DOCUMENT RESUME

ED 196 716 SE 033 766

AUTHOR	Galambos, Eva C.
TITLE	Engineering and High Technology Manpower Shortages: The Connection With Mathematics.
INSTITUTION	Southern Regional Education Board, Atlanta, Ga.
PUB DATE	80
NOTE	22p.
AVAILABLE FROM	Southern Regional Education Board, 130 Sixth St., N.W., Atlanta, GA 30313 ($2.00).
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	College School Cooperation; *Educational Demand; Educational Economics; Employment Projections; Engineering; *Engineering Education; *Higher Education; *Labor Problems; Mathematics; *Mathematics Education; Political Issues; *Social Problems; Technology

ABSTRACT

Current and projected manpower shortages in high technology areas are examined with respect to the region served by the Southern Regional Education Board (SREB). Many of the problems associated with the shortfall of trained individuals are viewed as connected to decreasing numbers of students taking advanced mathematics, and a lack of concerted efforts and strategies to reverse this trend. Sections presented include: (1) Wanted: High Technology Graduates; (2) Limited Supply of High Technology Graduates; (3) Constraint on Supply: High School Mathematics; (4) Women and Minorities: A Potential Source; (5) Mathematical Achievement: A General Decline; (6) The Shortage of Mathematics Teachers; (7) Supply and Demand Projections, Southern Region; (8) Mathematics and Computer Science; (9) The Outlook for Engineers; (10) How High Can Engineering Enrollments Go; (11) Supply and Demand for Engineers in the South; (12) Engineering Doctorates Sharply Down; (13) New Priorities and Changing Demands for High Technology Graduates; and (14) Conclusions. (MP)

Engineering and High Technology Manpower Shortages:

The Connection with Mathematics

Eva C. Galambos

130 Sixth Street, N.W. • Atlanta, Georgia 30313 • 1980 • $2.00

SREB

Southern Regional Education Board

This paper was reviewed by Dr. Paul Doigan, General Electric Company, Schenectady, New York; by Dr. W. Denney Freeston, Jr., associate dean, College of Engineering, Georgia Institute of Technology; and by Dr. William F. Atchison, professor, Computer Science, University of Maryland. The author wishes to acknowledge the valuable suggestions each made. The author, however, bears full responsibility for the opinions expressed in this paper.

Highlights

- A shortage of high technology manpower (graduates in engineering, mathematics, computer science, and the hard sciences) is expected in the region in this decade.

- This high technology manpower shortfall will be accentuated by changing national priorities toward increased research and development, greater capital expenditures to improve industrial productivity, and an emphasis on national defense.

- Although there will not be enough new entrants into high technology fields, labor market imbalances may be partly adjusted through upward and occupational mobility of persons with related skills. Still, since these persons too will be in high demand, the total economy may be impeded by the overall lack of personnel with the requisite skills for a highly technical society.

- Further increases in engineering enrollments are probably not to be expected in the immediate future. The traditional source of engineering enrollments—young white males—will be reduced by the demographic facts. Therefore, maintaining the present level of enrollments, or increasing them (if engineering colleges can expand to accommodate the increase), would depend on higher participation rates by women and minorities. These groups in the past have avoided the field.

- An increase of degrees in engineering and other high technology fields depends to a considerable extent upon greater stress on mathematics in the high schools. A rigorous four-year high school mathematics sequence is the usual prerequisite for enrollment in the high technology fields. Yet a limited proportion of today's high school students have this preparation.

- Greater participation in high school mathematics as well as the general improvement of mathematical achievement is hindered at the present time by the serious shortage of mathematics teachers in school districts throughout the region. The declining interest among college students in mathematics education diminishes the hope of any imminent improvement of the shortage of mathematics teachers.

Foreword

Colleges and universities are giving increased attention to the realities and implications of the new environment of the Eighties. They are keenly aware of the declining pool of college-age youth and of threats to the adequacy of higher educational funding. But they also realize that a decrease in the number of college graduates may lead to shortages in some types of professional manpower before the end of the decade.

These conditions may tempt some campuses to lower admission standards, not only to maintain enrollment levels but also to respond to society's manpower needs. Yet, the sacrifice of quality implied by reducing college entrance standards is not the answer to meeting manpower needs. A preferred approach is for all levels of education to work toward producing a greater number of youth qualified to complete a rigorous college curriculum. By not sacrificing standards, the focus is then on strengthening high school instruction and also on providing remedial studies for inadequately prepared college freshmen.

Today, more than ever, higher education leaders are aware of their dependence on the elementary and secondary school systems to prepare candidates for college study. This report singles out one area of this interdependency, namely, the relationship between the adequacy of high school mathematics instruction to the capacity of higher education to meet society's need for skilled, high technology manpower.

SREB recognizes a growing public concern for a more effective relationship between our schools and higher education. Currently, SREB is directing attention toward problems of teacher preparation and certification. The present report illustrates the fact that content of the secondary curriculum, as well as high school prerequisites for the various avenues of postsecondary education, deserve added attention by all educational sectors.

Winfred L. Godwin
President

Table of Contents

6

Wanted: High Technology Graduates

During the past several years, supply of high technology graduates has not kept up with demand. Employer demand for college graduates in the fields of engineering, computer science and mathematics, and the physical sciences has been very strong. But despite strong increases in the absolute number of enrollments in computer science and engineering, the current percentage of total college graduates in the highly technical fields remains below what it was in the early Sixties. In mathematics there has actually been a decrease in the absolute number of graduates. What do these contrasts bode for the future? Will graduates in the highly technical fields be in short supply through the decade, will there be a reversal of this tight situation, and is there possibly even a danger of overexpansion?

During the latter Seventies, demand for engineering graduates was phenomenal. Throughout the nation and in the Southern region, placement officers reported that on-campus recruitment activity showed engineering ranking among the highest demand disciplines. The high salaries engineering graduates command bear out the strong market. Although in other fields examined by the College Placement Council, salary offers to new baccalaureates declined in *real* dollars during the 1970s, for engineers they rose.[1] The strong market has held up despite an increase to 52,600 engineering baccalaureates in the United States in 1979—the highest annual number since the 1950s.

Similarly, the market has been strong for computer science graduates. Like engineers, they are in the position of choosing among employment offers, while their peers in the liberal arts scramble to find suitable jobs. Furthermore, complaints are being heard increasingly from school districts unable to locate mathematics and science teachers. Competing opportunities in business and industry for people with these technical skills are siphoning off the limited number of graduates.

