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ABSTRACT

This policy statement and report on computers and jobs examines some of the changes that are affecting jobs and the preparation of both young people and adults for those jobs. The policy statement addresses these selected issues: preparation of firms and new and experienced workers for the introduction of computers into the workplace, the role of schools and training institutions, and information needs to aid policymaking. Findings are that existing strategies for adopting computers are appropriate for handling human resource adjustments; careful planning is the key to effective integration; good basic skills continue to be critical; computer skills are an addition to, not a replacement for, other job skills; and education and training institutions should make changes in course offerings and procedures. The staff report that comprises most of this document assesses some employment consequences of the "computer revolution." Topics include the spread of computers, computers' effects on jobs, the role of human resource decisions, job loss and worker displacement, current estimates and projections of displaced workers the amount of computer training workers need, and the role of educational institutions. Listings of reports and publications of the National Commission for Employment Policy are attached. (YLB)

Computers in the Workplace: Selected Issues

Report No. 19
March 1986

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TO THE PRESIDENT AND THE CONGRESS OF THE UNITED STATES:

On behalf of the National Commission for Employment Policy, I am pleased to submit this policy statement and report on computers and jobs.

Computer-based equipment is bringing about significant changes in the way the American people work and conduct their lives. Our report examines some of the changes that are affecting jobs and the preparation of both young people and adults for those jobs.

The Commission's policy statement addresses a number of issues:

- The United States is in the midst of what is likely to be a lengthy period of adoption of computer-based equipment. We urge workers, managers, educators, and students to use this time to learn how to apply the new technology in the most productive ways.

- The Commission recognizes, however, that even with the most careful planning, some workers in some industries, occupations, and regions will be displaced because of technology or some other cause. Workers in those areas, industries and occupations which suffer the greatest degree of dislocation will continue to need assistance.

- The Commission urges that computer-based equipment be implemented in ways that make full se of firms' human resources, and emphasizes that early and ongoing cooperation and participation of workers is essential to successful implementation.

- A solid grounding in the basic skills -- English comprehension and communication, mathematics, and problem solving -- will continue to be critical for all workers, whether they are preparing to enter the workforce or are already in it. The Commission urges education and training institutions and programs, from elementary schools to vocational schools to colleges and universities to programs funded under the Job Training Partnership Act, to take into account in their planning the kinds of jobs that will likely require computer knowledge and how best to train people for those jobs.

- Education policymakers, particularly those in the elementary and secondary education systems, should consider carefully the potential role that computers can play in the education of our young people and plan accordingly for the use of the new technology in the schools.

We hope that this volume will be of assistance to you and to others concerned with, and responsible for, the development of policies and programs designed to prepare America's workforce -- both current and future -- for the jobs of tomorrow.

Gertrude C. McDonald
GERTRUDE C. MCDONALD
Chairman

TABLE OF CONTENTS

POLICY STATEMENT

COMPUTERS IN THE WORKPLACE: SELECTED ISSUES

NATIONAL COMMISSION FOR EMPLOYMENT POLICY
POLICY STATEMENT ON
COMPUTERS IN THE WORKPLACE: SELECTED ISSUES

The United States is increasingly and irreversibly being computerized. The "computer age," the "computer revolution" and the "technology revolution" are new phrases in the American lexicon, but they have already become commonplace. At the center of the "age" and the "revolution" are versatile, sophisticated, and important devices -- from automatic teller machines and computerized cash registers to giant mainframes and industrial robotic systems, computers and computer-based equipment are significantly changing our personal lives and our worklives.

The Commission's work focused on how this equipment is changing jobs, including the education and training they require, and the ways in which employers, employees, students and educational institutions are adjusting to the changes computers are bringing about. The Commission also looked to history and to the experiences of Western European nations for guidance and insights.

Briefly, the Commission found that:

- Some types of computers and computer-based equipment are being brought into the workplace at a relatively rapid rate. Still, the general pace of adoption is such that existing strategies -- such as providing (re)training through private and public sector programs, facilitating job search and mobility, and offering income support during periods of transition -- are appropriate for handling the necessary human resource adjustments.

- Careful planning is key to the effective integration of new technologies into the workplace. Human resource decisions are an essential part of the planning process. These decisions should seek to make the best use of both equipment and workers and to minimize any potential adverse effects on workers. The technology should be used in ways that are not threatening to the health and safety of workers.

- Good basic skills -- writing, reading comprehension, math, and problem-solving -- will continue to be critical for labor market success, even in the "computer age."

- Computer skills are an addition to, not a replacement for, the job skills previously needed in an occupation.

- Education and training institutions should make some changes in their course offerings and procedures, not only because of computers, but also because of changes in the potential composition of the student population and a need to stress basic skills and recurrent education.

PREPARATION FOR THE INTRODUCTION OF COMPUTERS INTO THE WORKPLACE

Technological progress is a major source of economic growth, and it is essential if the U.S. is to remain internationally competitive with its trading partners. That computers and computer-based equipment will continue to enter and influence the workplace is a fact. From an employment perspective, the challenge is to introduce computers in ways that make maximum use of both the equipment and human resources.

The United States is in the midst of what is likely to be a lengthy period of adoption of computer-based equipment. As with previous innovations, this "adoption phase" is characterized by a gradual improvement and modification of the new equipment, continuing competition from old technologies, and a period of "learning by using." For other innovations that have resulted in profound changes in jobs, this phase has been relatively long. For example, electricity -- whose effects on the workplace have been as pervasive as may occur with the computer -- took about 50 years to spread throughout American manufacturing after Edison opened his first power station. The analogous event for computers would seem to be the development of the microprocessor. The Nation is already more than 10 years into the microprocessor era, and while the adoption phase for computer-based equipment may not take 50 years, the equipment certainly has not yet diffused throughout the entire economy.

Workers, managers, educators and students should use this adoption phase to prepare for the changes computers are bringing about and to learn how to apply the new technology in the most productive manner.

The Preparation of Firms

Most firms have time prior to the adoption of computer-based equipment to consider fully the equipment's potential effects on the productivity of managers and workers and on the overall organization of work. Strategies for enhancing job satisfaction, worker motivation, working conditions, and the health and safety of employees are important aspects of the planning process.

There are many methods that firms can use to introduce computers into the workplace. Each of these methods can affect workers and their jobs differently, partly because the equipment has a myriad of uses and partly because of the wide variety of management approaches. Some methods require managers and workers to act together at all stages of implementation; other methods have management acting unilaterally; and there is a wide range of variation between these two. Some methods include retraining the existing workforce to work with the equipment. Other methods include hiring new and already trained workers, which may involve displacement of current employees. Finally, some methods stress restructuring jobs and organizations while others leave them largely unchanged.

Based on experiences to date, the introduction of computer-based equipment into the workplace has not led to massive worker displacement on a national scale. However, for various reasons, some areas of the United States and some industries and occupations have suffered severe dislocation.

<u>It is in the Nation's interest to continue current displaced worker strategies that are targeted on areas, industries, or occupations which suffer the greatest degree of dislocation.</u>

<u>Regardless of the circumstances leading to its introduction, the new technology should be implemented in ways that make full use of firms' human resources. The early and ongoing cooperation and participation of the workers who will be affected by the equipment is essential.</u>

The Commission asked the Manufacturing Studies Board of the National Academy of Sciences to review some of the various implementation techniques that have been used. A committee formed by the Academy is developing a set of general principles drawn from "best practices" used by firms which have already adopted advanced manufacturing technologies. The report, "The Effective Implementation of Advanced Manufacturing Technologies," will be issued in 1986.

The Preparation of Workers

About 12-1/2 percent of the American workforce used computers on the job in 1984 and the proportion is growing. Among those who used computers, only about 5 to 10 percent required lengthy specialized training or advanced academic degrees; they comprised less than 1 percent of the workforce. The remaining 90 to 95 percent of computer-users acquired the necessary skills through a relatively brief period of training, often on the job. Importantly, computer skills usually comprised only a small part of the total set of skills they needed for their work.

It is likely that over the next decade only a small segment of the workforce will need to have extensive technical knowledge of computers in order to perform their jobs. As systems become easier to use and pre-packaged software becomes more widely available, highly developed programming skills will probably be required in a small percentage of jobs.

A solid grounding in English comprehension and communication, mathematics, and problem solving -- the basic skills -- will continue to be critical for all workers, whether they are now preparing to enter the workforce or are already a part of it. In some occupations, workers must be able to read instruction manuals for the equipment and software they must use. In all occupations in which computers are used, there are times when workers must make educated judgments about the accuracy of the words or data being processed. For example, software packages which provide spelling assistance or do computations do not totally eliminate workers' needs to know mathematics or spelling.

New Workers

Those young people who graduate from high school and have good basic skills will have little difficulty moving into occupations that use computers but do not require sophisticated programming skills. They will also be better prepared to adapt to the introduction of computers into their jobs than their counterparts who do not have these skills.

The group of young people who remain "at risk" in the computer age is, and will be, that group which has historically required assistance in finding a foothold in the labor force -- youth who have not learned basic skills, whether or not they have graduated from high school. This group may require even greater assistance, to the extent that even minimal computer-related skills are required for employment.

College graduation is most likely necessary for young persons wishing to enter those fields in which programming or advanced knowledge of computer science is necessary. There will be a continuing demand for highly-educated young workers in occupations that require in-depth knowledge of computers -- such as engineering and systems analysis.

