas*

--Questions and Comments from the Audience

12:45 Lunch

1:45 Session 3: Interventions and Options

--Presentations

RITA C. ALTMAN, *Associate Superintendent, Curriculum and Instructional Development, School District of Philadelphia representing the Philadelphia Renaissance in Science and Mathematics (PRISM) and the Science Activity Kits Project*

GERTRUDE CLARKE, *Executive Director, New Jersey Business/Industry/Science Education Consortium*

REBECCA L. LUBETKIN, *Executive Director, Consortium for Educational Equity, Rutgers University*

ALEXANDER TOBIN, *Executive Director, PRIME, Inc., (Philadelphia Regional Introduction for Minorities to Engineering)*

DANIEL C. DAVIS, *Director, Minority Engineering Program, Pennsylvania State University*

JOAN BENNETT, *Coordinator of Undergraduate Research, University of Delaware*

--Panel Response

MARVIN COHEN,* *Professor of Physics, University of California, Berkeley*

RAYMOND HANNAPEL, *Program Director, Research in Teaching and Learning Program, National Science Foundation*

LILLI HORNIG,* *Executive Director, Higher Education Resource Services, Wellesley College*

JAMES M. JAY,* *Professor of Biological Science, Wayne State University*

SHIRLEY MALCOM, *Program Head, Office of Opportunities in Science, American Association for the Advancment of Science*

D. KAY WRIGHT, *Acting Secretary of Education, Pennsylvania Department of Education*

--Break

--Questions and Comments from the Audience

4:15 Wrap-Up

JAMES WYNGAARDEN,** *Director, National Institutes of Health*

4:30 Reception

5:30 Adjourn

* Members of the Roundtable Working Group on Science and Engineering Talent

** Chairman of the Roundtable Working Group on Science and Engineering Talent

PROGRAM CHANGE

PETER WARTER, *Chairman, Electrical Engineering, University of Delaware, replaces* Joan Bennett *during the Interventions session.*