In other technical fields, such as physics and chemistry, the job market has also been strong. Even at the doctoral level, where there was an oversupply of physicists in the mid-Seventies, conditions have improved. Fewer Ph.D.s are staying on as "post-docs"—positions sometimes serving as a "holding pattern" for doctorates who cannot find employment. The American Institute of Physics Employment Survey of 1978 Graduates reports that only 2 percent of those surveyed at all degree levels were still looking for work six months after graduation.

In sum, the market for highly technical graduates is booming. The Deutsch, Shea and Evans *High Technology Recruitment Index*, a nationally known indicator of the market for engineers and related personnel, rose to 144 in 1979—the highest point the *Index*[2] has reached except during 1966 (see Figure 1). Despite the recession, the *Index* continued to rise early in 1980, although it finally reflected the weakening economy with a decline by the spring months.

Limited Supply of High Technology Graduates

Degree production has not kept pace with this strong demand for high technology graduates. As shown in Table 1, the proportion of college students choosing such fields has declined in recent years. For both the nation and the region, the proportion of baccalaureates with degrees in engineering, mathematics, computer science, and physical sciences combined was one-third lower in 1977-78 than in 1963-64. At the master's level, this decline is even more marked—the proportion is less than half.

TABLE 1

Proportion of Total Degrees in High Technology Fields*

	Baccalaureate		Master's	
	United States	South	United States	South
1963-64	15.6%	15.1%	18.8%	16.7%
1970-71	11.7	11.2	12.8	11.3
1976-77	10.0	9.4	8.8	7.0
1977-78	10.7	10.3	9.1	7.1

* Included are computer science, engineering, mathematics, and physical sciences, as defined under HEGIS and as reported by NCES.

What is still more alarming is the fact that in the region the absolute number of degrees for these combined fields actually dropped between 1971 and 1977—a period during which the total number of bachelor's degrees awarded rose 16 percent. This drop is accounted for by the mathematics field, even when computer science is included (see Table 2). The 1977-78 degree data do show a slight turnaround in student avoidance of the highly technical fields, with engineering and computer science accounting for the overall gain. Mathematics, however, continues to be a loser—both relatively and absolutely—even in combination with computer science. The American Council of Education's 1979 report on the plans of freshmen regarding their college majors does indicate a small shift to the highly technical fields, both nationally and in the South.

The decreasing proportion of degrees in highly technical areas is not totally unexpected during a period when college enrollments have been rapidly expanding. These are the fields that in the past attracted young, male, high achievers. This group, for the most part, was already well represented in the college population before the huge enrollment expansion of the late Sixties and early Seventies. The "new" college students who contributed to the boom in higher education—women, minorities, and older students—have been less inclined to choose the fields in question.

TABLE 2

Proportion of Total Baccalaureate Degrees in High Technology Fields Selected Years

	1963-64		1970-71		1976-77		1977-78	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
South								
Computer Science	—	—	596	0.3%	1,676	0.7%	1,931	0.8%
Mathematics	5,450	4.6%	6,723	3.1	3,656	1.5	3,215	1.3
Engineering	8,238	6.9	11,646	5.4	12,197	4.9	14,551	5.8
Physical Sciences	4,251	3.6	4,989	2.3	5,987	2.4	6,271	2.5
United States								
Computer Science	—	—	2,388	0.2	6,426	0.8	7,224	0.8
Mathematics	18,649	4.1	24,912	2.9	14,295	1.5	12,701	1.4
Engineering	35,354	7.7	50,357	5.9	49,667	5.4	56,009	6.0
Physical Sciences	17,507	3.8	21,548	2.5	22,609	2.4	23,175	2.4

Source: *Degree Output* reports, based on HEGIS data, Southern Regional Education Board. The "engineering" field, as reported by the HEGIS system, includes engineering technology baccalaureates and is not comparable to the "engineering" category as reported by the American Association of Engineering Societies.

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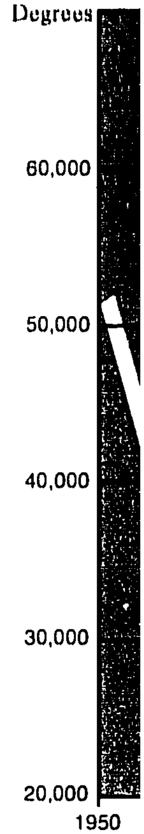

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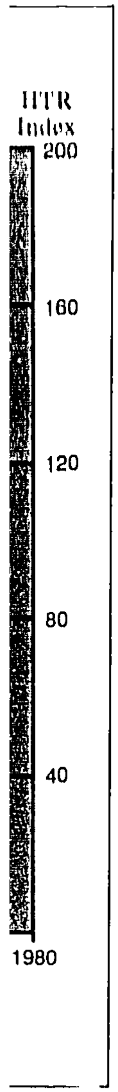

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There is considerable variation among reports on high school participation in mathematics sequences. The National Longitudinal Study (NLS), which has been tracking a national sample of 1972 high school graduates, corroborates the relationship between "math takers" in high school and the likelihood of completing college in any field, and also of majoring in one of the technical fields.[3] "Math takers" in the NLS report are those who took at least six semesters of math during their last three years of high school. This does not insure that they were all enrolled in a rigorous math sequence ending in trigonometry, but that experience may be inferred for a considerable portion of the group. Of the 1972 class, 28.5 percent were math takers. For blacks, the proportion was 19.4 percent. The proportion was higher for males than for females. Subsequent freshman choice of major among "math takers" gravitated toward the hard technical fields more often for white males than for minorities and women.

The Education Commission of the States recently reported on a study of 1978 high school seniors and the mathematics courses in which they were enrolled.[4] For males, 31 percent had taken or were taking trigonometry; for females, 27 percent. The National Assessment of Educational Progress, however, reported only 15 and 11 percent of the males and females, respectively, as having taken trigonometry in the same year.[5] Wakeland, of the University of Illinois College of Engineering, reported in 1978 that the proportion of high school students completing mathematics and science studies declined from 1970 to 1977, but that a turnaround appeared to be taking place.[6]

Women and Minorities: A Potential Source?

The absolute number of high school graduates in 1985 will be 15 percent lower than a decade earlier. Thus, to produce any substantial increases in high technology manpower, the potential pool will have to extend beyond its traditional constituency of white males. In the past, women and minorities have been very poorly represented in engineering and in the other fields under review here. Only 5.5 percent of the nation's engineers in 1978 were members of a minority. Among these, blacks constituted an even lower proportion—1 percent. Women in 1978 accounted for less than 3 percent of employed engineers.[7]

John S. Robottom, executive director of the Texas Alliance for Minorities in Engineering, estimates that only 10 percent of the annual high school graduates in Texas have completed trigonometry. "Fewer yet, only 1,700 students, have taken physics, the one science on which engineering is based. The Texas Education Agency (TEA) has no figures on the numbers of minority students who have taken these essential courses, but those of us in engineering education know that the number is infinitesimal."[8]

Mr. Robottom's concern over minority participation in high school mathematics sequences stems from his awareness of demographic trends. He points to the TEA projections that in the late 1990s, 60 percent of the state's K-12 population will be black or Hispanic, as compared to the current proportion of 40 percent. Yet minority students rarely consider technical careers. In Texas, he projects, ". . . a severe overall *decline* in engineering production commencing in the next few years; clearly, we must bring our minority population into the mainstream of technical careers—not as a response to federal mandate or from a humane impulse to aid the less fortunate, but to sustain the highly technical society which we have built here in Texas."