While a relatively small proportion of the workforce will be in computer-related positions, they, and the quality of their training, are critical: it is the computer scientists and engineers of the future who will improve computer technologies and facilitate the equipment's diffusion throughout the economy. It is to the Nation's advantage to have these occupations open to talented individuals from all segments of society. A policy-relevant aspect for these occupations is that women, Hispanics and blacks have been historically underrepresented in them compared to the various groups' proportions of degree recipients. Special encouragement such as counseling may be required if more members of these groups are to enter computer-related fields. Close cooperation among employers and educational institutions is particularly important. This cooperation should begin at least at the high school level.

Many employers and labor unions already have strong links with schools in their areas, helping with donated equipment or volunteer service by employees and managers. Many firms furnish employees to schools on loan. These strategies, and the interest in community welfare on which they are based, are to be commended.

College students in general tend to be flexible in selecting a field of study: they adjust to perceived changes in demand for different occupations. Thus, long-term shortages in computer-related jobs are not expected. However, spot shortages or surpluses may occur should demand conditions change abruptly.

Experienced Workers

Most adult workers who have already experienced the introduction of computers into their jobs have been able to adapt to the equipment with a minimal amount of (re)training either on the job or in the classroom. Nevertheless, there are some adults who, like their younger counterparts, already have limited employment opportunities and who may have even more severe problems in the "computer age." Adults who are functionally illiterate will likely have the greatest problems on the job since the operation of most equipment requires the ability to comprehend written material as well as oral instructions and to judge when the equipment requires adjustment. As has been true historically, this group will continue to have difficulty even finding job openings because they are unable to respond to written job advertisements or to complete written job applications. Other groups likely to continue to experience difficulties are those displaced or disadvantaged workers who need some occupationally related training but lack access to privately financed adult education and training programs.

THE ROLE OF SCHOOLS AND TRAINING INSTITUTIONS

Computers have been spreading rapidly throughout elementary and secondary schools. Between 1981 and June 1984 the number of microcomputers in public schools increased from 30,000 to more than 630,000, and the number may rise to 3 million by 1992. Computers are widely used as the subject of instruction and as a tool for learning, as well as for administrative purposes. At the same time, "computer literacy" has become an educational objective, although the precise meaning of the term varies across States.

Computers can make a significant contribution to the education of the Nation's youth. To date, the American school system on the whole has been unable to derive the maximum benefits that computers can offer.

The potential effectiveness of computers in the schools can be realized only when there is adequate advance planning for their use, adequate training of the teachers and other staff who will use them, and high quality software.

The movement of computers into grades K-12 has occurred so quickly that in most instances these conditions were not fully met. For example, quality software was not yet available, and in some applications is only now being developed.

Part of the needed planning relates to what courses will be offered and the reasons for offering them. For example, many schools encourage students to study computer programming as preparation for employment. As was noted previously, only a small percentage of workers use this knowledge in their jobs, and the percentage writing programs may decrease as newer equipment is introduced. For some youngsters, the time spent studying programming in preparation for work might be better spent learning English, math, and science. On the other hand, a course in programming may have value as a means of teaching youngsters logic and problem-solving, both of which can be used to develop basic skills.

Education and training institutions need to take into account in their planning the kinds of jobs that are likely to require computer knowledge in the future and how best to train young people for those positions.

Institutions of higher learning should also review their courses of study and individual course offerings, with the goal of ensuring that students in computer-related fields receive a high quality, "state of the art" education. The challenge for colleges and universities will be to alter or upgrade their engineering and computer science curricula by hiring newly trained faculty or updating the skills of existing faculty. This challenge is greater because financial pressures are increasing, student enrollments are declining, and the number of faculty required in most other fields is declining as well.

Education and training systems and programs should offer their students the full range of skills workers need to qualify for jobs, and recognize that knowledge of computers is only a small part of the needed (re)training effort. In addition to skill acquisition, activities of the private and public sectors should emphasize the distribution of occupational information so that youth and adults will have the knowledge to prepare adequately for employment opportunities.

INFORMATION NEEDS TO AID POLICYMAKING

The governments of many Western European nations are examining the development of computers and their application in industries. In the United States, the National Academy of Sciences, the Office of Technology Assessment, the National Science Foundation, and the U.S. Department of Labor have each undertaken research on various aspects of the relationship between computer-based equipment and employment.

There is, however, no comprehensive and consistent assessment of the overall situation, partly because data on the number of computers, robots, and other computer-based equipment are limited. If the word "computer" defined only one specific kind of equipment with only one use, any assessment would be much easier. It is the computer's great diversity, however, that both makes it a major innovation and makes its diffusion difficult to track. There is almost no information on the specific uses made of this equipment.

Further, while there are extensive data on the number and characteristics of workers in different occupations, these data are not linked to information on the types of equipment the workers use, or on the uses made of the equipment.

It is essential to update the current research and undertake new work in a few years. Such an update and expansion could signal if major occupational shifts or changes in training due to the spread of computers had been occurring or were likely to occur, and if so, whether new human resource policies were necessary.

CONCLUSIONS

The United States has, indeed, entered the "computer age." There are countless examples of computers permitting workers to store and manipulate information and materials in ways and at speeds never before thought possible. The challenge is to build on these experiences in order to manage computerization in the future. There are steps that individual workers, educators, managers, and policymakers can take to ensure that human resources are fully used as computers and computer-based equipment continue to diffuse. By taking these steps, we can employ both the new technology and America's workers to greater advantage.

STAFF REPORT

ON

COMPUTERS IN THE WORKPLACE:

SELECTED ISSUES

PREFACE

A few years ago, Universal Product Codes (UPCs) began to appear on a number of grocery items, much to the puzzlement of the vast majority of shoppers. We now know that UPCs were the beginning of a new system of grocery store operation. We have also seen the growth of automated banking stations, an increase in the use of robots on the factory floor and word processors in the office, and the rise and fall of video arcades. What was less apparent at first was that the introduction of this new computer-based equipment would bring with it changes in employment opportunities and in jobs, and that the grocery clerk, the assembly line worker, and the typist were not the only ones who have been, and will be, part of this phenomenon. It has become increasingly evident that the use of this type of equipment will continue to grow and that its effects on jobs and job opportunities will be far-reaching.

Computers are one of several advances in technology currently working through the economy. In turn, technological change is one of the many factors that are altering the type and number of goods and services produced and the ways in which they are produced. Consumer preferences (wanting a smaller, more fuel-efficient car), shocks to the economy (wanting such a car because of the price of gasoline), and international patterns of trade and investment (remembering when there were very few foreign cars on the roads), are examples of some of the other influences on what is bought and how it is produced. These factors, operating simultaneously, are profoundly affecting employment opportunities in the United States. They are also involved in a number of concerns surrounding broad, long-term changes occurring in the workplace, such as the rapid growth in service sector jobs, the relative decline in employment in manufacturing, and the future of America's middle class.

This staff report, and the policy statement it accompanies, are the culmination of the first phase of a multi-year workplan designed to investigate changes occurring in the workplace. Projects in this workplan, adopted by the Commission in 1984, will be looking into some of the employment and training issues that are emerging due to technological advances, the internationalization of the economy, and changing consumer preferences, among others.

The Commission chose to start its workplan with technological change, and specifically with computers, because:

- One of the Commission's functions under the Job Training Partnership Act is to "identify and assess the goals and needs of the Nation with respect to economic growth and work improvements including ... technological changes."

- The computer promises to be a major instrument in effecting change in the workplace. Because of its wide range of applications, called here computerbased equipment, computer use will continue to spread across industries and occupations and will help bring about changes in a number of employment related areas -- such as the numbers and types of jobs that are available, the amount of education and training that will be required to perform those jobs, and working conditions. Some of the many examples of computer-based equipment that have already been introduced into the workplace are robotic systems, computer numerically-controlled machine tools, computer-assisted design equipment, integrated office systems and desktop computers for office use.

From among the many issues raised by the introduction of computers into the workplace, the Commission chose to study those that relate directly to the Commission's overall mission, that did not duplicate other research efforts both inside and outside the Federal government, and in which the Commission's resources had the greatest prospect of closing gaps in knowledge. A listing of Commission-sponsored research undertaken for this project is in Appendix A. Appendix B contains a selected bibliography.

This staff report was designed to provide background material for the Commission's policy statement and information for policymakers and others, such as private and public sector managers and workers, and the education and training communities. The report is not intended to be the authoritative source of information on all issues relating to computers and employment.

Carol Jusenius Romero headed the Commission staff assigned to this project. She, Sara B. Toye, and Stephen E. Baldwin designed the project's overall approach and the research which was undertaken for it. This team supervised all aspects of the series of Commission-sponsored research reports for the project and wrote this staff report with the assistance of Larry Fenster and Janet W. Johnston. The authors are grateful for comments and suggestions provided by Commissioners and other members of the staff.

EXECUTIVE SUMMARY

The purpose of this staff report is to assess some of the employment consequences of the "computer revolution." It challenges or modifies many of the predictions made about computers and employment -- such as "upskilling," "deskilling," mismatches between workers and jobs, and massive job losses -- and attempts to allay some of the fears they have produced.

An Historical Perspective

While the computer is one of the most recent innovations society has witnessed, it is not the first to have a major impact on employment or to be described as revolutionary. Although the computer is unique in many respects, experiences with previous innovations, such as the sewing machine, power loom, and electric power, provide several insights into what we might reasonably expect as the computer revolution continues to spread.

- Whether an innovation is perceived as beneficial or detrimental to a nation's employment opportunities depends largely upon the overall well-being of the national economy during the period of diffusion.

