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ABSTRACT

The changes to be effected by high technology in both projected employment growth and existing jobs seem to require significant changes in the American educational system. However, government estimates for the period 1978-90 suggest that employment growth will favor jobs that require little or no training beyond the high school level (for instance, janitors, nurses' aides, sales clerks, cashiers, and restaurant workers). Although the percentage of high technology occupations will increase quickly over this decade, the contribution of these jobs to total employment will be quite small. On the other hand, the evidence from past and present applications of technology to existing jobs suggests that future technologies will lead to further job fragmentation (where work tasks are simplified or routinized) and job "deskilling" (the reduction of opportunities for worker individuality and judgment). While such mechanization does reduce labor costs, it also allows management to control more easily the pace of production. This assessment favors a solid basic education over narrow vocational preparation, since a strong general education improves understanding of modern complexities and enhances worker adaptability in a changing job market. Quick and efficient response by educators to training needs and recurrent education are also important, since workers' skills may not be useful over their entire work lives. (PB)

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Institute for Research on Educational Finance and Governance

SCHOOL OF EDUCATION STANFORD UNIVERSITY

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THE EDUCATIONAL IMPLICATIONS OF HIGH TECHNOLOGY

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and
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Abstract

Many business leaders, government officials, and educators believe that high technology will dominate America's economic future, will upgrade the skill requirements of future jobs, and will require a transformation of our educational system to meet these needs. Despite the popularity of these beliefs, available evidence contradicts them: the expansion of the lowest skilled jobs in the American economy will vastly outstrip the growth of high technology ones; and the proliferation of high technology industries and their products is far more likely to reduce the skill requirements of jobs in the U.S. economy than to upgrade them. Nonetheless, the educational system should strengthen the analytical and communicative skills of students, not because of the needs of high technology, but because such skills will help them deal with the changing political, economic, social, and cultural institutions they will face in their adult lives.

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New advances in technology—in genetic engineering, in robotics, and particularly in computers—are transforming the lives of Americans in the home and the workplace. While the micro-computer has signalled the arrival of "high-technology" in the home, many observers believe that its influence in the workplace will be even more profound. Not only do industries producing micro-processors, robots, and the fruits of bio-technology promise rapid growth in sales and employment, but micro-computers and robots are also expected to transform other industries and occupations throughout the economy. One observer predicted that 40 to 50 percent of all American workers will be using electronic terminals by 1990 (Giuliano 1982, p. 152).

Government leaders, Republican and Democrat alike, see the growth of high-technology as one key to solving America's current economic problems. As President Reagan said in his State of the Union Address on January 25, 1982:

> ...as surely as Americans' pioneer spirit made us the industrial giant of the 20th century, the same pioneer spirit today is opening up another vast frontier of opportunity—the frontier of high technology. In conquering this frontier, we cannot write off our traditional industries, but must develop the skills and industries that will make us a pioneer of tomorrow.

Business leaders have echoed this sentiment, calling on the educational system to make the changes necessary to provide enough skilled workers to fuel the growth of high technology. As Steven Jobs, co-founder of Apple Computer, recently stated in a speech at Stanford University: "A massive retraining effort by government and private industry could alleviate the problem of job skill obsolescence created by the expanding computer industry" (<u>Stanford Daily</u> 1983).

Policymakers have proposed vast changes in the educational system to respond to these challenges. The proposed changes are based on the belief that our high-technology future will require workers with more sophisticated job skills. A recent publication from the Education Commission of the States (1982) exemplifies this widespread belief:

> Occupational growth throughout the 1980s is projected to expand most rapidly in the higher-skilled, technical occupations. Tomorrow's workers will likely need improved skills in the selection and communication of information. Many of today's skills considered to be of a "higher" level are the potential basic skills of tomorrow (p. 1).

Such beliefs have prompted proposals to upgrade math and science education in our nation's secondary schools, to place computers in all elementary and secondary schools, and to generate $1 billion in new support for high-technology education (Botkin, Dimancescu, and Stata, 1983).

