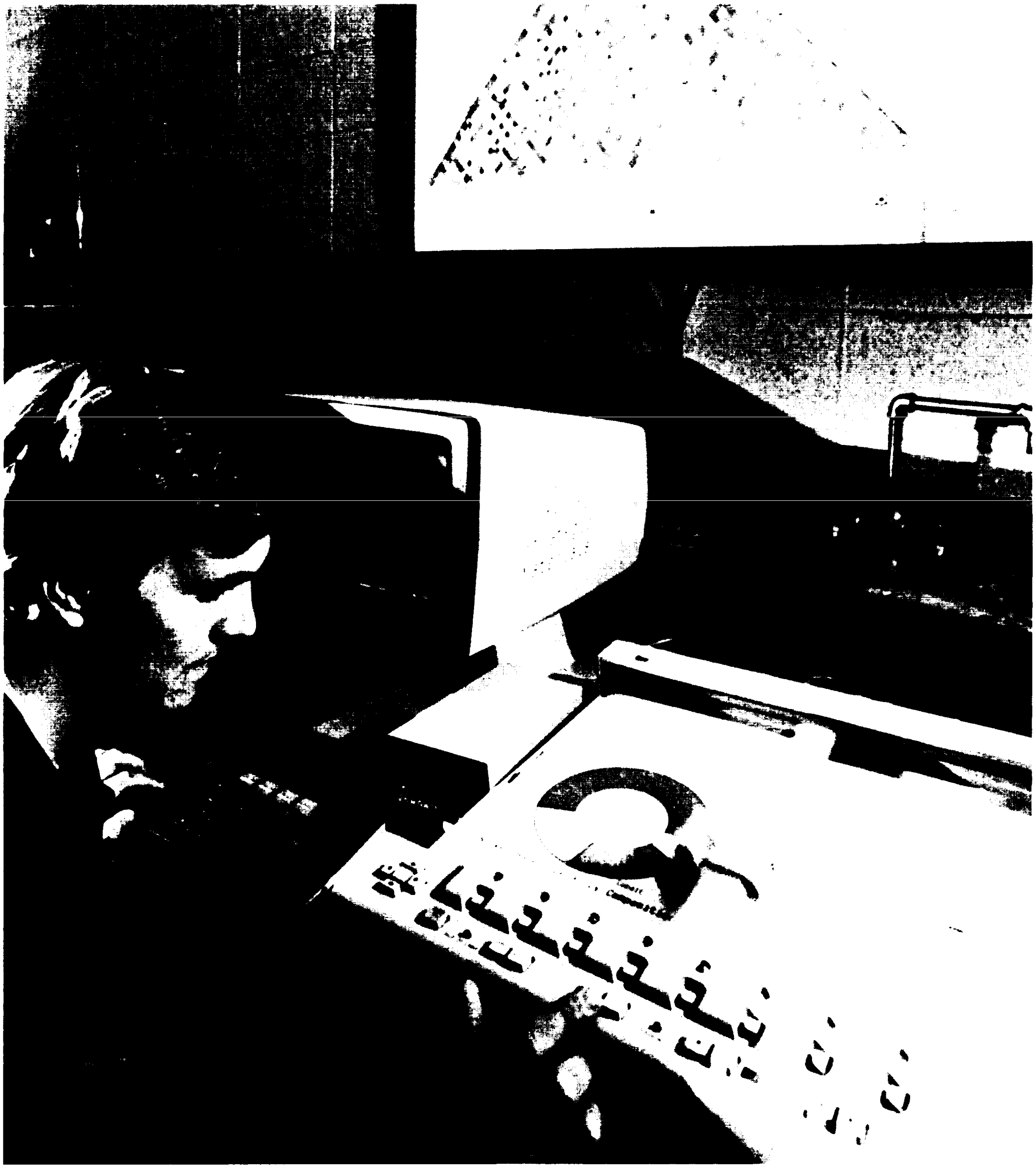
Chapter 3

Implications for Economic Growth and Human Capital



This Ph. D candidate is using a console connected with Columbia University's Computing Center. A small modem connects the computer console and graphic plotter with the mainframe computer at the computer campus facility. The graphics plotter is displaying the composition of a six-element super alloy used in the space shuttle turbines and a preliminary predictive phase diagram relating to the six-element alloy's performance under stress