- The full range of changes that will ensue from an innovation cannot be known in advance.

- Major innovations tend to be adopted over many years, allowing people time to adjust to the ensuing changes.

The Spread Of Computers

Assessing the spread of computers is difficult, in part because there are many different types of computers available for many different applications and each type or application can be spreading at a different rate. Further, data on computers are both scarce and scattered. There is no central source of information on the number of different types of equipment that have been installed or on the uses being made of the equipment.

In general, the best information on the spread of computers suggests that "the computer" is not revolutionary in the sense of causing sudden or abrupt change throughout the workplace. While some types of equipment, such as microcomputers, are diffusing relatively rapidly, others, such as mainframes, have, and are likely to continue to, spread at a slower pace. It is likely that the "computer revolution" will be taking place over the coming decades, not over the coming months or years.

Computers' Effects on Jobs

The computer may be revolutionizing the workplace in another way -- by dramatically altering how work is done and the number of workers required to do it. Since the United States is somewhere in the midst of the diffusion of computers, the best we can do at present is to analyze the changes that have occurred in offices and factories and add some of the lessons learned from experiences with previous innovations.

The Role of Human Resource Decisions

The installation of computer-based equipment sometimes compels, but more often permits, industries and individual firms to reorganize and to restructure jobs. The effects of these changes on workers vary, in part as a result of the nature of the equipment and in part because of managerial decisions and worker-management relations.

There are a number of ways that computer-based equipment can be installed within factories and offices. Management may unilaterally redesign an organization or individual jobs, or workers may be participate at any or all stages of the planning and implementation process.

Job Loss and Worker Displacement

Computers have been blamed for the decline of some occupations and credited with the growth of others. However, it is impossible to separate the effects of technology on changes in employment from the effects of other factors operating simultaneously in the economy. An important aspect of the simultaneity and interdependence of these changes is that a technology-caused decline in the number of jobs in an industry or an occupation does not necessarily result in layoffs or in all laid-off workers experiencing long-term unemployment -- becoming displaced workers. Job openings in other parts of the local economy, for example, can reduce the extent of displacement.

Current Estimates and Projections of Displaced Workers

Estimates of the number of unemployed workers who are categorized as "displaced" vary greatly, as do estimates of the numbers of workers who might become displaced as a result of computerization. Despite the wide ranges in the estimates of future displacement, it is clear that there will be some decline in the number of jobs needed to produce the same level of output because of robotization and computer-based office equipment.

It is also relevant that employment and training opportunities for different demographic groups differ when computers are introduced into the workplace. According to available research, women, minorities and older workers are less likely than white males under the age of 45 to have access to computer-related training and to more-skilled jobs.

Key aspects of bringing computers into the workplace include how jobs are changed and which workers are (re)trained for new or changing jobs. Decisions will be based in part on the amounts and types of skills that workers need in order to work with computers and in part on the amount and types of skills that workers have.

How Much Computer Training Do Workers Need?

Workers now use computers in at least 140 of the 673 occupations listed by the Bureau of Labor Statistics as employing 5,000 or more workers in 1982. Thirty percent of employed workers are in these occupations, but less than half of the workers in them now use computers. About twelve and one-half percent of U.S. workers used computers on the job in 1982, or about 12 million people.

Workers who use computers on the job can be divided into three broad occupational categories, based on the amount of computer training needed. The first group requires lengthy training in computers, often several years, and their training typically involves a combination of formal schooling and on-the-job training. Workers who design, program and repair the equipment or perform such work as systems analysis are included here. These occupations will account for no more than about 1 percent of the total U.S. workforce projected for 1995.

Computer skills are a relatively small addition to the total amount of job skills required in the second group, in which workers learn how to use computers by taking a single college course, other brief training, or by reading a manual. Their "real" learning takes place on the job as they gain experience. While few become as expert as professional programmers, some occasionally write their own computer programs. Included in this category are scientific and technical workers, accountants, architects and a few others. This group is projected to amount to 7 percent of all workers by 1995, up from about 1 percent currently.

Use of computers in the third group of occupations can either raise or lower the level of skills required of workers. This group operates computer-based equipment with standardized software for data or word processing, information storage/retrieval, industrial process control or as part of their craft. A few hours to a few weeks of formal training, followed by a period of learning on-the-job, are usually sufficient. Secretaries, bank tellers, real estate agents, airline reservation clerks and airline mechanics are examples of occupations included in this category. By 1995, this group is projected to account for about 23 percent of employment, increasing from the current share of 11 percent. In the future, as now, the vast majority of computer-using workers will be in the third group.

Members of all three groups will need to possess one characteristic in common -- "trainability." At the heart of trainability is the ability to read and understand, write and communicate, compute and comprehend one's computations -- the most basic of skills -- along with the motivation to learn. The greatest number of employment opportunities will be available to people with these skills, whether they are experienced workers with a job, displaced workers, or young people preparing to enter the job market.

Preparation of the Workforce

Preparation of the workforce for the computer age means preparing people to be adaptable to change. The major issues for youth are: (1) the extent to which they receive the amount and quality of education that computer-using and other occupations require, and (2) the extent to which they are flexible in altering their courses of study. Policy issues for adults are: (1) the extent to which they have previously obtained or can acquire the basic skills that computer-using and other occupations require, and (2) the likelihood that they can adjust should computers enter their already established worklives.

High School Youth It is difficult to judge whether or not young people have received the basic skills necessary to qualify for computer-using or other jobs. A standard approach has been to use the proportion who have a high school diploma as a measure of those who have basic skills. However, measures of high school completion provide information on the amount of schooling youth receive, but not necessarily the quality. Evidence on trends in academic achievement is mixed, with no general conclusion possible at the present time.

College Youth Between 15 and 17 percent of college graduates obtain a degree in quantitatively based fields, the physical and biological sciences, computer sciences, engineering, and mathematics. Women and minorities remain underrepresented in these areas even though they have increased their share of total degrees awarded.

Regardless of their sex, race or ethnicity, young people entering and already in college tend to be flexible in their educational goals: they generally respond to perceived changes in employers' demands. This point is demonstrated by their tendency to enter fields of study which are likely to lead to good job prospects and move out of fields where job prospects are poor.

A large number of youth graduate from college each year, a fact that reinforces the view that spot shortages in computer-using occupations will not last a long time. Combined with other sources of job turnover, even modest shifts in fields of graduation can make a significant difference in the balance between firms' demand for workers and the supply of job applicants.

Adults Most adults in the workforce are generally well educated, according to standard measures of educational attainment. They also change occupations and geographic areas relatively easily. Adults' movement among occupations is one way that occupational shortages are reduced, including shortages that may arise in the early stages of a technology's diffusion. Adult education and training is another way to facilitate the spread and efficient use of computers in the workplace. Adults are willing and able to engage in training, as demonstrated by the fact that a considerable amount of privately financed adult education and training occurs every year.

Despite this generally optimistic picture, there are two groups of adult workers who are likely to continue to have employment problems as computers spread -- functional illiterates and workers who face financial or other barriers to entering adult education and training programs. Adults least likely to take training are those not doing well in the job market.

The Role of Educational Institutions

Computers in Grades K-12 The number and scope of evaluations of computer effectiveness in education are limited. However, two major conclusions can be drawn from the evaluations:

- The computer is a potentially valuable tool for educators; it can be of great assistance in improving the education of some students in some situations.

- The effectiveness of computers in schools is largely determined by the presence of three conditions: good advance planning, extensive teacher training, and high quality software.

A nationally standardized definition of the term "computer literacy" and a Federal requirement that all high school graduates be computer literate would be ill-advised. Computers are likely to be only one component of a newly emerging and much broader concept of "technology literacy," and the term "computer literacy" may well become obsolete in a few years. Furthermore, educational resources might be better allocated to teaching the basic skills rather than intensive computer or technology skills.

Part of the planning process for computers in schools involves deciding who receives which kind of computer training. Computers are currently being used in many of the same ways as traditional educational materials. As a consequence, such usage appears to be perpetuating some historical inequities.

Four-year colleges and universities A combination of events, largely outside the control of colleges and universities, may lead to challenges in the coming years. The challenges are expected to be greater for four-year college and universities than for other post-secondary institutions.

One of the events is a decline in enrollment, which will reduce the number of faculty required if class size remains constant. It will also cause financial pressures that make it difficult for institutions to alter the composition of their faculties by hiring, or promoting into tenured positions, teachers who are newly trained and most likely to be up-to-date in their professions.

Second, because of the slowdown in hiring new teachers, the average age of the faculty at four-year colleges and universities is rising. This increasing average age, in combination with the tenure system, may pose problems as institutions seek to reorient individual course offerings or entire curricula.

In all sectors of education, there is a continuing need for quality teacher-training, motivated teachers, good educational materials, good planning and good administration, especially with respect to the integration of computers into the educational process. Schools at all levels need to learn how to teach students about computers and how to use computers to help students learn. This, on a foundation of mastery of basic skills, will help both students of today and workers of tomorrow be ready for changes that can only be imperfectly foreseen.

Preparing for a Change

The conclusion of this staff report is that computerization is proceeding irreversibly, but at a rate which is manageable given intelligent and well-informed preparation. Part of this preparation is the provision of information on the extent and implications of technological change, a need addressed by the Commission-sponsored studies underlying this report.