These beliefs are based on two assumptions. First, future job growth in the United States will favor professional and technical level jobs--such as engineers and computer programmers--that require considerable education and sophisticated training in computer-related areas. Second, high technology will upgrade the skill requirements of existing jobs because workers in those jobs will work increasingly with technologically sophisticated equipment, such as computers.

Despite the widespread propagation of these assumptions, both are contradicted by available evidence. Most new jobs will not be in high technology occupations, nor will the application of high technology in existing jobs require a vast upgrading of the skills of the American labor force. To the contrary, the expansion of the lowest skilled jobs in the American economy will vastly outstrip the growth of high technology ones. And the proliferation of high technology industries and their products is far more likely to reduce the skill requirements for jobs in the U.S. economy than to upgrade them.

In the remainder of this paper we will examine the two common assumptions about high technology and the supporting evidence in greater detail. We will then discuss the educational implications of our high-technology future.

Future Employment Growth

To what degree will high technology jobs dominate future employment growth? Accurate predictions on the composition of future employment depend on the analysis of many factors. These include such influences as economic growth, labor force demography, foreign trade movements (many of which are influenced by changes in international exchange rates), technological breakthroughs, and decisions of multi-national organizations with respect to the international rationalization of production. Many of these factors are difficult to predict because they are subject to political and economic vagaries on a world scale.

While no methodology is likely to provide completely accurate results, those that consider a large number of pertinent influences are likely to be superior to simple extrapolations or other uncomplicated projections. In this respect, the estimates of the Bureau of Labor Statistics (BLS) of the U. S. Department of Labor represent some of the most refined attempts to project the growth and composition of future employment.

Since the 1960s BLS has periodically conducted a series of projection studies based on an economic growth model. Over the last two decades "the methodology has been continually modified to include greater industrial detail, other models, more rigorous analytical techniques, a more automatic system for processing calculations, and broader coverage including labor force and occupations in the current version" (Oliver 1982, p. 1). The methodology incorporates several assumptions about growth in the labor force, economic output, and productivity. Further, to allow for uncertainty, recent projections—for the year 1990—are based on three different scenarios regarding the growth of these various factors. The more optimistic projections assume high growth rates in economic output and productivity, while the more conservative projections assume lower growth rates.

The employment projections are based on occupational employment patterns within detailed industries in 1978, projected employment patterns within these industries in 1990, and projected total employment within each industry based on the economic projections. It is important to note that employment growth refers only to new jobs added to the economy rather than job openings. Job openings will be much higher. BLS estimates that employment growth will account for only one-third of total job openings between 1978 and 1990 (excluding openings due to workers' changing jobs), with the remaining two-thirds due to the replacement of workers in existing jobs who withdraw from the labor force because of death, retirement, or other reasons (U.S. Bureau of Labor Statistics 1980, p. 6).

We will limit our discussion to employment growth resulting from projected creation of new jobs using the BLS figures based on assumptions of modest growth rates. According to these figures, employment will increase by 22 million or 23 percent between 1978 and 1990 (Table 1). The fastest growing job categories in relative terms--percentage change between 1978 and 1990--include several high technology areas. This projected expansion apparently has led to the commonplace assumption that aggregate job growth will be biased toward high technology occupations. Of the five fastest growing occupations, three--data processing machine mechanics, computer systems analysts, and computer operators--deal with high-technology products. Employment in these five occupations is projected to increase by over 100 percent, more than four times the employment growth rate in all occupations.

Such percentage changes are misleading, however. The total number of new jobs generated in these and other high technology occupations will be vastly outweighed by employment growth in other areas. Slower-growing occupations with a large employment base are expected to contribute far more jobs to the economy than high technology occupations. Of the 20 occupations expected to generate the most jobs in the economy during this period, not one is related to high technology. As Table 1 shows, the five occupations expected to produce the most new jobs are all in low skilled areas: janitors, nurses' aides, sales clerks, cashiers, and waiters and waitresses. These five jobs alone will account for 13 percent of the total employment growth between 1978 and 1990. Only 3 or 4 of the "top 20" occupations in terms of total contribution to job growth require education beyond the secondary level, and only two require a college degree (teaching and nursing).