Much has been written about "math anxiety and avoidance" among women. The subject becomes more important, now that women constitute over half of total college enrollments. Is there any innate difference to account for their math avoidance and their consequent disproportionately small representation in technical fields?

Current research finds mathematics achievement at least as high for females as for males into the lower high school grades. By the 12th grade, however, males surpass females in both the number of math courses they have taken and in their achievement levels. When only those males and females are compared who have taken an equal number of math courses, males perform somewhat better than females in the problem-solving and application areas. However, the two sexes perform at par on the purely computational skills.[9]

The relative failure among females to persist as "math takers" has been explained as stemming from environmental factors. Girls are said to have less confidence; they perceive less parental, teacher, and peer expectation that they should take mathematics and that they will succeed in mathematics. Many continue to expect that their future career choices will not depend on a mathematical grounding. Intervention to change such attitudes has been suggested in order to increase high school mathematics participation among women.[10]

Some colleges have developed programs to help women overcome math anxiety.[11] The success of these programs in breaking the psychological barriers that many women face in approaching math, however, does not imply that such courses will put these women at the levels required for successful completion of highly technical fields. Such programs tend to improve their Graduate Record Examination (GRE) scores, but it is still not the ideal way to embark on a calculus sequence as part of an engineering program.

Considerable effort has been expended by professional engineering groups to increase female and minority participation in engineering. Various task forces and special projects throughout the nation have focused on this need over the past decade — with limited success. In 1978, the proportion of women among engineering baccalaureates was 7 percent, up from 1.4 percent only five years earlier.

For blacks, the change was only one-half of a percentage point. Participants in a 1977 conference sponsored by the Engineers Joint Council concluded that minority members would not play a large role in the supply of engineers. "Engineering, as a way of life, is not today the so-called 'in' thing with minority groups. Their previous training, environment, educational background, and even their way of thinking do not portray a mass movement toward the engineering professions."[12] Although not a sign of a "mass movement," black engineering enrollments in the South in 1979 represented 6 percent of the total — up from the 4 percent five years earlier.

Mathematical Achievement: A General Decline

Increasing the proportion of high school students who take rigorous math sequences is only part of the concern over the current status of mathematics education in the schools. The general decline in mathematics achievement, as evidenced by Scholastic Aptitude Test (SAT) scores and other assessments, is a worrisome trend to a society that seeks to maintain a lead in a technological era.

The decline of SAT math scores has been thoroughly analyzed. By 1979, the 10-year drop in math SATs in the South was 4 percent, from an average of 458 to 444.[13] A longer perspective is available for national average SAT scores—from 1952 to 1980—with verbal scores down 11 percent and math scores down 6 percent, from 494 to 466. (The average scores for the region are lower than those for the nation.)

The analysis of the decline in the national average SAT scores by the Advisory Panel that studied this issue concluded that the change in the composition of students taking SATs accounted for most of the drop during the 1960s.[14] In 1964, only one-third of the high school graduates were entering college, while by 1970 the proportion had risen to approximately one-half. However, the continued drop in SAT scores since 1970 cannot be explained simply by the changing composition of test takers. Instead, the proliferation of electives in high school, declining academic standards, television viewing, and the changing role of the family are all thought to contribute to the poorer results.

The National Assessment of Educational Progress (NAEP), a recurring testing program of 9, 13, and 17 year olds, also found a drop in mathematical scores in the 1978 tests, compared with 1973. The scores for all three age groups declined, although the greatest decline was for the oldest group. The most pronounced drop in scores was for problem-solving portions. Computational skills, such as adding, subtracting, and multiplying, were mastered. But on such a relatively simple task as figuring the per unit cost of an electricity bill, only 10 percent of the 17 year olds were able to comply. Only 37 percent of this age group was able to correctly estimate on a multiple choice question that "2" is the whole number most nearly equaling 12/13 + 7/8. On the tests in 1973 and 1978, the students in the Southeastern region performed below the national level.[15]

The competency-based movement in public education has been blamed for the decline in problem-solving abilities. Rote procedures and simple word problems at the end of a chapter that repeat, rather than restructure, material presented in the lessons facilitate repetitive drills but do not encourage reasoning abilities. Dr. Shirley Hill, president of the National Council of Teachers of Mathematics, warns that ". . . excessive attention to minimal competencies could result in minimums becoming ceilings of performance, and I think there is considerable evidence today that this is indeed what has happened. . . . Short-term retention is the goal, not long term retention and ability to apply."[16]

The Shortage of Mathematics Teachers

It stands to reason that an increase in "math takers" in the high schools and an improvement in the general school population's mathematical achievement levels depend on the availability of mathematics teachers. Yet a shortage of mathematics teachers in elementary and secondary education was generally recognized in the United States during the spring of 1980. What had been isolated reports about math teacher shortages in various localities and from some state education agencies during the preceding year have now been translated into national press front-page accounts about the pervasive scarcity of mathematics teachers.

Reports indicate that in Houston, Texas, for example, one-fourth of the math classes are staffed by nonspecialists. Virginia reports a gap of 38 percent between the number of openings last year for beginning math teachers and the number of graduates prepared by colleges to teach the subject within the state. A North Carolina report estimates an annual shortage of 300 math and science teachers, with the deficit becoming worse.

Two immediate reasons explain much of the shortage: a sharp decline in the number of majors in the discipline, and the lure of higher pay in non-teaching jobs for those who do have the preparation. In the region, the number of baccalaureate degrees awarded in mathematics in 1978 was 51 percent below the number in 1971. Although the potential supply of new graduates prepared to teach mathematics does not originate solely among math majors, the decline in that group is indicative of the trend. The National Education Association (NEA) estimates of 1978 graduates prepared to teach mathematics at the secondary level showed a 12 percent national decline in one year. NEA still estimated supply as exceeding demand for the field, although it did list the discipline, together with trade-industrial, agricultural, and science, as teaching fields on the "tight" end of the scale.[17]

Another analysis of baccalaureates prepared to teach mathematics showed a 9 percent decline in 1979 from the previous year. Of all baccalaureates prepared to teach that year, only 2.2 percent were in the mathematics specialty area, while 12.2 percent were included in the health, "phys ed," and recreation area.[18] The actual number of 1978 baccalaureates with degrees in "mathematical education" was only 445 for the entire region. But 7,502 were prepared to teach physical education.