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The principal goals underlying Federal involvement in education have historically been: 1) to contribute toward national economic well-being, 2) to assure national security, and 3) to provide an equitable distribution of economic opportunities to U.S. citizens. Because future Federal education policy will presumably continue to be predicated on one or more of these or related goals, OTA examined the links between education, technological trends, and these goals.

Findings

- Strong evidence exists for linking economic growth with the creation of new knowledge and the transfer of technology into the production of goods and services. Knowledge creates new goods and services, improved production techniques, and better management and organizational strategies.
- Many experts believe that there is a close link between the level of education and the productivity of workers—even though such a relation is complex and difficult to establish analytically.
- The link between education, training, and economic growth is becoming more critical because of structural shifts in the economy toward the service and information sectors.
- While greater access to education and training cannot directly create new jobs and may not increase overall wage levels, there are strong positive correlations between workers' educational levels and their employability.
- The rate at which automation can be introduced and the contribution it makes to the growth of productivity will partly depend on the ability to retrain workers for new jobs, either within the same industry or in a new industry. Their ability to be retrained will in turn be determined, at least in part, by their levels of literacy and their familiarity with information technology.
- There is a severe shortage of engineers, computer experts, information specialists, and other trained workers needed to support the growth both of the information industry itself and of the use of information technology in other sectors of society.
- The failure of the U.S. education system to respond to the changing needs of the information society at a rate comparable to that of foreign competitors may impose serious economic costs in the form of low growth rates and reduced competitiveness in world markets.

Knowledge and Growth

A number of studies have postulated links between information, technological innovation, and economic growth. The relationship between knowledge and economic development has been studied both in the context of the U.S. economy[1] and in that of developing

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[1] E. F. Denisen, *Accounting for Slower Economic Growth* (Washington, D. C.: Brookings Institution, 1979): (Kendricks article).

countries.[2] In one analysis, nearly two-thirds of the economic growth that occurred in the United States between 1948 and 1973 was attributed to increases in the size and quality of the work force and to the development of new knowledge. Other studies have examined the direct contribution of research and development (R&D) to economic growth.[3]

There are several ways in which the links between knowledge and economic growth may operate:

- Better and more timely information can lead to better organizational structures and to *improved management decisions,* which can lower costs by more efficient allocation of resources, to better scheduling of production, and to better economic planning.
- Technical innovation leads to *new or improved products and services* and in some cases to the emergence of new industries that are more competitive in the marketplace. Most of the firms in the *Fortune 500* deal in products and services that did not exist a century ago.
- New technology can lead to *more efficient production methods* that improve manufacturing productivity. Some anticipate that the new computer-based flexible manufacturing systems will provide the critical technological underpinning for U.S. reindustrialization.

OTA has found strong support not only among economists but also in the business community for the view that the availability of literate, well-educated workers is an important determiner of productivity and economic growth.[4] The interest that business has shown in the performance of public education, and the growing investment that industry has made in specialized education and training programs are strong indicators of such concern.

High school students in Oxford, Mass., work with a learning aid that familiarizes them with electrical and electronic wiring patterns. This helps them prepare for entry-level work in the burgeoning electronics industry in Massachusetts. The school board of this old mill town in southeast Massachusetts hopes that their creation of a young labor pool skilled in electronics will help draw new industry into the town

Education and training may affect the contribution that workers make to productivity in at least three ways. First, education and training improves *the productivity of the work force* if it allows workers to use current production techniques more effectively and to adapt more readily to new techniques. Second, the growth rate of new industry is determined, in part, by the availability of individuals *trained to fill the new types of jobs* created by

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[2] T. W. Schultz, *Investment in Human Capital* (New York: Free Press, 1971).