This picture is further reinforced by examination of individual high technology job categories. While jobs for computer systems analysts will increase by over 100 percent between 1978 and 1990, only 200,000 new jobs will be created. In contrast, there will be over 600,000 new jobs for janitors and sextons. In fact, more new jobs for janitors will be created than new jobs in all the five occupations with the highest relative growth rates. Consider another example: about 150,000 new jobs for computer programmers are expected to emerge during this 12 year period, a level of growth vastly outpaced by the 800,000 new jobs expected for fast food workers and kitchen helpers.

Employment growth for the economy as a whole will favor low and middle level occupations. While employment in professional and technical occupations is expected to increase by 20 percent for the twelve year period, this growth rate is lower than in either of the two preceding decades (Table 2). Employment in all professional and managerial occupations increased by 36 percent between 1960 and 1970, and 45 percent between 1970 and 1980. But it is projected to increase by only 28 percent between 1978 and 1990. Clerical and service occupations will account for 40 percent of the employment growth during this period.

Revised BLS estimates show that high technology occupations, as a group, will account for only 7 percent of all new jobs between 1980 and 1990 (Coleman 1982). BLS forecasts are further supported by other government analyses, such as those by the Department of Defense (Choate 1983).

In summary, government estimates suggest that employment growth will favor jobs that require little or no training beyond the high school level. Although employment in high technology occupations will increase quickly in percentage terms over this decade, the contribution of these jobs to total employment growth will be quite small.

The Impact of Technology on Existing Jobs

While the growth of high technology occupations will not have a major impact on overall employment growth in the foreseeable future, high technology will have a profound impact on many jobs in the economy. Increasingly workers in a variety of work settings will find their jobs altered by sophisticated computer technologies. Secretaries will work with word processing equipment; bookkeepers will use computerized, financial spread sheets; clerical workers in purchasing and inventory will apply their skills to automated and computerized record systems; mechanics will use diagnostic equipment employing mini-computers; and telephone operators will rely on computerized directories. But will the use of these new technologies require workers with more sophisticated skills?

To answer this question, it is necessary to examine how technology is applied in the workplace. The application of technology is part of a more fundamental process that has characterized production historically--the process of dividing work tasks into simplified operations that require few skills to perform. Through this process production tasks are fragmented into repetitive and routinized activities for which unskilled and low paid workers can be employed. This movement toward a minute division of labor was first advocated by Adam Smith in The Wealth of Nations and later refined by Charles Babbage:

> Babbage's principle is fundamental to the evolution of the division of labor...it gives expression not to a technical aspect of the division of labor, but to its social aspect. Insofar as the labor process may be dissociated, it may be separated into elements some of which are simpler than others and each of which is simpler than the whole. Translated into

market terms, this means that the labor power capable of performing the process may be purchased more cheaply as dissociated elements than as a capacity integrated in a single worker. Applied first to the handicrafts and then to the mechanical crafts, Babbage's principle eventually becomes the underlying force governing all forms of work ...no matter in what setting or at what hierarchical level (Braverman 1974, pp. 81-82).

Technology aids this process. The division of work tasks into component parts is often accompanied by the mechanization of some of those tasks. For example, the assembly line adopted by Henry Ford early in this century, although first controlled by nonmechanical methods, was soon mechanized (Gartman 1979, p. 200). As technology advances, an increasing number of work tasks can be mechanized. Advances in micro-electronics, in particular, threaten to further fragment work tasks and contribute to the "deskilling" of jobs (Cooley 1983).

The process of fragmentation not only allows employers to lower their costs, but to better control the production process. The organization of work in the United States has evolved from many small, local units into a much smaller number of large, hierarchical, national and international organizations. This transformation has been accompanied by more sophisticated methods of control (Marglin 1974; Edwards 1979).