The general oversupply of teachers in recent years probably contributed to the lack of awareness about the impending shortage in the mathematics area. Rigid teacher pay plans, that do not differentiate salaries by specialties, generally cannot respond to shortages in any one discipline. With good opportunities in business and government, where math majors can adapt their skills to computer programming, research, and analysis, school systems are at a competitive disadvantage.

If a greater number of teachers prepared to teach mathematics is one answer toward reversing the achievement declines of these students, enrollment in college mathematics courses does not provide evidence of an imminent turnaround. The latest report on undergraduate mathematics enrollments compares 1976 data with those for 1971.[19] While total enrollments in four-year institutions during this period rose 11 percent, math enrollments were up only 8 percent. What enrollment increases did occur were concentrated in the lower division courses and in computer science and statistics courses. Upper division mathematics courses (calculus and above) were down 32 percent. These are the courses commonly taken by math, physical science, and engineering majors, whose enrollments in the 1970s did not keep pace with college enrollments generally. Enrollment in "mathematics for elementary teachers" declined 24 percent.

Increases in *lower* division courses are explained in part by the declining mathematical preparation among entering freshmen. In the two-year colleges, the same trends were evident—1976 enrollments compared to 1971 showed shifts to remedial arithmetic and high school algebra, with slower growth in the pre-calculus and calculus courses.

Supply and Demand Projections, Southern Region

A comparison of openings versus graduates in mathematics and computer science and in engineering indicates that the Southern region will experience shortages in these fields. Projections of occupational openings which reflect employment growth, as well as replacement needs, are contained in reports of the State Employment Security Agencies (ESAs). These projections are developed by the ESAs on the basis of underlying assumptions established by the United States Bureau of Labor Statistics. Among these assumptions are the suppositions that no long-lasting energy shortages or technological changes will drastically affect the economy. To the extent that such assumptions may not reflect the actual state of future affairs, the demand for high technology graduates may differ from the projected openings. Still, these projections provide a point of departure for estimating the number of graduates who will be needed annually in the region to fill job openings over the next five years.

Supply and Demand, Mathematics and Computer Science Specialists, SREB Region, 1985

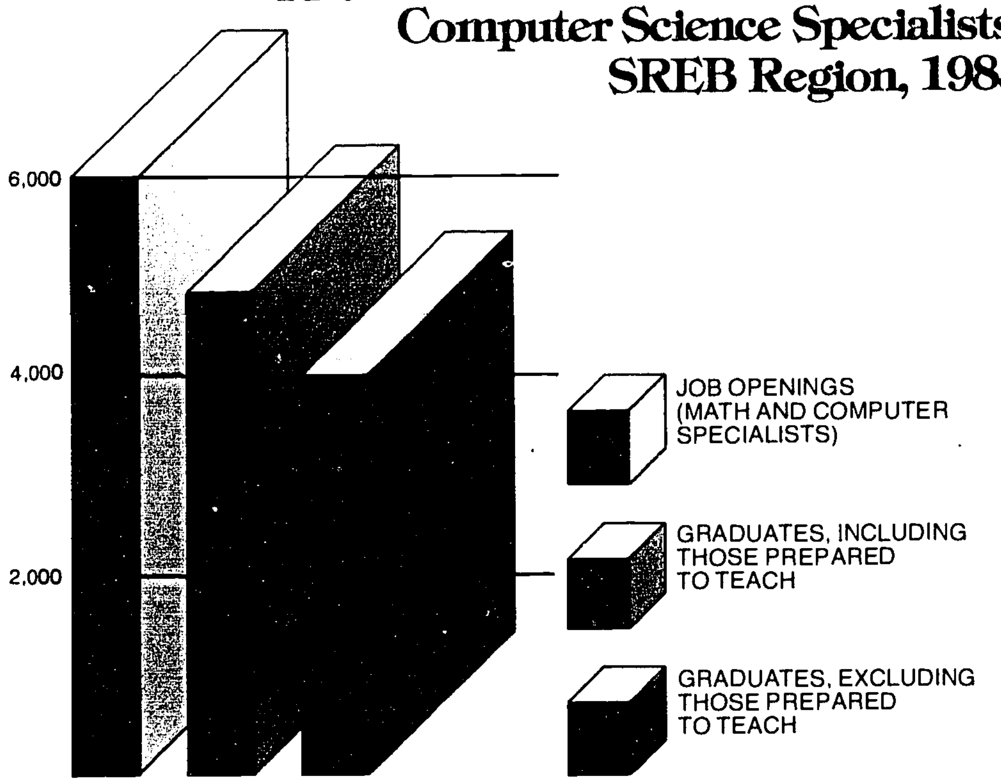

Figure 2

Mathematics and Com uter Sciences

Although teaching has traditionally been tl argest employment sector for mathematics majors, other areas offer good opportunities. Mathematicia pply their skills in business and government at jobs as diverse as developing insurance rates to trackı satellites. A recent report on the exodus of mathematics teachers from the schools listed a cartographer's as an example of a higher paying opportunity that lured a math teacher out of the classroom. At the prese time, computer programming, operations research, and systems analysis offer widespread opportunitie for mathematics majors with exposure to computer applications.

With the exception of elementary and high schc l teaching of mathematics, for which computer science majors who lack education credentials are not eligit ., many mathematics and computer science majors tend to be interchangeable in the job market. Thus makes sense to consider projected openings for mathematics and computer specialists together, for parison with the emerging supply of graduates in the two fields combined.

A comparison of supply versus projected openir for mathematics and computer science specialists in the South is shown in Figure 2.

According to the projections of the ESAs in 4 SREB states, there will be approximately 6,150 average annual openings to account for growth a placement needs through 1985 for mathematics and computer specialists. (It is assumed that these op n. s will require persons with a college degree.) Yet in 1978, in the South, only 5,146 baccalaureate degre were granted in these two disciplines, or 16 percent less than the number of openings.

This supply of graduates includes those mathe n. es who take education courses to qualify for teaching certificates. If the latter are presumed as e g re for teaching openings, the annual entering supply is diminished by perhaps as much as one- r g a supply deficit of more than one-third against projected openings. It is no wonder that s d up for such graduates, and that majors prepared to teach gravitate toward non-teaching jobs. h they have not taken computer courses, these graduates can still command higher salaries as er programmer trainees than as beginning teachers.