[3] E. Mansfield, "Research and Development, Productivity, and Inflation, " *Science,* vol. 209, Sept. 5, 1980, pp. 1091-1093; J. Walsh, "Is R&D the Key to the Productivity Problem?" *Science,* vol. 211, 13, Feb. 13, 1981, pp. 685-688.

[4] A. W. Clausen, "The Quality of Public Education, " *Vital Speeches,* 1981.

innovation. Finally, the process of innovation requires individuals *trained to do R&D at all levels* from basic research to product development.

A number of labor economists have suggested that the link between education and economic growth is becoming more important because of structural shifts toward the service and information sectors. Eli Ginzberg and George Vojta state, “Human capital, defined as the ‘skill, dexterity, and knowledge’ of the population, has become the critical input that determines the rate of growth of the economy and the well-being of the population. We contend that the competence of management and the skills of the work force . . . determine the ability of enterprises to obtain and utilize effectively other essential resources . . . "[5]

The suggestion that U.S. economic growth and competitiveness are dependent, in part, on the production of new information and on the literacy of the work force has serious implications for Federal and local education policy. A decline in the performance of the educational system could be costly to U.S. society in terms of lower productivity of the work force; less flexibility for industry to adopt new production methods and management techniques; higher unemployment rates, particularly among the disadvantaged; and decreased R&D, particularly in the basic sciences and engineering.

Education and Growth

In this century, particularly since World War II, there has been a steady increase in the number of years of education completed by American workers. This trend is illustrated in table 3. The degree to which this growth in education level is accompanied by an increase in the skill levels of jobs held, however, is a matter of some debate. While some see the extension of education as evidence of the expansion of skills, others see it as a devaluation of the high school and college degree, or, in other words, as an inflation of the certification required to obtain work that is no more—and may even be less–demanding than before.’

Table 3.—Percentage Employment in the Business Sector by Sex and Years of Education Completed

	1948	1959	1969	1976
school years completed	44.4	1.0	0.5	0.3
Elementary, 1-8	—	32.0	21.2	12.7
High school, 1-4	43.3	48.7	54.7	54.5
College, 1-4	—	14.7	19.0	25.7
College, 5 or more	11.5	3.6	4.7	6.9
school years completed	32.4	0.5	0.2	0.3
Elementary, 1-8 . . . . , ...	—	22.5	14.5	8.4
High school, 1-4	56.1	63.8	68.6	65.9
College, 1-4	—	12.2	15.2	22.7
College, 5 or more	11.5	1.0	1.5	2.8

SOURCE: E. F Denisen, Accounting *for Slower Economic Growth* (Washington, D. C.: Brookings Institution, 1979),

An increase in job skill requirements could take place in three ways: 1) industrial growth and sectoral shifts in the economy could create more jobs demanding higher skill levels; 2) the availability of a more highly trained labor pool could encourage employers to raise their performance expectations, even if the basic job classifications remain the same; and 3) rapidly changing job requirements could place a premium on employees’ flexibility and on their ability to be retrained in new skills.

Justifiably or not, education is, generally speaking, a major factor in the competition for jobs, and those lacking the requisite educational level are less employable. Unemployment rates by education level are shown in

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‘E. Ginzberg and G, J. Vojta, “The Service Sector of the U.S. Economy,” Scientific *American,* vol. 299, March 1981, pp. 48-55.

‘Randall Collins, “The Credentials, ”*Society: A Historical Sociology of Education and Stratification* (New York: Academic Press, 1979).

table 4. Two conclusions are suggested by the data:

- Education is an important selection criterion for employers.
- More sensitive to fluctuations in overall employment rates than their more skilled counterparts, less educated workers are more likely to lose their jobs when unemployment rises, and less likely to get them back when it drops.