The conclusion that adjusting to computerization is manageable means that individuals and firms have time to prepare for change. They should use this time to plan and adjust to new labor market realities. The political, educational and social institutions which play their own roles in the labor market, such as government agencies, schools and unions, must also use this time to adjust. Parents have a special responsibility: in order that their children can become educated for a changing environment, parents will need to be aware of what is happening in the schools, in terms of both basic curriculum and the role played by computers. Employment opportunities and job requirements will change regardless of whether preparation or planning takes place: the hope is that preparation will maximize the benefits of computerization.

Chapter 1

INTRODUCTION

Of the equipment, Scientific American heralded:

> We believe that it is one of the most important inventions of the age. We will yet live to see it forming part of every household's furniture, for it is undoubtedly a family labor-saving machine.

Of the industry, the same periodical asserted:

> The rapid rise of the ... business constitutes one of the wonders of this enterprising age. No industrial revolution can equal that which has been produced by it withi the short space of sixteen years.

The first statement appeared in 1851; the second in 1862. The innovation was the sewing machine.(1) This report begins with these 125 year-old quotes because of their resemblance to statements being made today. For example:

> The new microtechnology ... is bringing change which is perhaps even more revolutionary than the industrial revolution....(2)

Predictions about specific ways that computers will affect the workplace are also being made. It is said that computers will:

- Decrease the skills required to perform jobs. Such "deskilling" implies an increasing routinization of work and an overeducated and bored workforce.(3)

- Increase the skill requirements of jobs. This "upskilling" implies that many workers will be unable to qualify for available jobs unless they acquire additional training, and that the least educated segments of the population will have greater difficulty finding work than they do now.(4)

- Dramatically increase the mismatches between the skills that jobs require and those available in the workforce, implying that the skills workers now possess will become largely obsolete.(5)

- Mandate that workers be "computer" or "technology" literate.(6)

- Eliminate many clerical jobs as the "paperless office of the future" becomes a reality.(7)

- Eliminate many operative jobs as the "factory of the future" becomes a reality.(8)

These statements, which are being made in the United States and a number of Western European countries, carry with them the inference that computers pose a threat to workers and to young people preparing for work. The fears are generalized to include most workers and most young people and are also personalized: computers will replace me in my job; my job is going to change so much that I will not be able to perform it; my job will become boring; or when I finish school I will not be qualified to get a good job.

The purpose of this report is to assess the employment consequences of the "computer revolution." The report challenges or modifies the predictions reported earlier and attempts to allay some of the fears they have produced.

Examining the impact of computers is a difficult undertaking for several reasons. First, there are many types of computers and computer-based equipment and they are used in a variety of ways. There are mainframe computers, minicomputers, and microcomputers, differentiated on the basis of computing power and price.(9) Equipment which uses these computers, termed here computer-based equipment, includes, for example, industrial robotic and computer-assisted design systems(10), automatic teller machines, and computerized cash registers. For the purposes of this report the terms computers and computer-based equipment are used interchangeably.

Second, there is a paucity of information on the number of computers in place, on the ways they are being used, and on the occupations and industries affected. Where there is information on particular types of computer-based equipment, it is used in this report; in other cases the discussion relies upon whatever reasonable evidence is available.

Finally, assessing the impact of computers is a difficult undertaking because they are not being adopted in a vacuum. Other forces are operating simultaneously and affecting the number and types of employment opportunities. For example, economic growth is stimulating increases in employment and can be offsetting decreases in employment due to the introduction of computers. Also, changes in both consumer preferences and patterns of world trade are affecting the number of jobs that exist and in which industries they are found.

The discussions in this report are based primarily on research sponsored by the Commission. Much has been written in recent years about the spread of computers and the implications of this "new technology" for the labor market and for training. Some of this literature consists of case studies of firms and industries, from which it is difficult to generalize to the economy as a whole. Other studies use national or State data, developed for other reasons, to infer findings about the impact of computers on employment. The literature is of uneven quality and only some of it bears directly on the topics covered here. Those references not cited elsewhere in this report which were most useful are listed in the Appendix.

The next chapter is a backdrop to the examination of the computer's effects on jobs. It looks first at experiences with previous innovations for guidance on what might reasonably be expected. The lessons from history are important because the economy is in the midst of a "computer revolution" whose ultimate outcome cannot be predicted. The chapter then discusses the spread of computers into the workplace in order to determine whether the introduction of the equipment will be revolutionary in the sense of causing abrupt and sudden change.

Chapter 3 investigates how decisions to computerize the workplace affect jobs, including job loss and worker dislocation, projections for future growth and decline, and occupational skill requirements. The chapter emphasizes that while computerization sometimes mandates certain changes, it more often allows change to occur. How and when technological change is implemented, and the resulting employment effects, are human resource decisions. It further shows that the vast majority of computer-using occupations require little computer training and that the training required can be incorporated into workers' daily worklives.

Chapter 4 addresses the question of how prepared the current and future workforces are for change, such as that brought about by the introduction of computers into the workplace. The discussion covers characteristics of workers and potential workers, such as occupational mobility and education, and characteristics of the institutions that educate and train them.

The evidence suggests that most workers are sufficiently flexible to adapt to most changes in the job market, including those associated with computers. At the same time, the advent of computers may exacerbate problems for those already having difficulties, such as functional illiterates.

Findings also indicate that computers in grades K-12 are potentially valuable educational tools, but that several steps need to be undertaken for the equipment's potential effectiveness to be realized. The chapter concludes by pointing to possible future challenges to the post-secondary system's historical capacity to graduate well educated computer scientists and engineers.

Chapter 5 concludes the report by indicating that the changes likely to happen due to computers should take place over decades, rather than months or years. Even so, individuals and institutions must begin now to prepare for change.

ENDNOTES

1. John A. James, Perspectives on Technological Change: Historical Studies of Four Major Innovations, Research Report 84-07 (Washington, D.C.: National Commission for Employment Policy, September 1984).

2. AFL-CIO Committee on the Evolution of Work, The Future of Work (Washington, D.C.: AFL-CIO, August 1983).

3. Henry M. Levin and Russell W. Rumberger, The Educational Implications of High Technology, Project Report No. 83-A4 (Stanford, Ca.: Institute for Research on Educational Finance and Governance, School of Education, Stanford University, February 1983).

4. Education Commission of the States, The Information Society: Are High School Graduates Ready? (Denver, Co.: Education Commission of the States, 1982).

5. H. Allan Hunt and Timothy L. Hunt, Human Resource Implications of Robotics (Kalamazoo, Mi.: The W.E. Upjohn Institute for Employment Research, 1983).

6. Northwest Regional Educational Laboratory, "Technological Literacy Skills Everybody Should Learn," in Ideas for Action in Education and Work (Portland, Or.: Northwest Regional Educational Laboratory, August 1984).

7. Georgia Tech Research Institute, Impact of Office Automation on Office Workers (Washington, D.C.: U.S. Department of Labor, Employment and Training Administration, Grant No. 21-13-82-13, 1984).

8. Robert Ayres and Steven M. Miller, Robotics, Applications and Social Implications (Cambridge, MA.: Ballinger Publishing Co., 1983.

9. A computer is a processing unit that can perform computations and logical operations. Advances in computer technology over recent years are due to the development of the microprocessor, which may be characterized as a miniaturized integrated circuit. It is the central processing unit of a computer.

The different types of computers vary mainly in their capacity for computation and communication. Microcomputers, also called personal computers, are used by one person at a time to perform word and data processing. Minicomputers have greater computing capacity, and so are able to be used by a number of people simultaneously. In addition to word and data processing, they are used in industrial robotic systems and computer-numerically-controlled machine tools. The micros and minis of today are capable of doing work much more rapidly than the mainframes of earlier computer generations.

Mainframes have the ability to handle computations from hundreds of sources simultaneously. They are also widely used for large-scale scientific calculations. A mainframe computer is capable of processing millions of pieces of information in a single second. Today's mainframes are hundreds of times more cost-effective and powerful than their earlier counterparts.

10. According to the Robot Institute of America a "robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools, or other specialized devices through variable programmed motions for the performance of a variety of tasks." Cited in H. Allan Hunt and Timothy L. Hunt, Human Resource Implications of Robotics (Kalamazoo, Mi: The W.E. Upjohn Institute, 1983.), p. 8. The important point is that the equipment can be reprogrammed: it can perform different tasks on either one or on many pieces of material. Computer-assisted design uses an electronic "drawing board" that permits very rapid and complex manipulations of detailed drawings.

Chapter 2

COMPUTERS IN PERSPECTIVE

The first electronic digital computer, COLLOSUS, was developed in England during World War II. The first comparable American computer, ENIAC, was completed in 1946. Both were developed to meet military needs.(1) Some forty years later, computers are the basis of many types of equipment and are used for a wide variety of purposes. Considerable anecdotal evidence suggests that they are being brought into the workplace at such a rapid pace that managers, workers, educators and students have little time to prepare.

The purpose of this chapter is to provide an historical perspective on computers and information on how fast the "computer revolution" is taking place. The section indicates that the revolution is proceeding more smoothly than the anecdotal evidence would suggest.

An Historical Perspective

While the computer is one of the most recent innovations society has witnessed, it is not the first to have a major impact on employment or to be described as revolutionary. Although the computer is unique in many respects, experiences with previous innovations provide several insights into what we might reasonably expect.

First, whether an innovation is perceived as beneficial or detrimental to a nation's employment opportunities depends largely upon the overall well-being of the national economy during the period of diffusion. The introduction of the power loom into the English economy in the 19th century serves as an example. Because it was introduced during a period of -- and contributed to -- massive growth in factory jobs, it has generally been viewed as beneficial, despite the fact that its adoption displaced the handloom weavers.