The booming job market for computer specialist trated by a report from a national personnel consulting firm noting that, in 1979, employers hired 5 ent more programmers than in the previous year. For systems programmers and systems analysts, d had risen 35 percent and 29 percent, respectively.[20] Yet national totals for baccalaureates in com science are projected to increase less than 10 percent annually in the 1980s.[21]

The shortage of personnel in computer science is borne by Hamblen's recent assessment. He concludes annual needs for manpower at the baccalaureate leve ceeding annual production by more than five to one.* The deficit at the master's level is shown as one. Even in the event of gross inaccuracy in assumptions and data, such ratios indicate a severe pro a society which may be largely dependent on sophisticated automation to pull itself out of the produ ity ump.[22]

The one exception to the rosy outlook for mathematics majors is e doctoral level. The academic market has been the major employment sector for such persons in the pa but a recent study projects that new academic hires will decline to perhaps as low as 8 percent of the 1976 el during the next decade.[23]

The Outlook for Engineers

In the past, supply and demand for engineers have often been out of sync. Enrolln ts and the number of graduates expanded in response to rising demand and high salaries, overshot the mark. d were then caught in a downward swing of the economy. By the time enrollments and graduates respond to the diminished market, the demand was once again on the upswing, outstripping supply. Figure 1 illus es this situation with the Deutsch, Shea and Evans *Index* and the gyrations in numbers of engineering aduates at the baccalaureate level.

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* Hamblen recognizes the large production of computer personnel by two-year college programs and by proprietary schools, and concludes that the job market for such graduates is balanced. The deficits at the baccalaureate and higher degree levels exist despite the huge outputs at the lower levels.

The drop in demand during the late 1960s (as NASA and defense spending were cut) was not mirrored in the trough of degree production until the mid-Seventies. By then, demand was once again on the rise. The current large enrollment expansion in the engineering schools raises the spectre of another boom-bust cycle which could be in the offing.

Unemployment rates for engineers, which in recent years have been negligible, and certainly lower than for other professional-technical manpower, substantiate the very strong demand for engineers. College graduates in general were hard-hit in the recession of the mid-Seventies. But the National Science Foundation (NSF) follow-up surveys of 1974 and 1976 graduates show unemployment rates two years after graduation for baccalaureate engineers at only 2.9 percent and 0.6 percent, respectively. These rates are one-third of the rates shown for all graduates covered by NSF surveys.[24]

The impact of the mid-Seventies recession on the *High Technology Recruitment Index*, as seen in Figure 1, was less severe than the declines of the late 1960s when the United States economy was shifting towards emphasis on social services rather than space and research and development spending. Even then, when the plight of laid-off aerospace and space program engineers attracted great attention, the unemployment rate of engineers was still only in the 2 percent range. These layoffs accounted for the one instance in the last decade when the unemployment rate of engineers was higher than that for all professional-technical workers.[25] During the spring of 1980, when the current recession took hold, the demand for engineering baccalaureates held up very well, despite the increased number of graduates in 1980.

How High Can Engineering Enrollments Go?

Engineering enrollments in the United States grew substantially in the late 1970s. These increases resulted because of the strong job market for engineers, as well as relaxation of student distrust of technology and "big business" that had prevailed earlier. By 1979, junior-year enrollment, as shown in Figure 3, had risen 80 percent above the low point in 1973. These junior-year enrollments, which reflect transfers into engineering from other majors as well as the effects of attrition, give an indication of the trend in degree production, and point to further increases above the 52,598 baccalaureates granted in 1979. As shown in Figure 4, the number of baccalaureates in the United States has finally returned to the level of 1950, reversing the sharp decline of the early and mid-Seventies.

Extrapolating the number of degrees from current junior enrollments indicates that some 62,000 to 67,000 engineering baccalaureates will be granted annually in the nation during the Eighties. In addition, some 9,000 baccalaureate degrees in engineering technology* are likely to be earned annually. Does the surge of engineering enrollments presage an even greater expansion of degrees?

Most observers think it unlikely that this range will be exceeded. Although large numbers of students continue to seek admission to engineering schools, state schools, now at peak capacity, see no way to further expansion, given the climate of governmental fiscal stringency. Some colleges of engineering have already raised entrance requirements to cope with the surge of applicants. Institutional rigidities make it very difficult to shift resources, especially faculty, from declining higher education fields to expanding ones. Some private institutions are not yet at full capacity of engineering enrollments, but it remains to be seen whether unmet demands for admission to engineering programs will shift to the private sector, where costs are higher.

The surge of admissions may be self-limiting. The major pool from which engineering students are drawn—18 to 21 year olds—is declining. Therefore, a continuation of the high volume of engineering applications would have to come by way of a higher proportion of students choosing engineering to offset the absolute decline in the total pool. This increase has occurred, as shown in Table 3: freshman engineering enrollments stood at 8.4 percent of undergraduate first-year enrollments in four-year colleges in 1978—already much higher than the 4.8 percent proportion of 1973. It is questionable whether there is any considerable potential for this proportion to rise further, given the constraints of adequate high school preparation discussed earlier.

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* The engineering technology programs do not include the same stress on the fundamentals of science, math, and technology as do the traditional engineering programs. They are designed to provide manpower for middle level management jobs, with stress on the *production* process rather than the design, planning, and administrative functions. The content of the bachelor of engineering program stresses creativity towards new technology, while the technology programs are more concerned with the continuous functioning of existing technologies.

Supply and Demand for Engineers in the South

Despite recent increases in engineering graduates in the 14 SREB states, it is unlikely that demand will be met. The supply is composed of baccalaureate graduates in engineering and in engineering technology. The growth of engineering enrollments and degrees in the Southern region has paralleled the national pattern. In 1979, 12,685 baccalaureates in engineering were granted in the South, plus 1,986 in engineering technology. This represents a 20 percent increase over 1976. This total will probably be exceeded during the next several years, as recent enrollment increases are reflected in graduation totals. However, it is unlikely that such growth will be sustained when the demographic drop takes hold.

From this supply of graduating seniors in any one year a reduction must be allowed to account for engineering students who choose to go into some occupation other than engineering, as, for example, management. Estimates at the national level indicate that eventually 80 to 85 percent of the graduates, including those who pursue full-time graduate studies, enter the profession.[26] For the region this would reduce the total annual supply of new entrants to approximately 13,000.