Technology also aids efforts to control the workplace:

Machinery offers to management the opportunity to do by wholly mechanized means that which it had previously attempted to do by organization and disciplinary means. The fact that many machines may be paced and controlled according to centralized decisions, and that these controls may thus be in the hands of management, removed from the site of production to the office--these technical possibilities are of just as great interest to management as the fact that the machine multiplies the productivity of labor (Braverman 1974, p. 195).

In the case of the automotive assembly line, for example, mechanization not only reduced labor costs but allowed management to more easily control the pace of production (Gartman 1979).

It is often asserted that while machines will increasingly perform tasks previously performed by workers, generally the machines will perform the most tedious and least skilled tasks. That is, the most desirable and challenging tasks will continue to be performed by workers. Further, as automation becomes more widespread, with more and more workers using complex, sophisticated machines, workers will need increasingly complex skills to work with them.

James Bright, a professor at the Harvard Business School, investigated similar claims more than 20 years ago. He examined the effects of automation on job skill requirements in a variety of U.S. manufacturing firms. The general assumption, which was as common then as today, was that increasing levels of automation required increasing skills by operators and other production workers (Figure 1). Bright observed, however, that the skill requirements of jobs first increased and then decreased sharply as the degree of mechanization increased:

> ...there was more evidence that automation has reduced the skill requirements of the operating work force, and occasionally of the entire factory force including the maintenance organization...automated machinery tends to require less operator skill after certain levels of mechanization are achieved. It seems that the average worker will master different jobs more quickly and easily in the use of highly automatic machinery. Many so-called key skilled jobs, currently requiring long experience and training, will be reduced to easily learned, machine-tending jobs (Bright 1958, pp. 86-87).

Evidence for the United States as a whole supports Bright's conclusions: aggregate skill requirements of jobs in the U.S. economy have changed very little over the last two decades despite widespread automation in many industries (Rumberger 1981).

Case studies that have documented the application of more recent technologies in a broad variety of work settings confirm this tendency (Zimbalist 1979a). For example, many of the jobs in the printing industry, such as typesetting, press operating, and photoengraving, historically have required highly complex craft skills (Zimbalist 1979b). A series of technological advances over the last 30 years has enabled many of these operations to be performed by machines. The introduction of teletypesetting machines in the 1950s took over many manual typesetting operations. Then the introduction of computer-aided phototypesetting in the 1960s took over the tasks of word hyphenation and line justification. Finally the introduction of video display terminals removed the tasks of composing from the press floor altogether (Zimbalist 1979b, pp. 107-109). These advances reduced sharply the skill levels of workers who remained in the newspaper composing room.

The computer industry itself, the heart of the high technology revolution, provides another case. Early computers were not only large and expensive by today's standards, but they required programmers and operators with fairly complex skills to use them (Kraft 1977; Greenbaum 1979). But as the technology changed, so did the tasks and the skills involved in their operation. Computer programming was soon divided into the more creative, skilled tasks--performed by computer systems analysts--and the more tedious, routine tasks--performed by computer programers and coders. Programming itself became easier as computer languages evolved from high-level machine languages to packaged programs to more "user-friendly", menu-prompted packages (Kraft 1977).

Advances made in computer software have meant that workers can use computers in a wide variety of work settings without any knowledge of computer languages. The new generation of office computers, for example, are specifically designed so that "no special computer skills are needed to operate" them (Giuliano 1982, p. 149). Moreover, office computers perform many of the tasks formerly done by secretaries, actually reducing the requisite skills of office work (Glenn and Feldberg 1979). Word processors can correct typing errors automatically by use of electronic dictionaries, so letter-perfect typing and strong spelling skills are no longer required. In addition, supervisors can monitor each operator's output and compare productivity among workers instantaneously (Glenn and Feldberg 1979; Arnold, Birke, and Faulkner 1981).