Attitudes toward computers have changed over the decades as general economic conditions have changed. When there was high unemployment in the early 1960s and again in the early 1980s, there was fear that computers would cause massive nationwide unemployment; many of these fears dissipated as unemployment rates declined. History's judgment of computers will in part reflect the health of the economy during the period of diffusion.

Second, the full range of changes that will ensue from an innovation can not be known in advance. For example, the sewing machine's greatest contribution to economic growth was in the method used to produce it. The machine tools developed to manufacture sewing machines could be used to produce a number of items in addition to the sewing machine; they were subsequently used to mass produce such things as other machine tools, steam engines, firearms, bicycles and locomotives.

As a further example, while electric power was developed as an alternative to gas lighting and steam power, one of its greatest impacts was the flexibility it offered manufacturing operations. Machines driven by steam derived their power from a central shaft which ran the length of the factory, and they had to be clustered near the central shaft in order to run. With electric power, the location of the power source no longer constrained the location of the machinery. Equipment could be placed in a more efficient sequence, thereby increasing workers' productivity. Indeed, even the location of factories was no longer determined by their power source.

When computers were first developed, observers of the day could not foresee the full range of ways in which they are already used. Although the world is rife with predictions about computers of the future it is similarly unlikely they will have captured either the full range of computer uses or the full range of changes they will bring about.

Third, major innovations tend to be adopted over many years, allowing people time to adjust to the ensuing changes. The spread of electric power, the "Second Industrial Revolution," spanned decades. It took about 50 years after Thomas Edison opened his first power station for electric power to diffuse through all of American manufacturing. The development of the microprocessor in 1971, 35 years after COLLOSUS, seems to be the analogous event of the "computer age." The Nation is already more than ten years into the microprocessor era, and the diffusion of computers is far from complete. How far along we are in the diffusion process is the subject of the next section.

The Spread Of Computers

Assessing the spread of computers is difficult, in part because there are many different types of computers available for many different applications. Each type or application can be spreading at a different rate and can have a different influence on how jobs are structured.

The complexity in the uses and applications of computers can best be described by examples. Computers are used in fields such as accounting, finance, sales, health care, education, insurance, and real estate. They are also used in the metal-working industries and in the automobile, movie, aircraft, appliance, foundry and textile industries. In some cases, computers are used in relatively simple stand-alone applications, such as word processors. In other cases they are used in highly complex operations which require the reorganization of whole work environments. For instance, a flexible manufacturing system uses different types of computers in various combinations for many purposes. Its essential feature is that the robotic systems, machine tools and controlling computers are reprogrammable and can be used to make different products.

Assessing the spread of computers is also difficult because data on computers are both scarce and scattered. There is no central source of information -- comparable to the data on workers available from the U.S. Department of Labor -- on the number of different types of equipment that have been installed, whether they are robots, personal computers, numerically-controlled tools, or computer-assisted design (CAD) devices. Further, there is no central source of information on the uses being made of the equipment. This section discusses the types of computers for which there is the most information available.

Mainframes, Minis, and Micros

The first American computer designed for multiple purposes, UNIVAC, entered the commercial market in 1951. However, few firms could afford it: it cost over $500,000 (in 1951 dollars), occupied a room about 10' x 10' and required a highly skilled and specialized staff to operate it.(2)

The growth path of mainframes is typical of expensive, technically complex innovations: sales increase slowly for an average of fifteen to twenty years; and while technical advances and lowered costs may lead to more rapid sales, a need for even more modifications and a still-high cost of the equipment may continue to keep sales growth low.

Sales of mainframes have generally been rising over the past 20 years, even though fluctuations have occurred, as shown in Diagram 1. There were probably no more than 100,000 mainframes in use in the U.S. by 1982.(3) Assuming mainframes follow the path of another complex, expensive innovation -- electric power generation -- it would be 2020 or later before the number of mainframes doubled from its 1982 level.(4)

Growth in sales of microcomputers differs markedly from that of mainframes, as shown in Diagram 2. Their growth rate is typical of innovations which are less expensive and

Diagram 1. Mainframe Computer Units Sold, 1960 - 1982

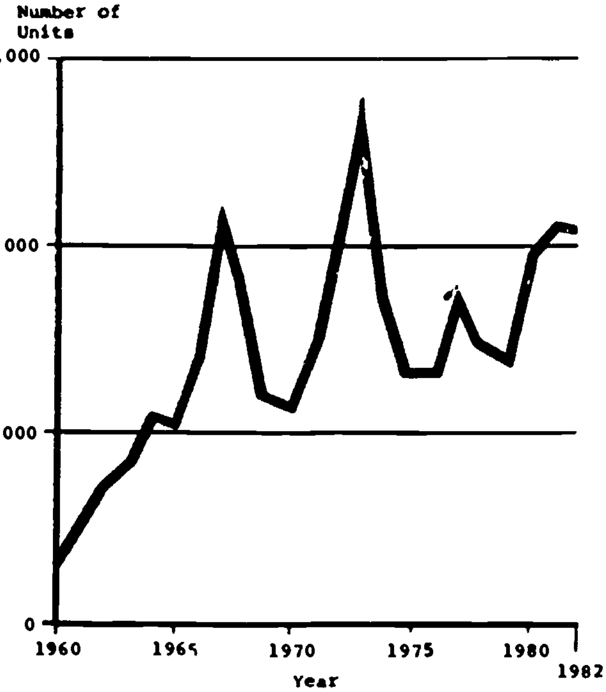
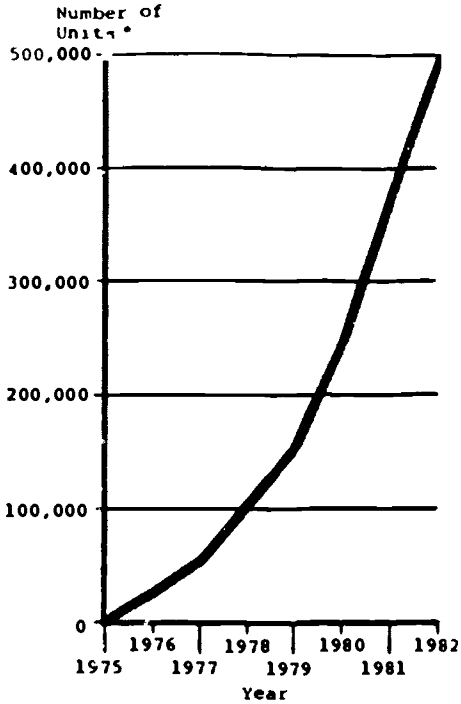
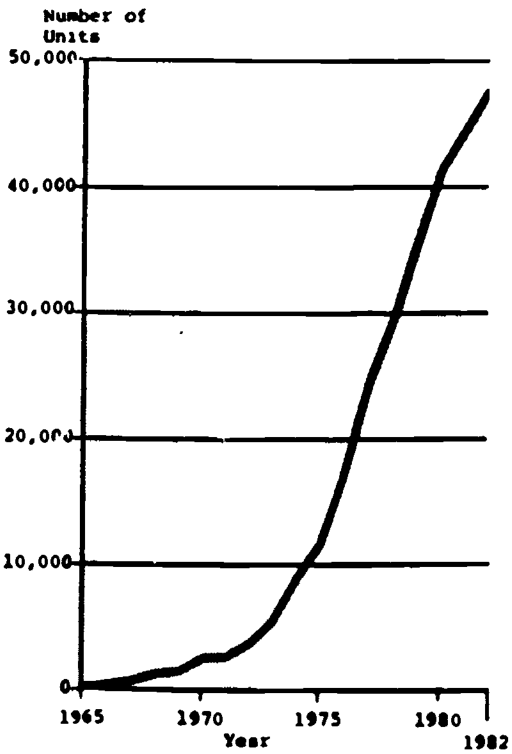


Diagram 2. Microcomputer Units Sold, 1975 - 1982



*Excludes units with a list price less than $1,000.

Diagram 3. Minicomputer Units Sold, 1965 - 1982



Source: Computer and Business Equipment Manufacturers Association (CBEMA), The Computer and Business Equipment Marketing Data Book. (Washington, D.C.: Industry Marketing Statistics Program, CBEMA, 1983), p. 90.

less technically complex. Initial sales of this type of innovation may be slow, but problems in using the equipment can be resolved relatively quickly; and once problems are resolved, sales of the equipment accelerate rapidly. However, because simple technologies do not require significant technical improvements, their attractiveness does not greatly improve. Firms which had not adopted in response to initial improvements, will not have a greater incentive to do so in the future. Consequently, the accelerated phase is often short-lived, ending within fifteen years. Thereafter, the growth of sales drastically slows down, often long before the innovation has fully supplanted competing older technologies.

Microcomputers entered the market in 1975; sales skyrocketed after one year and have continued to increase. In 1982 alone, one-half million were sold. Assuming microcomputers follow the growth path of less complex innovations, rapid growth will continue for another ten years, whereupon there will be a rapid slowing of sales increases. By 1983, only 30 percent of U.S. firms had purchased at least one microcomputer.(5) This would double by 1995, after which only slight inc. ses in the proportion of U.S. firms with a microcomputer would occur.(6)

Minicomputers are between microcomputers and mainframes in their technical complexity and cost, as is reflected in their growth path, shown in Diagram 3. Minis entered the commercial market in 1965; sales rose slowly for ten years, and then began to increase rapidly in the mid-1970s. It is likely that sales of minicomputers will increase more slowly than micros, but that the increase will continue for a longer time.