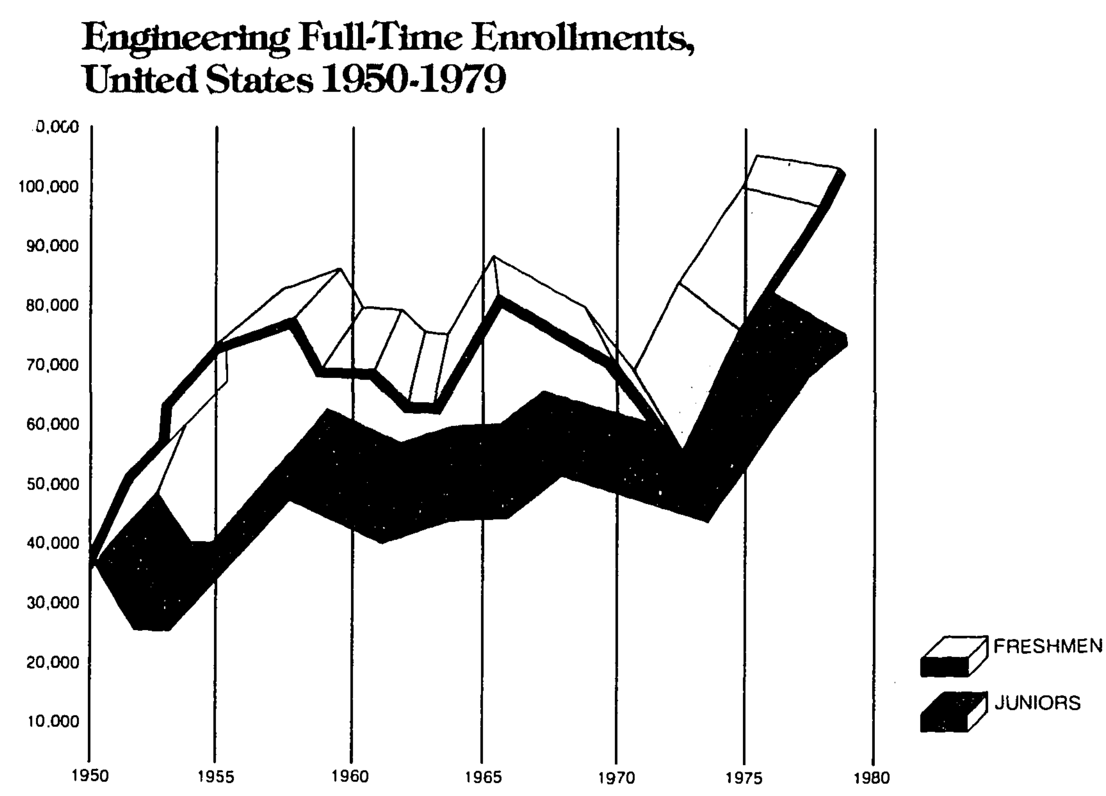

Figure 3

Source: American Association of Engineering Societies, *Engineering Manpower Bulletin*, March 1980.

TABLE 3

Engineering Enrollments As Part of Total Enrollments
Fall 1967-1979

	Full-Time Undergraduate Engineering as Percent of Full-Time Undergraduate Enrollment, 4-Year Institutions	Freshman Engineering as Percent of First Year Enrollment, 4-Year Institutions
1967	7.4%	7.8%
1968	6.4	7.2
1969	5.7	6.7
1970	5.6	6.4
1971	5.0	5.3
1972	4.7	4.9
1973	4.5	4.8
1974	4.8	5.6
1975	5.3	6.5
1976	5.9	7.3
1977	6.5	7.8
1978	7.1	8.4
1979	7.7 (preliminary)	N.A.

Sources: Engineering Manpower Commission, Manpower Bulletin Number 51, and National Center for Education Statistics, *Announcements* of Fall Enrollment in Higher Education, and *Projections 1985-86*, and preliminary tables, *Projections 1987-88*.

On the demand side, which is expressed in terms of average annual openings, there are the following components: openings to account for growth and retirements of engineers (13,200*) and for engineering technologists (3,300**), and openings to account for transfers out of the profession. According to national estimates,[27] perhaps 3 to 4 percent of the engineering work force transfers out of engineering annually, thus creating additional job openings. Engineers promoted to management responsibilities are an example of such transfers. Applying a 3.5 percent transfer rate to the engineers employed in the region in 1978 yields 11,400 additional openings to replace transfers. With these, the total number of annual openings is 28,000.

To some extent transfers *out* of engineering are offset by transfers into the profession from other jobs. For example, job shifts by computer specialists, chemists, physicists, and promoted engineering technologists may fill openings for engineers in the normal course of occupational mobility. Yet, since such transfers are from high technology fields, some of which may also face manpower shortages, the overall supply of such technical people would only be shifted, without making a contribution to overall balance. Thus, the extent to which transfers into engineering openings may serve to balance what would otherwise be a serious manpower imbalance is indeterminate.

An additional uncertainty must be considered. Engineering has been one of the most popular fields in attracting foreign students. In 1978, 6.7 percent of baccalaureates in engineering were granted to foreign students. The proportion for advanced degrees was much higher—over one-third at the doctoral level. Thus, some part of the engineering graduates represents manpower supply for other nations. These losses are somewhat offset by immigration of foreign engineers. However, this flow has been restricted since 1973, when the United States Department of Labor removed engineers from the shortage classification.

* The reports of the ESAs of the 14 Southern states indicate 13,200 average annual openings for engineers to 1985 to account for growth and replacements. Replacement openings account for deaths and retirements but not transfers into other occupations.

** The reports of the ESAs of the 14 Southern states indicate 16,700 average annual openings for engineering technicians to 1985. On the assumption that 20 percent of these openings are for individuals with a college degree, 3,300 openings are included in these comparisons of demand for baccalaureate engineers.

Taken together, as shown in Figure 5, these various factors indicate that the region will probably experience a shortage of engineers in the next decade. The most promising possibility for balancing supply and demand appears to be the upgrading of employed engineering technologists to fill engineering needs. However, the balancing of the market for engineers through shifts of employed persons from other high technology occupations, which may also experience shortages, will not solve the overall deficits of high technology manpower.

Engineering Doctorates Sharply Down

The professional literature and other media are beginning to detect impending shortages of engineering faculty. The explosion of total undergraduate engineering enrollments (up 82 percent in the 1973-79 period) has put pressure on faculties in the college of engineering. In the early stages, the enrollment expansion was accommodated by excess resources not fully utilized when engineering became unpopular as the Vietnam period closed. But eventually this growth necessitated an expansion of faculties.