Table 4.—Unemployment Rates by Sex and Number of Years of Education Completed

	1970	1979
High school, 1-3 years	4.8	8.3
High school, 4 years	3.4	5.5
College, 1-3 years	3.8	4,2
College, 4 years or more	1.2	1.8
High school, 1-3 years	6.8	10.4
High school, 4 years	4.6	6.0
College, 1-3 years	4.0	4.3
College, 4 years or more	2.0	3.0

SOURCE Chronicle *of Higher Education,* citing BLS data

Human Capital Theory

Human capital theory regards expenditure on education as an investment in improving the quality of labor input to production, hence as a factor of production. Because of the investment focus, worker income is regarded as the measure of return. Researchers have demonstrated correlations between both current and lifetime education levels and incomes. In the 1960's, human capital theory formed a rationale for much of the Federal education policy that aimed at improving educational opportunity as a means of fighting poverty.[7]

Most experts agree with the concept that, in many cases, education and training can create a more productive worker. However, many raise objections to human capital theory, both with respect to the analytical basis of the field and to the policies' implications that have been drawn from them. Chief among these objections are the following:

- The assumption that individuals make their decisions about education and career opportunities based on their reading of the labor market is questioned.
- Improvements in the quality of labor and the resulting increases in productivity are not necessarily directly reflected in a concomitant rise in salaries and wages. Hence, the societal payback from further education may be underestimated.
- Particularly at higher levels of education, individuals may decide to continue their education for another year not because it would increase their lifetime income return, but rather because they want to develop special talents and to pursue other personal goals.[8]
- According to screening theory, education does not "add value" to labor as such, but merely serves to prescreen the most able workers.[9] There is a difference of opinion between those who advocate screening theory and the proponents of human capital theory with respect to how much significance should be attributed to screening when calculating the return on investment in education.
- An increase in the social investment for improving the quality of the labor pool does not necessarily serve to increase overall levels of employment or to raise wage levels. Hence, by itself, investment in education is not an effective strategy, either to raise the income of the disadvantaged or to increase employment.[10]

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[7] *Chronicle* Mar. 16, 1981, p. 2; G. S. Becker, *Human Capital (New* York: Columbia University Press, 1975).

[8] S. Rosen, "Human Capital: A Survey of Empirical Research," in *Research in Labor Economics* (Greenwich, Corm.: JAI Press, 1977), vol. 1, pp. 2-39.

[9] K. J. Arrow, "Higher Education as a Filter, " *Journal Public Economics,* vol. *2, 1973,* pp. 173-216.

[10] *The Productivity Problem: Alternatives for Action* (Washington, D. C.: U.S. Congress, Congressional Budget Office, January 1981); L. C. Thurow, *The Zero Sum Society (New* York: Basic Books, 1980).

Need for Technical Education

The labor market is too complex to be described in simple terms of oversupply or undersupply. It can be generally said, however, that while the American work force does not appear to be undereducated in terms of the years of schooling or in terms of the number of high school and college graduates needed to meet overall employment requirements, there do seem to be deficiencies in what students have learned in school and severe shortages of graduates trained in certain job areas. And while the demand for traditional full-time, degree-oriented education may be leveling off or even slackening, the demand for specific or continuing job-related education is growing. In particular, the trend in the U.S. economy toward a growing service and information sector is creating an increased demand for education in engineering and science, especially the computer sciences, at all levels. If these needs are not met, U.S. economic growth and international competitive position may decline.

The clients for technical education can be loosely categorized into three groups, according to their respective needs:

1. The general work force–workers in all occupational categories, from blue collar to the professional, who increasingly need to gain literacy in information technology.
2. Information professionals-specialists who program, operate, repair, and in other ways directly support information products and services.
3. Information scientists and engineers—technical experts who conduct research, develop new products and applications, or teach at the college level.