Computer-Assisted Production and Design

Computer-numerically-controlled machine tools, robots and computer-assisted design (CAD) are the best documented applications of computers in manufacturing. These three types of equipment have some important similarities: they are all relatively expensive investments; they still have a number of unresolved technical difficulties; and they are primarily being purchased by firms in the metalworking and electronics industries.

Numerically-controlled machine tools, which cut or shape metal according to programmed instructions, became commercially available in the early 1950s. Purchases grew moderately for the first 20-25 years, but began to increase rapidly after 1975, when instructions were received via computer rather than tape (see Diagram 4).(7) Numerically-controlled tools were 4.5 percent of the 1983 U.S. machine tool stock.(8)

Diagram 4. Numerically-Controlled Tools Purchased by the Metalworking Industries, 1953-1983

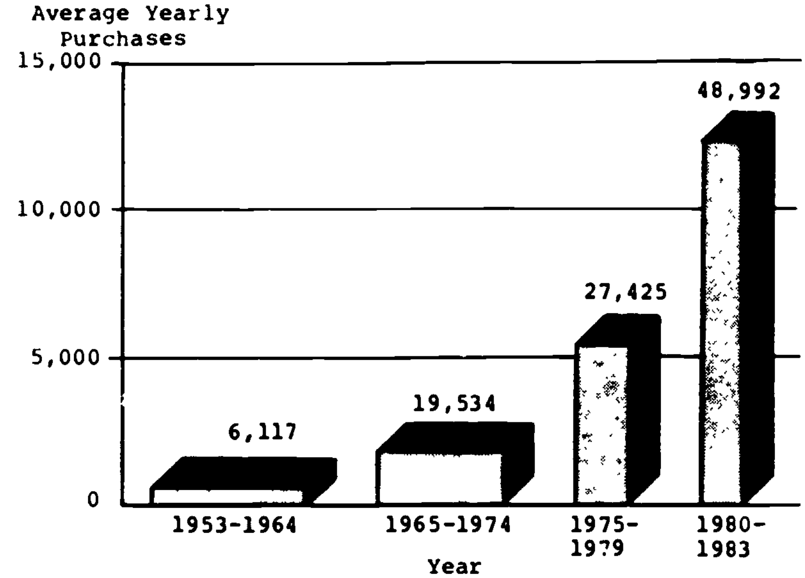
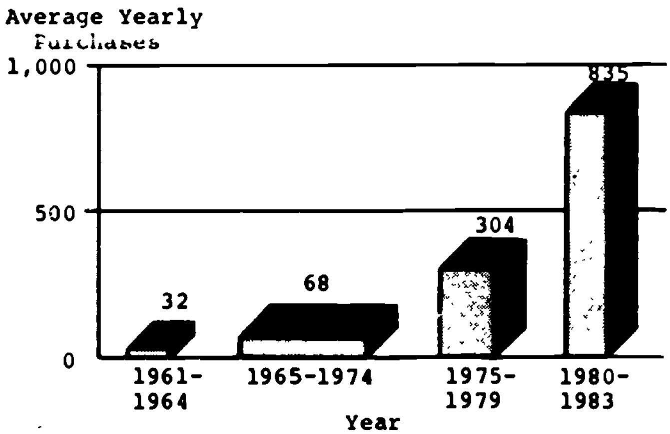


Diagram 5. Robots Purchased by the Metalworking Industries, 1961-1983



Source: "13th American Machinist Inventory of Metalworking Equipment 1983," <u>American Machinist</u> (New York, N.Y.: Dun & Bradstreet, 1983).

Note: The areas in each period correspond to the total purchases during the period. A constant yearly purchase is assumed for purposes of comparison.

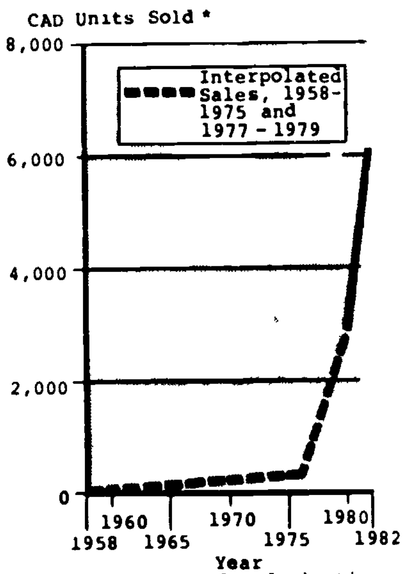
*See footnote 7.

Rohotic systems are most often associated with the production of automobiles, but they are also used to produce electronic, industrial, metalworking, and construction machinery; nuts; bolts; and other metal products such as saws, blades and blast furnaces. It should be stressed that today's industrial robots are nothing like C3PO or even R2D2 in Star Wars. Almost all are specially configured arm-like mechanisms that look something like a dentist's drill and can be programmed to perform a limited number of repetitive operations.

Modern-day rohots were first used commercially in 1961. The path of their purchases is similar to that of minicomputers, as shown in Diagram 5. Purchases were slow for the first fifteen years after the machinery's introduction into commercial markets, but hegan to increase more rapidly after 1975. Between 1980 and 1983, just over 3,000 were purchased and during that same period, robots were used in 3-4 percent of all metalworking plants -- the sector where almost all robots are used.(9)

CAD was introduced into commercial markets in the late 1950s. As with robots and numerically-controlled tools, sales were slow for the first fifteen years, but since 1976 sales have surged (see diagram 6). In 1982, there were an estimated 32,000 CAD units in operation in the U.S.(10)

Diagram 6. Sales of CAD Units, 1958-1982



*See footnote 10 for derivation of data.

Source: Office of Technology Assessment, Computerized Manufacturing Automation: Employment, Education and the Workplace. (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-CIT-235, April 1984), p. 273, and Raphael Kaplinsky, "Firm Size and Technical Change in a Dynamic Context," The Journal of Industrial Economics 32 (September, 1983), p. 41.

Numerically-controlled tools, robots and CAD are all following a growth path similar to that of minicomputers; a slow beginning with a distinct and prolonged acceleration in sales. The potential for prolonged and increasing sales is enhanced by the fact that the industries that use this equipment currently employ large numbers of highly skilled workers relative to their stock of machinery. They are ripe for such labor-saving technologies.

However, these types of equipment are unlikely to spread so rapidly over the next several years that they will become the predominant technologies in the manufacturing sector. They are technically complex pieces of equipment, expensive, and have unresolved problems. For example, their programming languages are cumbersome and not standardized among different firms or even by the same firm at different times. An additional problem in robotics is the difficulty the devices have in dealing with even small changes in the location of materials; for example, slight shifts in the location of parts bins can stop production.

In general, the best information on computers -- mainframes, minis, micros, numerically-controlled tools, robots and CAD systems -- suggests that "the computer" is not revolutionary in the sense of causing sudden or abrupt change throughout the workplace. While some types of equipment are diffusing relatively rapidly, others have, and are likely to, continue to spread at a slower pace. It is likely that the "computer revolution" will be taking place over the coming decades, not over the coming months or years.

However, the computer may be revolutionizing the workplace in another way -- by dramatically altering how work is done and the number of workers required to do it. The next chapter examines how computers are changing jobs and what might be expected in the coming years.

ENDNOTES

1. Kenneth Flamm, Technology Policy in International Perspective, Brookings General Series Reprint 406 (Washington, D.C.: The Brookings Institution, 1984).

2. Of course, the cost and time required to process a given amount of data are much lower for more recent mainframes than they were for those of the UNIVAC generation. IBM estimates that an identical mixture of typical operations which took 375 seconds in 1955 could be done in 1 second in 1983 and that the processing cost dropped from $14.54 in 1955 dollars to just 7 cents in 1983 dollars. IBM Corporation, Innovation in IBM Computer Technology (Armonk, N.Y.: IBM Corporation January 1984).

3. This calculation assumes that mainframes are kept in use for 10 years, so that mainframes purchased prior to 1972 are no longer being used. If mainframes are kept in use longer, say for 15 years, then the number is about 130,000. Computer and Business Equipment Manufacturers Association (CBEMA), The Computer and Business Equipment Marketing Data Book (Washington, D.C.: Industry Marketing Statistics Program, CBEMA, 1983).

4. John A. James, Perspectives and Larry Fenster, Patterns of Demand for New Technologies, Research Report 86-03 (Washington, D.C.: National Commission for Employment Policy, 1986).

5. Joseph Duncan, Personal Computer Survey -- Penetration by Size of Business (New York, N.Y: Dun Bradstreet, 1983).

6. Larry Fenster, Patterns

7. "13th American Machinist Inventory of Metalworking Equipment 1983," American Machinist (New York, N.Y.: McGraw-Hill Inc, November 1983). The data in this survey are actually the age of equipment in use in the metalworking-industries. This would be identical to purchases made if no equipment were scrapped. For diagrammatic purposes, 1953 is taken to be the year numerically-controlled tools were commercially introduced.

8. Ibid.

9. Ibid.

10. Office of Technology Assessment, Computerized Manufacturing Automation: Employment, Education and the Workplace (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-CIT-235, April 1984) and Raphael Kaplinsky, "Firm Size and Technical Change in a Dynamic Context," The Journal of Industrial Economics 32 (September 1983). For diagrammatic purposes, 1958 is taken to be the year CAD was commercially introduced. Sales were $80 million in 1976. In 1982 sales were over one billion dollars. No data on units sold were available, but assuming a constant price of $200,000 there would have been 400 CAD units sold in 1976 and 6,035 in 1982.