Ironically, just as demand for engineering faculties began to grow, the production of doctorates declined sharply. From a peak of 3,691 doctorates in engineering for the nation granted in 1970, the number fell in

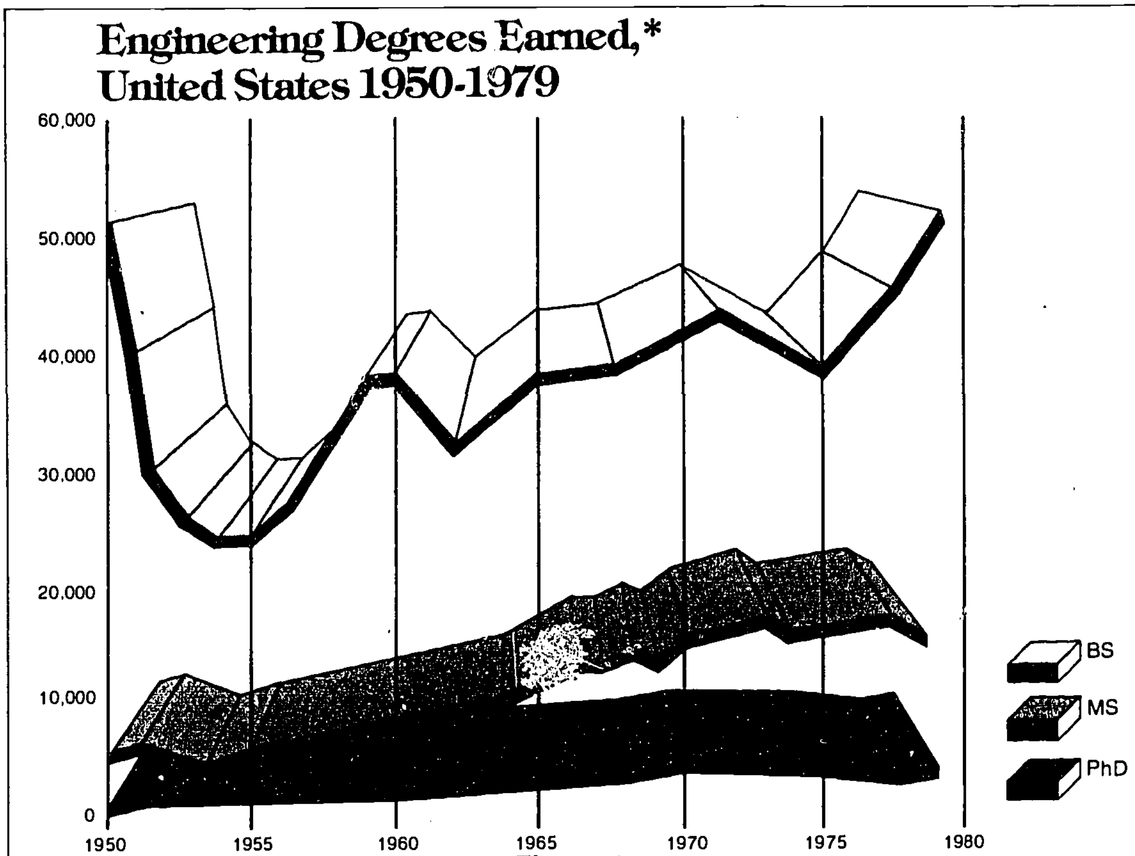

Figure 4

*This does not include engineering technology baccalaureates—6,609 in 1979.
Source: American Association of Engineering Societies, *Engineering Manpower Bulletin*, January 1979.

1978 to only 2,440 (427 in the South). Exacerbating the decline is the high and growing percentage of foreign students among engineering doctorates, who would ordinarily be expected to return to their own countries. In 1978, over one-third of the engineering doctorates were earned by foreign students, thus diminishing the American supply to some 1,600.

Graduate enrollments in engineering have been declining relative to undergraduate enrollments: in 1973, the number of graduate engineering students was 18 percent of the undergraduate engineering population; in 1979, graduate students constituted only 12 percent. Under highly competitive recruitment conditions (and therefore high salaries), young baccalaureate engineers have reduced incentives to pursue graduate studies. The lure of immediate employment is reflected in the declining proportion of students at the doctoral level. In 1972, there was one new American doctorate in engineering for every 12 American baccalaureates graduated four years earlier. By 1978, there was one for every 23.[28] Engineering colleges are increasingly concerned about the prospect of having to rely on foreign-born faculty to staff their programs.

In contrast to other disciplines, only 35 percent of the total stock of engineering doctorates was employed by the academic sector in 1977, as compared to 57 percent for doctorates in all sciences and engineering.[29] Industry and government research and development are heavily dependent on engineering doctorates. If this overall pattern is any guide, only about 600 new doctorates earned by American citizens are available to the academic sector. One recent estimate of new hires of engineering faculties (at all degree levels) through the early Eighties vastly exceeds this number, although it shows supply and demand as being in better balance by the mid-Eighties.[30]

New Priorities and Changing Demands for High Technology Graduates

The impending shortages of high technology graduates detailed above may be greater than shown in the preceding analysis. The demand projections that are used are based on a continuation of the existing national priorities. But some of these priorities are now being reappraised and, if changed, might increase considerably the demand for engineers and related manpower.

The current national preoccupation over the need to increase productivity as the long-run solution for improvement of U.S. competition in foreign markets bodes well for technical manpower. Productivity improvement is usually considered as related to investment in research and development and modernized capital investments. These investments require engineers and other technical personnel. Although output per worker in U.S. manufacturing still exceeds that of other industrial nations, the U.S. rate of growth in this productivity measure in the last decade has lagged behind improvements in competing economies.

Research and development (R & D), which are generally thought to play an important role in stimulating productivity, have languished in recent years. In constant dollars, total R & D expenditures in the United States grew by 50 percent during the Sixties, but declined through the mid-Seventies, and barely showed a gain by the end of the decade. There is growing conviction, as by the Conference Board, that in order to improve economic growth in this country, R & D expenditures in real dollars will have to rise, especially in view of the fact that United States R & D expenditures now constitute a slightly lower share of Gross National Product than in 1970, while the proportion has risen in Japan, West Germany, and the Soviet Union.[31]

Another factor that prevailed during the Seventies, but that may change in the coming decade, relates to the proportion of engineers relative to other scientific manpower employed. In the mid-Sixties, there were two employed engineers for every employed scientist.* By 1978, this ratio had changed to almost parity.[32] Also, although the absolute number of employed engineers has grown steadily, it has not kept pace with the growth rate of the labor force. During the 1970s the annual growth rate of engineering employment was only a quarter of that for the entire work force, and one-tenth of that for scientists.**[33] In private industry, which employs almost two-thirds of all scientists and engineers, there has been a shift in recent years to nontechnical resources. There is concern now that this relative decline in the highly technical component of the work force may be a contributing factor to the decline in U.S. productivity.

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* "Scientist" in this context includes social scientists.