Computers and other products of the micro-electronics revolution are transforming work in virtually all sectors of the economy, from agriculture to transportation to engineering design (Scientific American 1982). The future suggests that this transformation will become even more widespread and that technologies will become increasingly sophisticated. Machines will be able to perform more complex, mental tasks as more advanced software is developed. But the use of such sophisticated equipment will not necessarily require workers with more sophisticated skills. In fact, past technological advances suggest the opposite is often the case. The automobile of today is far more sophisticated than its predecessor of fifty years ago. Yet, today's car is far easier to drive. Computers are far more sophisticated today than they were 10 or 20 years ago. But programming and using computers are considerably less demanding today, and many computer-related jobs require virtually no knowledge of computers.

A related concern is that entire classes of skilled workers will disappear or will be severely reduced in numbers as their jobs are replaced by robots or computer software. For example, robots could replace up to 3 million operative jobs in the next 20 years and potentially eliminate all 8 million operative positions—currently 8 percent of the workforce—by the year 2025 (Ayres and Miller 1982, p. 42). The widespread use of computer-aided design (CAD) may virtually eliminate the occupation of drafter in the not-too-distant future, a potential loss of 300,000 skilled positions (Gunn 1982). The potential of high technology to displace jobs more generally is ominous (Leontief 1982).

It is clear that applications of high technology can be used to enhance the quality of working life and the utilization of worker skills, or to reduce them (Walton 1982). The outcome will depend on how the technologies are applied and how employers use them. Past applications of technology in the workplace as well as present evidence suggest that future technologies will further simplify and routinize work tasks and reduce opportunities for worker individuality and judgement. Moreover, the displacement in jobs and the downgrading of skill requirements for most of the new positions will undermine employment generally, and especially the employment of skilled workers.

Educational Implications

Given the widely, advertised view that high technology will dominate the demand for new workers and raise skill requirements of jobs, the usual prescription is that there must be a vast transformation of the educational system. It is assumed that rising skill levels for employment will require more training in mathematics, computer science, and technical applications for the labor force as a whole as well as an increasing number of workers with specialized training in these fields. Consequently, schools must adapt to these new responsibilities through major upgrading of mathematics and science curricula as well as teacher preparation. Schools also need to establish specialized courses of study in computer applications and programming to provide vocational training for high school and community college students.

We have asserted, however, that while some jobs will require these skills, the vast majority will not. Indeed, one of the major purposes and effects of high technology is to simplify or reduce the skill requirements for performing a particular work task. With the exception of a relatively small number of highly specialized positions for designing and implementing high technology applications, most jobs will not require higher skill levels. Industrial shifts and technological change may require different skills, but the preponderance of persons affected by such shifts will not need more mathematics or computer science. And, for significant numbers of jobs, the skill requirements that will have to be met will be less-demanding.

Based upon these assessments, what educational policies are implied?

First, the general educational requirements for creating good citizens and productive workers are not likely to be altered significantly by high technology. Everyone should acquire strong analytic, expressive, communicative, and computational skills as well as extensive knowledge of political, economic, social, and cultural institutions. These aptitudes and knowledge are required for understanding daily experiences and for ensuring access to social opportunities. To the degree that the present schools fall short of providing these results, they should be sought for their own sake rather than because of the claim that they are required for a high technology future.

Second, since we cannot predict in any precise sense which jobs will be available to particular persons, which jobs they will select from among those available, and what the characteristics of jobs will be over a forty year working life, it is best to provide students with a strong general education and an ability to adapt to a changing work environment. Such adaptation requires a sufficient store of information about culture, language, society and technology as well as the ability to apply that information and acquire new knowledge. Accordingly, general academic and vocational preparation should be stressed, as opposed to specific training, especially for young students.

Specific job skills can best be learned on the job, if a worker's general background is sufficient (Thurow 1975). Recent surveys of both U.S. and British employers indicate that they seek new employees with a sound education and good work habits rather than narrow vocational skills (Maguire and Ashton 1981; Wilms 1983).