Chapter 3

COMPUTERS' EFFECTS ON JOBS

A commonly expressed fear about computers is that they will either replace workers in their jobs or change job requirements so much that many workers and potential workers will not qualify for the jobs they hold or want. This fear is reflected in predictions about the "paperless office," the "factory of the future," "upskilling", and "mismatches" between what people know how to do and the skills that jobs require.

Determining the accuracy of such predictions can only occur through hindsight. Since, as the previous chapter indicated, the United States is somewhere in the midst of the diffusion of computers, the best we can do at present is to analyze the changes that have occurred in offices and factories and add some of the lessons learned from experiences with previous innovations.

This chapter briefly discusses the crucial role that human resources decisions play in the introduction of computer-based equipment. It then examines the issues of job loss and work displacement associated with changes occurring in the economy. Finally, it presents information on the extent to which workers currently use the equipment and the amount of computer-related training they receive.

The Role of Human Resource Decisions

The installation of computer-based equipment sometimes compels, but more often permits, industries and individual firms to reorganize and to restructure jobs. The effects of these changes on workers vary, in part as a result of the nature of the equipment and in part because of personnel decisions.(1) For example, computerized equipment enables some firms to decrease their demand for workers in some low-skill jobs, such as spot painting in the automobile industry and taking inventory in supermarkets. Other types of computerized equipment can decrease the demand for higher-skill jobs, such as drafting.

Computers also permit workers in some occupations to reduce the amount of time spent on routine tasks and thus increase the amount of time available for problem diagnosis, problem solving and in some cases, interacting with the public, as in some service representative jobs. This "upskilling" is in contrast to the "deskilling" possible in other occupations, where the effect of computers is to make the work less demanding, as with cash registers that calculate the change due a customer.

Many computer applications allow managers to monitor workers' performance more closely. The most publicized stories involve people who have been fired as a result of computer surveillance -- telephone operators, word-processor operators, and people who clean hotel rooms. These cases have given rise to one of the fears of computers. However, there are also instances in which the capability for rapid feedback on performance has been incorporated into performance evaluation systems and has allowed workers to be rewarded for outstanding performance or to learn how they might improve their performance.

What happens to employees -- whether their jobs are abolished, "deskilled," "upskilled" or increasingly monitored -- is primarily determined by managerial decisions and worker/management relations. There are a number of ways that computer-based equipment can be installed within factories and offices. At one end of the continuum, management may unilaterally redesign an organization or individual jobs. The workers have no say in any aspect of implementation, including which workers are to be trained to use the equipment. Alternatively, management may involve workers at all stages of the planning and implementation process. This means that workers' concerns will be considered along with engineering and financial ones.

In order to broaden knowledge of what works best, the Commission is sponsoring a study which describes practices that are most effective in implementing advanced manufacturing technologies. The study, conducted by a committee of the National Academy of Sciences, complements the present report and will be issued in early 1986.

Job Loss and Worker Displacement

The problems of workers who have been displaced due to computers have been matters of widespread concern over the past several years. Addressing these problems has been complicated by uncertainty over how many workers are involved and who they are.

Computers have been blamed for the decline of some occupations and simultaneously credited with the growth of others. However, it is possible to separate the effects of technology on changes in employment from the effects of other factors operating simultaneously in the economy. Some of these other factors are structural, such as changes in patterns of international trade and changes in consumer preferences. There are also cyclical effects; for example, firms may be more financially able to keep and retrain workers in good times than in bad.

An important aspect of the simultaneity and interdependence of structural and cyclical changes is that a technology-caused decline in the number of jobs in an industry or an occupation does not necessarily result in layoffs. Further, not all laid off workers experience long-term unemployment -- that is, become displaced workers. Some industries and areas of the U.S. may experience layoffs without WOrkers becoming displaced because there are job openings in other parts of the local economy;(2) other industries and areas may experience a disproportionate amount of both layoffs and subsequent dislocation because there are few opportunities elsewhere in the local economy; and still other industries and localities may experience slow growth, but neither layoffs nor dislocation.

A lesson from history -- that major innovations tend to be adopted over long periods of time -- is important to remember. The length of the period of diffusion influences an innovation's effects on employment. As the previous chapter indicated, the spread of computers is likely to continue for a number of years. This means that some computer-related job losses that might otherwise result in layoffs can be handled through attrition. It also means that the number of workers categorized as displaced may be lower than if computers were spreading more rapidly, simply because there are some job openings every year.

Nonetheless, policymakers need to realize that even if attrition relieves some problems, some worker displacement in the future is inevitable. It is also certain that a substantial number of these people will need some sort of assistance in finding work. To do so, many of them will need to acquire a good working knowledge of English, math, and problem solving -- the basic skills.

A second policy issue is whether displacement, regardless of its cause, is manageable through existing mechanisms such as job search, mobility assistance and income support programs or if new policies and programs will be necessary. At the root of this issue are the size and characteristics of the displaced worker population. Characteristics in this context refers to who they are, where they are, and the reasons for the long duration of their unemployment.

Current Estimates

Estimates of the number of "displaced workers" vary greatly.(3) A study conducted for the Commission focused on workers who had the greatest difficulty finding jobs.(4) The study, which investigated dislocation problems in five States, defined workers as displaced if they had lost jobs in industries experiencing decline in the workers' local area, and had also exhausted their unemployment benefits. Under this definition, about 11 to 19 percent of all unemployed workers, depending upon the State, were considered displaced. Applying this range to the country as a whole means, for example, that of the more than 8 million people reported as unemployed in September 1985, between 900 thousand and 1.5 million of them would be categorized as displaced.

The prototypical displaced worker is a middle-aged white male, living in the Great Lakes region, with at least ten years work experience in the auto or steel industries. However, that image is only part of the picture. There is, in fact, considerable diversity among displaced workers in terms of the industry in which they had worked, the region of the country in which they live, and their ages. This diversity becomes especially apparent when looking at local labor markets. National estimates mask particular regional or local dislocations because they combine dislocations resulting from plant closings in some areas of the country with openings or expansion in the same industry in other parts of the country.

__Projections__

Only a few studies have predicted the effects of computers on the number of jobs available over the next several years.(5) Two of the studies examined the employment implications of robotic systems in factories, but most focused on office service work. The studies in robotics resulted in a b range of estimates of the number of jobs potentially lost or not created because of their introduction: from 100,000 to 800,000 over the 1980s.(6) Similarly, the projections of clerical employment changes also varied widely: from an absolute decline of 250,000 to an increase of about 50,000 between 1982 and 1995.(7)

Despite the wide ranges in the numbers emerging from these studies, it is clear that there will be some decline in the number of jobs needed to produce the same level of output because of robotization and computer-based office equipment. To put these numbers in perspective, in 1980, about 3 million workers, or just over 3 percent of all employed people, were in those assembly-line occupations that are most susceptible to robotization: welding, assembling, painting and machine loading and unloading. Most of these workers are men who live in the industrial Northeast or Midwest. About 19 million workers, or 20 percent of all employed people, are in those clerical occupations most susceptible to the introduction of computer-based office equipment. The occupations range from bank teller to office machine operator to postal clerk to secretary, reflecting the diversity of uses of the equipment. Most of these workers are women and the jobs are spread throughout the Nation.

The preponderance of women or men in particular jobs brings up another aspect of the impact of computers on jobs, and one which has received relatively little attention. Computers are sex, age, race, and national origin "neutral." That is, personal characteristics are not necessarily related to the ability to use computer-based equipment. However, employment and training opportunities for different demographic groups differ when computers are introduced into the workplace. According to available research, women, minorities and older workers are less likely than white males under the age of 45 to have access to computer-related training and to more-skilled jobs.(8) This reflects employers' (and sometimes employees') preconceptions about either what is "appropriate" for different groups of workers or what abilities and commitments to work different groups have.

The fact that the "computer revolution" is still underway means that there is time to incorporate human resource implications into decisions to computerize and to modify past decisions (such as discrimination in access to the new jobs) if necessary. Key aspects of bringing computers into the workplace include how jobs are changed and which workers are (re)trained for new or changing jobs. Decisions will be based in part on the amounts and types of skills that workers need in order to work with computers and in part on the amount and types of skills that workers have. The next section discusses the skills that are required; Chapter 4 discusses the skills that different groups of workers have.

How Much Computer Training Do Workers Need?

Computers are changing the skills that many occupations require. How extensively and how dramatically has been a source of controvery and fear on the part of both current workers and young people preparing to enter the labor market. One way to assess these changes in skill requirements is to determine how much computer-related education and training different occupations require and how important computer skills are relative to the skills that have historically been required.

Such a determination is important for several reasons. The first is that one of the main concerns surrounding computerization is whether or not bottlenecks might occur between the demand for, and supply of, workers for occupations which require lengthy training in the use of the equipment. The second is that there has been considerable discussion about changes in the skill requirements of jobs in general -- have they changed or will they change so substantially that current and future workers will not be qualified to perform them?

Finally, programs that train disadvantaged and dislocated workers, such as those funded under the Job Training Partnership Act, must take into account the full range of skills that jobs require. To the extent that jobs are beginning to require prior computer-training, program operators must either alter their training programs or limit their programs to occupations in which computers are not used.