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Information Literacy

Economists, educational experts, and business leaders assert that there is a growing need in U.S. society for at least a minimum level of literacy in science, engineering, mathematics, and, in particular, information technology.[11]

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[11] Schultz, op. cit.; R. J. Seidel, R. E. Anderson, and B. Hunter (eds.), *Computer Literacy* (New York: Academic Press, 1982);

As stated by the president of the Bank of America:

> . . . increasingly, business is looking for and the better jobs are going to, individuals with some modicum of computer literacy. Basic communication and data-processing skills are among the hottest commodities in the employment sector today.[12]

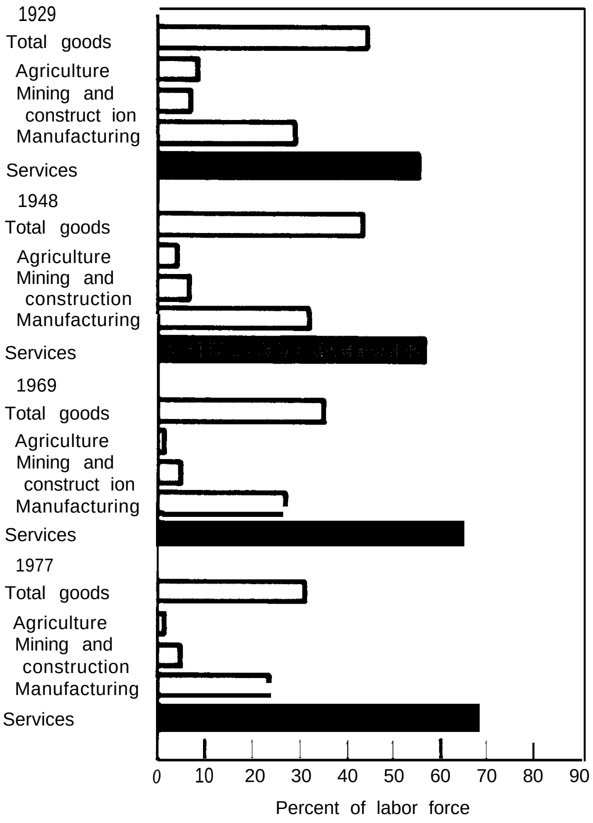
The shift in the United States from a manufacturing and agricultural economy to an information and service economy is creating more jobs with information handling requirements. The occupational mix in the service sector is compared with that in other sectors in figure 1. Furthermore, traditional jobs will increasingly require the handling of automated equipment, a trend that is already visible in the office. With the advent of automated information systems, the skills required of a clerical staff are changing. Moreover, the job skills of a secretary in the wired office of the future will be substantially different from what they are today. In fact, the concept of "secretary" may disappear altogether.

A similar trend may also occur in the factory, where robotics and other forms of computer-aided manufacturing are beginning to transform the way that goods are produced. There, automation will require that the worker learn new skills oriented toward operation and control of computerized equipment. (Some experts maintain that few of the current 20 million jobs in the manufacturing sector will remain two decades from now.)

Faced with these pressures for a more technically literate work force, the schools are apparently falling short of supplying those needs.

- Overall achievement levels of high school and college graduates, as measured by the National Assessment of Educational Progress, are steadily falling. In particular, declines in achievement have been noted in science and mathematics.[13]

Figure 1.—Shifts in Employment



Shifts in employment since 1929 are **charted** for the goods-producing industries and the service sector. The service sector includes distributive services such as communications, utilities and wholesale trade; retail trade; consumer services such as restaurants, dry cleaning and recreation; producer services such as accounting, banking and legal work, and nonprofit and government services including health, education, and national defense.