Third, if changes in work requirements arise abruptly and change occurs at a faster rate than previously, the educational system may need to respond more quickly and efficiently to training needs. It may require better ties with industry and should not exclude the possibility of more industry-based training activities. It should also be tied to a system of recurrent education, since workers will no longer be able to acquire a set of job skills at the beginning of their careers that will be useful over their entire work lives (Levin and Schutze 1983; Mushkin 1974).

In summary, the educational implications of high technology are that a solid basic education rather than narrow vocational preparation will become more important in the future. This will require elementary and secondary schools to strengthen virtually all their instructional offerings that require analytical and communicative skills.

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Table 1

Employment and Employment Growth in the Fastest Growing Occupations: 1978-90

Occupations	Employment (thousands) 1978	Employment (thousands) 1990	Employment Growth 1978-90: Percentage Increase	Employment Growth 1978-90: Number of Jobs (thousands)	Employment Growth 1978-90: Number of Jobs (percent of all occupations)
Fastest relative growth[a]					
1. Data processing machine mechanics	63	156	148	93	0.4
2. Paralegal	28	66	132	38	0.2
3. Computer systems analysts	185	384	108	199	0.9
4. Computer operators	169	317	88	148	0.7
5. Office machine and cash register servicers	49	89	81	40	0.2
Total	494	1012	105	518	2.4
Fastest absolute growth[b]					
1. Janitors and sextons	2585	3257	26	672	3.1
2. Nurses' aides and orderlies	1089	1683	55	594	2.7
3. Sales clerks	2771	3362	21	591	2.7
4. Cashiers	1501	2046	36	545	2.5
5. Waiters/Waitresses	1539	2071	35	532	2.4
Total	9485	12419	31	2934	13.3
Total, all occupations	97610	119590	23	21980	100.0

[a]Based on the percentage increase in the number of jobs created

[b]Based on the number of jobs created

Source: Carey (1981), Table 2

Table 2

Employment Growth by Major Occupation Group:

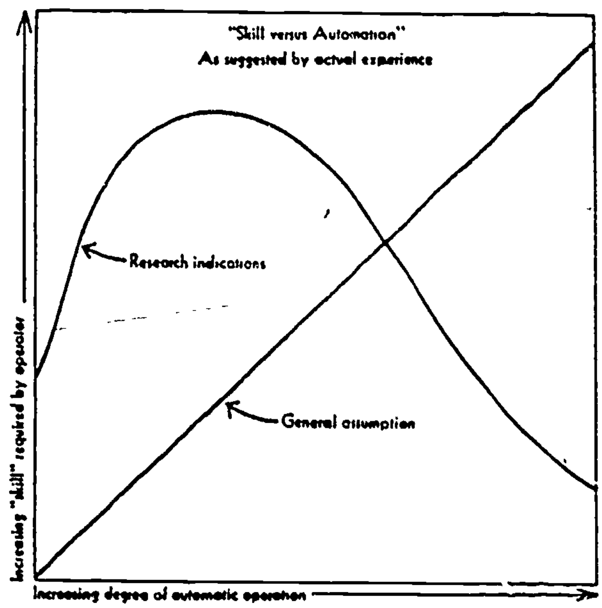
1960-90

Major Occupation Group	Employment Growth (percentage distribution) 1960-70 (1)	1970-80 (2)	1978-90 (3)
Professional and technical	30.0	22.3	20.3
Managerial	6.0	22.7	7.7
Sales	5.8	2.6	7.0
Clerical	32.9	21.0	20.0
Crafts	11.2	9.5	12.2
Operatives	7.5	1.8	10.0
Laborers	.7	4.8	4.8
Farm workers	-14.5	- .2	- 2.6
Service	20.4	15.5	20.7
Total	100.0	100.0	100.0

Sources: (1)-(2) Rumberger (1983), Table 2; (3) Carey (1981), Table 2.

Figure 1

The Relationship Between Increasing Levels of Automation and Job Skill Requirements



Source: Bright (1966), p. II-209.