** Excluding social scientists, in this case.

The national purpose of deflecting energy dependence from oil to other sources creates a demand for technical manpower. Ironically, even the automobile industry—the hardest hit sector of American manufacturing in the current turnaround—will need engineers to redesign its products for the new energy situation. This same need to redesign in other industries, and to develop alternate energy sources, will require an expanded supply of technical manpower. Also, defense spending, which correlates with the employment of engineers, appears to be on the upswing in response to uncertain foreign developments.

Important technological innovations which in turn spawn applications having a major impact on society usually cannot be predicted. Yet there are indications that some developing technologies are on the verge of pervasive uses and thus will create expanded demands for high technology manpower. The possibility of fueling transportation with liquid hydrogen, the accelerated use of industrial robots, the adaptations of satellite communications for business and consumer uses, and the commercial applications of genetic engineering are examples of such potential innovations.

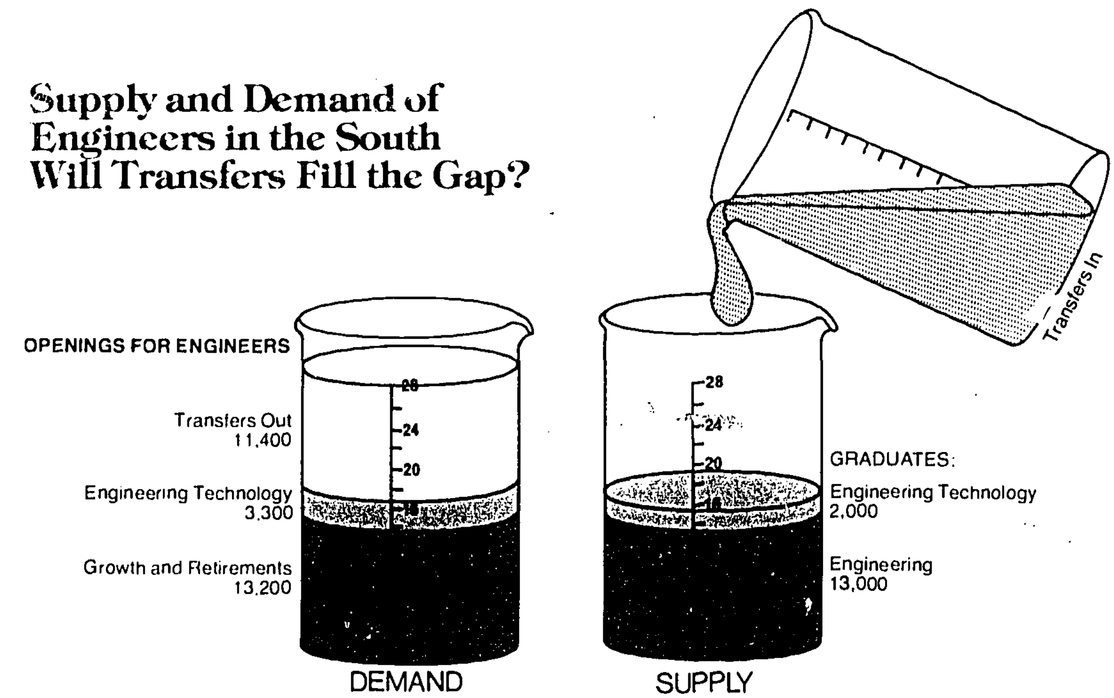

Figure 5

Conclusions

The signs in terms of demand are fairly clear: even with a continuation of past trends, the demand for engineers, computer and mathematics specialists, and other high technology manpower will exceed supply. After a period of national priorities which deemphasized R & D expenditures and defense spending, the United States economy appears to be on the threshold of renewed focus on these areas. This shift in priorities will place further demands on the availability of highly technical skills. Will manpower shortages be a limiting factor?

The fundamental constraint on a rapid expansion of high technology manpower centers on the number of high school students with adequate preparation in mathematics to embark on "hard science" curricula when they enter college. Yet the shortage of mathematics teachers currently plaguing school districts will limit the rate of improvement that may be expected in mathematics achievement in the schools. The decline of enrollments and degrees in college mathematics holds forth no promise of any imminent response toward solving the shortage of mathematics teachers. In short, without deliberate action at all educational levels, if present trends are allowed to continue their own apparent course, then a serious shortage of high technology manpower may be in the offing.

In conjunction with greater stress on mathematics in the high schools and colleges, it will be important to increase participation in the high technology fields among high achievers in those groups that in the past have shied away from these subjects. With the declining number of college-age students, it will be very difficult to produce more engineers by relying only on the traditional entrants to the field—white males. Efforts to involve more women and minorities in the high technology areas are justified not only on the basis of equity but also from the standpoint of societal economic necessity. Improved counseling in the high schools is needed to convince more students to take rigorous mathematics sequences and thereby to secure options for pursuit of high technology careers.

As part of a strategy to address supply shortages, rigidities that restrict market responses need attention. For example, the current shortage of mathematics teachers in the schools would be reduced if school districts could pay higher salaries to teachers in fields where prospective applicants are lured away to other jobs with higher salaries. At the college level, the shortage of engineering faculties results to some extent from the high salaries that baccalaureates now command in the job market. The incentives to pursue graduate study and to prepare for an academic career in engineering have been too low to produce enough Ph.D.s in engineering. A measure introduced by Congressman Don Fuqua, Florida, in the 1980 Congressional session to fund Ph.D. traineeships for American engineering students is a sign that the need for such incentives is gaining recognition. The inability of colleges to shift funds to expanding departments, such as engineering and computer science, from other departments with less demand is another rigidity that impedes adjustment to changing conditions.

Greater attention to quality offerings and increased participation in high school mathematics is warranted not only because of high technology manpower demands but also to meet societal needs. There has been a general uproar in recent years about the inability of most high school graduates to compose a coherent paragraph. The inability of a major portion of young people to solve simple computational problems that relate to everyday life is appalling. The unemployment problems of disadvantaged youths who can find no niche in an increasingly technological economy stem to a large extent from their lack of fundamental skills in mathematics and English.

The American tendency to swing widely in one or the other direction, whether this be in wholesale adoptions of a new educational theory or doubling the number of medical school graduates in a little more than a decade, has often amazed friendly foreign observers. The Sputnik reaction was rapid and effective, culminating in Americans landing on the moon. There is no reason to believe that once this shortage of high technology manpower becomes generally perceived, it will not once again be possible, via crash methods, to meet the needs. In that case there is the further likelihood of overreaction. A more gradual but determined anticipatory strategy of strengthened preparation in mathematics at the high school level, which almost certainly will produce greater college participation in the hard sciences and engineering in response to market demand, is the preferred alternative. Such a strategy will avoid overexpansion in the high technology fields, and will achieve a greater stability for meeting long-run needs.

Footnotes

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