SOURCE E Ginzberg and G J. Vojta, "The Service Sector of the U S Economy, " *Scientific American*, March 1981

Historical trends over the last decade in the achievement levels of students for selected subject areas are shown in table 5. The well-documented decline in the science literacy

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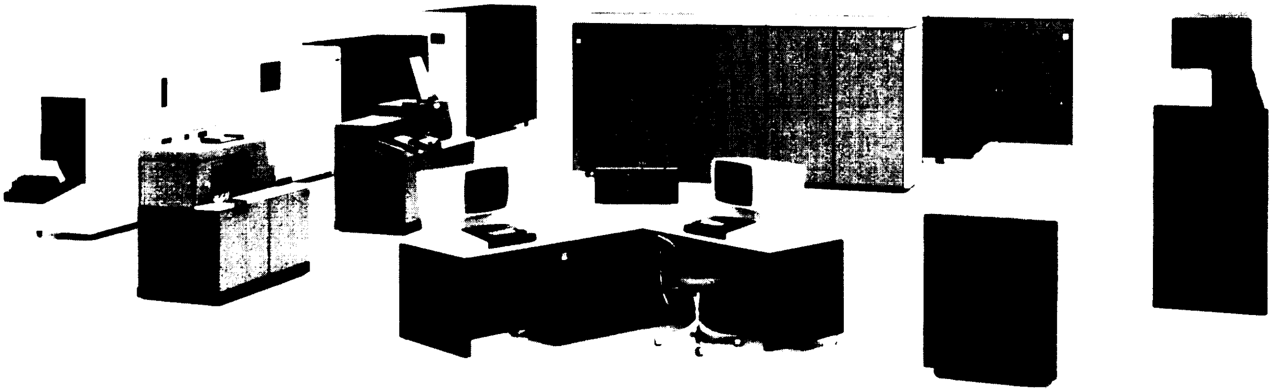
(continued from p. 29)
R. J. Marano, "Educational Disenfranchisement in a Technological Age, " *Vital Speeches,* 1982, p. 222.

[12] Clausen, op. cit.

"National Assessment of Educational Progress, Three *National Assessments of science,* report 08-5-00 (Denver,Colo.: Educational Commission of the States, 1978); National Assessment of Educational Progress, Changes in *Mathematical Achievement* report 09-MA-01 (Denver,Colo.: Educational Commission of the States, 1979); *Science Education Databook,* 1980 report, SE 80-3 (Washington, D. C.: National Science Foundation, 1980).



Office design model for information gathering and communications is in use in many modern offices and has changed the design concept of many offices throughout the business community

Table 5.—Achievement Test Score Averages, 1972-79 (numbers in thousands)

	1972	1973	1974	1975	1976	1977	1978	1979
	526	527	533	531	538	533	531	529
English composition	516	517	517	515	532	516	512	514
Mathematics Level I	541	537	545	545	546	547	541	537
American history and social studies	492	498	498	494	493	492	496	480
Biology	535	532	545	544	543	543	544	547
Chemistry	568	572	581	569	567	574	577	575
Mathematics Level II			—	660	665	666	665	657
French	539	544	560	553	553	553	552	554
Spanish	530	539	560	544	547	535	554	542
Literature	—	—	—	522	525	526	521	522
Physics			—	601	592	593	591	580
German				547	555	551	553	550
European history and world cultures			—	521	531	526	507	516
Latin			—	514	524	517	508	524
Average SAT scores for takers of achievement tests*								
Verbal	—	—	—	—	501	504	507	508
Mathematics	—	—	—	—	553	553	554	554

“Data not computed prior to 1976. Data for 1976 are estimated from scores of individual achievement tests for that year

SOURCE Science Education Databook, National Science Foundation, derived from the Admissions Testing Program of the College Board, *National Report*, College *Bound Seniors*, 1977, p 8, *1978*, pp 13.14, 1979, pp 13-14

rates of students does not necessarily imply a failure of the schools themselves. Declines in student performance might stem from social factors that are independent of the classroom. Moreover, because the schools have had to expand to accommodate an increasing number of students, some of whom have come from disadvantaged backgrounds, it may be that literacy rates have declined because more selectivity factors are operating now than in the past.

- There has been an insufficient response by schools to the need for increased mathematical, technical, and computer literacy.

A sociologist studying how schools in a district heavily populated by high-technology industry responded to the increased needs for technological literacy concluded that these schools have in fact ‘moved away from a science and technology curriculum.[14] The National Science Foundation (NSF) and Department of Education, in their report to the President on science and technology education, concluded that the secondary schools were not carrying out their responsibilities effectively.[15] The report notes that the divergence is widening between the amounts of science and mathematics education made available to the few who wish to become professionals and to those who do not, a divergence further increased by a general lowering of performance standards and expectations. A shortage of mathematics and physical science teachers and the erosion of the teacher support system weaken the capacity of the schools to provide quality instruction to all students, majors and nonmajors alike.

The NSF report to the President also examined the status of technical literacy in other countries. To the extent that there is a connection between technical literacy, economic productivity and growth, and national security, the comparisons should be worrisome. Examining the state of science and engineering education in West Germany, Japan, and the Soviet Union, the report observes:

> . . . these countries are educating a substantial majority of their secondary school population to a point of considerable scientific and technological literacy, in part because they apparently believe that such literacy is important to their relative international positions.

In addition, the report states that the Soviet Union has elementary and secondary level curricula in science and mathematics that “surpass that of any other country. ” (A British study of engineering education noted that in Japan, even high school students majoring in the fields of humanities and liberal arts obtain enough knowledge in science and mathematics to attend engineering school and compete successfully.)[16]

‘Elizabeth Useem, “Education and High Technology Industry: The Case of Silicon Valley,” unpublished August 1981, Institute for the Interdisciplinary Study of Education, Northeastern University, Boston, Mass.

[15] *Science and Engineering Education for the 1980's and Beyond* (Washinton, D. C.: National Science Foundation and Department of Education, October 1980).

[16] *Engineering Our Future*, report of the Committee of Inquiry into the Engineering Profession. Her Majesty's Statement Office, London, January 1980.

Information Professionals

The Bureau of Labor Statistics (BLS) has prepared a study of the growing demand for professionals trained specifically in computer skills.[17] Its estimates, shown in table 6, indicate that 685,000 new jobs will be created and 250,000 replacement openings will occur over the next decade, creating a need for nearly 1 million new professionals trained in computer skills.

The estimates of BLS are probably conservative, since only traditional computer job categories were examined. Other types of jobs likely to become important over the next decade include design engineers to create new types of microelectronic chips, industrial engineers trained in computer technology to support what some experts see as a necessary surge in industrial automation, information special-

Table 6.—Requirements for Computer Specialists (data in thousands)

Occupation	1980	Projected 1990
Systems analysts	243	400
Programmers	341	500
Equipment operators	522	850
Data entry technicians	266	230
Service technicians	83	160
Total	1,455	2,140

SOURCE: Employment *Trends in Computer Occupations*, Bulletin 2101 (Washington, D. C.: Department of Labor, Bureau of Labor Statistics, October 1981).

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[17] Employment *Trends in Computer Occupations*, Bulletin 2101 (Washington, D. C.: Department of Labor, Bureau of Labor Statistics, October 1981).

ists to help the average user make effective use of automated data systems, marketing and management personnel for the emerging information industry, and content producers for entertainment and information services.

OTA was unable to find any reliable estimates of the projected growth of these types of jobs. However, these jobs will no doubt add to the total demand projected by BLS of 2,140,000 specialists by 1990. These numbers are significant because all of these jobs require individuals with similar types of knowledge and work skills. Thus, employers will be competing to fill such jobs from the same limited pool of information specialists.

Against the requirement of nearly 1 million new jobs, NSF projects that there will be a total of 157,000 baccalaureates and masters level graduates in the computer professions. Projections of community college and public and private vocational education graduates over the next decade have not been made. In the academic year 1977 to 1978, these schools produced about 67,000 graduates trained in the computer field.

Several observations can be made:

- The enhancement of productivity in the computer field will likely affect jobs at the lowest levels first. For instance, advances in programing languages may decrease the need for entry-level program coders. However, neither BLS nor NSF examined the structure of these jobs in any detail; furthermore, they did not look at trends in skill requirements.
- Some of the jobs included in the BLS estimates do not require college degrees. While no estimates have been made of the number of jobs requiring lesser skills in proportion to the total number of jobs, they are probably concentrated in the categories of data entry, equipment operation, and repair. Some low-level programing jobs may also be available.
- The production of entry-level computer science and engineering graduates will need to be sustained during a period when the number of people of traditional college age will be growing more slowly and may consist of an increasing proportion of educationally disadvantaged students.
- It is possible that, assuming no decrease in levels of support for vocational education, the community college and vocational programs may be able to meet many of these needs. It is noteworthy, however, that some concern has been expressed by business about the mismatch between current vocational programs and the needs of industry. (See ch. 6 for a discussion of vocational education and industrial training.)
- Since computers are a relatively new technology, the industry has had to live with personnel shortages from the start. One response has been to hire graduates from other fields and train them in computer science and engineering. All the major computer firms have extensive training programs, an approach that is less feasible for smaller sized companies.
- The rate at which computer science and engineering training programs can grow may be limited not only by the existing shortage of experts but also by the fact that, with salary scales that are uncompetitive in comparison with private industry, educational institutions may be unable to hire qualified faculty.
- The generally inadequate educational preparation at the secondary level could reduce the pool of potentially qualified college entrants, an eventuality which could compel colleges and universities to lower admission standards for computer science majors and to require extensive remedial programs at the undergraduate level.

The U.S. position in relationship to other countries is also unfavorable. As shown in table 7, of the four Western industrialized countries examined, the United States produces the fewest number of engineers measured as a percentage of the relevant age group. The percentages of engineers produced in each country correlates directly with the growth in their share of international trade over the last decade. While this is not proof of a cause-effect relationship, it does suggest that one may exist.

Table 7.—Percentages of Engineering Graduates and Trends in Shares of World Trade

Country	Engineering graduates	Share of world trade	
		1963	1977
United States	1.6%	21%	16%
United Kingdom	1.7%	15%	9%
West Germany	2.3%	20%	21%
Japan	4.2%	8%	15%

SOURCE: National Science Foundation

Information Scientists

Doctorate-level graduates in engineering and science are needed to support innovation and growth in a high-technology society by conducting research that builds a foundation for new development, conducting applied research and product development, and staffing college-level computer science and engineering programs. NSF found that the most serious shortages of Ph.D.'s are in computer sciences and in engineering, the two areas that are at the leading edge of technological growth. The production of Ph.D.'s in the computer sciences and in engineering has not grown significantly over the last decade. In fact, in the case of engineering, it has dropped. The situation may be even worse than the numbers indicate, since NSF estimated that in some departments nearly half the engineering graduate students are foreign nationals. While some foreigners may stay in the United States and enter the U.S. labor pool, others will return to their native countries.

Several factors have been mentioned as underlying the Ph. D. shortage:

- Engineering programs are experiencing repercussions from an oversupply of two decades ago followed by strong student antipathy in the late 1960's and 1970's.
- Computer science programs have experienced their strongest growth pressures in a time of general retrenchment in academic budgets.
- A shortage of top-level, research-oriented faculty prevents the growth of graduate programs; 10 percent of the faculty openings in computer science were unfilled in 1980.
- High private sector salaries and tight basic research funding are drawing the best faculty out of the classrooms and laboratories.
- High salaries for programmers, analysts, and engineers at the baccalaureate and master levels are attracting students away from Ph. D. programs.