Workers now use computers in at least 140 of the 673 occupations listed by the Bureau of Labor Statistics as employing 5,000 or more workers in 1982.(9) Thirty percent of employed workers are in these occupations, but less than half of the workers in them now use computers. About twelve and one-half percent of U.S. workers used computers on the job in 1982, or about 12 million people.(10)

Workers who use computers on the job can be divided into three broad occupational categories, based on the amount of computer training needed.

- The first group requires lengthy training in computers, often several years, and their training typically involves a combination of formal schooling and on-the-job training. Workers who design, program and repair the equipment or perform such work as systems analysis are included here.

- About 0.6 percent of all workers in 1982 were in jobs that require long periods of training in computer use. While the numbers of such workers are growing more rapidly than employment generally, these occupations will still account for no more than about 1 percent of the total U.S. workforce projected for 1995.(11)

Computer skills are a relatively small addition to the total amount of job skills required in the second group.

- The second group learns how to use computers by taking a single college course, other brief training, or by reading a manual. Their "real" learning takes place on the job as they gain experience. While few become as expert as professional programmers, some occasionally write their own computer programs. Included in this category are scientific and technical workers, accountants, architects and a few others.

- The importance of these occupations is projected to increase significantly by 1995, although not all the workers in them will use computers even then. Workers in the second group of occupations were about 1 percent of all workers in 1982. This group is projected to amount to 7 percent of all workers by 1995.

Use of computers in the third group of occupations can either raise or lower the level of skills required of workers.

- The third group operates computer-based equipment with standardized software for data or word processing, information storage/retrieval, industrial process control or as part of their craft. A few hours to a few weeks of formal training, followed by a period of learning on-the-job, are usually sufficient. Secretaries, bank tellers, real estate agents, airline reservation clerks and airline mechanics are examples of occupations included in this category.

- The vast majority of workers who used computer-based equipment are in the third group of occupations. Employment in these jobs amounted to about 11 percent of all workers in 1982. By 1995, this group is projected to account for about 23 percent of employment.

Additional occupations are certain to be added to the list of those in which workers use computers. However, which specific occupations they are, and into which categories they will fall will depend on both the relative number of workers with the skills and preferences for working with computers, and the ability of firms to adapt job requirements to available workers.

It is possible that a much larger proportion of occupations will require extensive computer-related training. This would especially be true if firms use a background in computers as a screening device for new employees, whether or not the employees need this knowledge to perform their jobs.

Alternatively, there has been a proliferation of new software packages and a trend toward "user friendly" computer systems. This suggests that many employers may prefer to hire people with the primary skills required in the occupation and provide brief on-the-job training in computers. This outcome is the more likely, and means that "trainability" will continue to be a major criterion for hiring new employees and retraining currently employed or dislocated workers.

At the heart of "trainability" is the ability to read and understand, write and communicate, compute and comprehend one's computations -- the most basic of skills -- along with the motivation to learn. The greatest number of employment opportunities will be available to people with these skills, whether the people are experienced workers with a job, displaced workers, or young people preparing to enter the job market. Computerization requires workers who can solve problems: who can recognize abnormal computer responses, understand error messages from the equipment, and take corrective action. Further, the new technology will be superceded by even newer technology, and the ability to adapt to new conditions will also require mastery of the basic skills and problem-solving abilities.

Decisions about human resource utilization -- what happens to people when computers are introduced into the workplace -- need not be dictated by technical and financial factors alone, but can be made with the best interests of the workers in mind. Even so, some workers will be displaced. Their ability to find new work, and the ability of new entrants to the labor market to find jobs, depend on the full range of skills they possess.

ENDNOTES

1. A firm's motivation for computerizing may have little to do with a desire to affect jobs. For example, computer control of office building heating and cooling systems occurred in response to higher energy costs, and the implications of these systems for building service jobs is unclear. More sophisticated equipment may require more frequent and/or more skilled maintenance, even as it may reduce skill requirements for equipment operators. However, most decisions to computerize reflect, at least in part, a desire to lower labor costs.

2. Of course, new jobs may offer lower wages than those the displaced workers received in their previous jobs. A recent survey found that displaced workers who found a new job experienced an average loss in earnings of about 9 percent. See, Displaced Workers, 1979-83, BLS Bulletin 2240 (Washington, D.C.: U.S Department of Lahor, Bureau of Labor Statistics, July 1985.) Many displaced workers face a dilemma: remain jobless or locate and (re)train for jobs with lower earnings' potential than the ones they previously held.

3. These variations exist largely because there are several definitions of the term displaced worker, each with different criteria for inclusion. The different criteria include layoff from a declining industry or from a declining occupation, or the duration of unemployment.

The BLS report noted in the previous endnote estimated that about 5 million workers were displaced between 1979 and 1984. The criteria used in making this estimate were that the workers had been with their previous employer for at least three years; had lost their jobs due to plant closings, layoffs or plant relocations; and were at least twenty years old at the time they lost their jobs. Many of these workers were displaced from the primary and fahricated metals industries, automobile production, the transportation industry, and wholesale and retail trade. This variety in the industries of origin reflects in part two cyclical downturns which occurred in the early 1980's, and in part structural changes such as those due to technology and international competition.

4. Robert Crosslin, James Hanna, and David Stevens, Identification of Dislocated Workers Utilizing Unemployment Insurance Administrative Data: Results of a Five State Analysis, Research Report No. 84-03 (Washington D.C.: National Commission for Employment Policy, April 1984).

5. The studies relied largely on case studies of industries and firms in order to estimate the number of units of computer-based equipment already in place, their uses, and the number of workers that the equipment was potentially capable of replacing.

6. One study, which emphasized what tasks robots are technically capable of performing, suggested that up to 800,000 jobs could be replaced by the equipment by 1990. Another study projected 100,000 to 200,000 jobs lost during the 1980s. This estimate appears to be more realistic since the authors attempted to take into account the economic feasibility of robotic systems for firms. Robert Ayres and Steven Miller, Robotics, Applications and Social Implications (Cambridge, Ma.: Ballinger Publishing Co., 1983); and H. Allan Hunt and Timothy Hunt, Human Resource Implications of Robotics.

7. For example, one study estimated a decline of about 250,000 clerical workers between 1982 and 1995, while another study projected growth, albeit below average, for the period 1978 to 1990. A third study, which looked at clerical employment in the banking and insurance industries specifically, projected slow growth to 1990 and a decline thereafter. (A survey of these studies is given in H. Allan Hunt and Timothy Hunt, "Clerical Employment and Technological Change: A Review of Recent Trends and Projections."

In contrast to these studies, the Bureau of Labor Statistics (BLS) estimates that clerical employment will increase about 25 percent between 1982 and 1995, the same rate as employment generally. The BLS projections are the most useful. According to an examination of these projections, if technological change occurred but the economy did not grow, clerical employment might decline in some industries. Employment opportunities for clerical workers are expected to increase because overall economic growth is projected, as well as growth in those industries in which clerical workers are concentrated, such as finance and services.

8. Patricia M. Flynn, The Impact of Technological Change on Jobs and Workers (Washington, D.C.: U.S. Department of Labor, Employment and Training Administration, Grant No. 21-25-82-16, March 1985).

9. For a complete listing and description of these occupations, see Harold Goldstein and Bryna Shore Fraser, Training for Work in the Computer Age: How Workers Who Use Computers Get Their Training, Research Report No. 85-09 (Washington, D.C.: National Commission for Employment Policy, June 1985).

10. Bureau of Labor Statistics, Occupational Projections and Training Data, Bulletin 2206 (Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics, 1984), Appendix Table B-1.

11. Ibid. Appendix Table B-1 is the source for projections for all three categories discussed here.

Chapter 4

PREPARATION OF THE WORKFORCE

Chapter 2 showed that the spread of computer-based equipment is by no means complete. Because no one can predict precisely either how pervasive the equipment will be or how it will change the number and types of employment opportunities, it is not realistic for workers, or the systems that train them, to make long-term plans based on specific technologies.

Preparation of the workforce for the computer age means preparing people to be adaptable to change. This is easier to say than do, since most people regard uncertainty and change with apprehension, even while they may recognize the need for adaptability. The key policy-related questions are -- How adaptable is the workforce to changes, perhaps unanticipated, in the work environment? How readily does the education and training system respond to changes in the demand for workers with different skills? The general answer is that both individuals and institutions are sufficiently flexible for shortages and surpluses of most types of workers to be of relatively short duration.

This chapter addresses these questions in greater detail. It looks into some of the characteristics of youth and experienced workers that indicate the extent of their adaptability; then it investigates the institutions that educate them.

The Characteristics of the Workforce

Adult workers -- defined here as persons 25 years of age or older -- typically have completed their formal education and have some work experience. Their education and training in new equipment, or in new fields, occurs either during their workhours or is undertaken on the workers' own time and initiative. By contrast, youth -- defined here as persons between 16 and 24 years of age -- are often still in school. Young people in school can and often do adjust their courses of study to meet changing labor market conditions for different occupations. Youth out of school may be able to intersperse periods of study with periods of employment, and can also alter their educational programs in response to changes in occupational demand.(1)

It is clear that there are differences between youth and adults in the options for education and training. Youth tend to have support from the education system and their families, while adults must rely more on their own initiative.

The major issues for youth are: (1) the extent to which they receive the amount and quality of education that computer-using and other occupations require, and (2) the extent to which they are flexible in altering their courses of study. Policy issues for adults are: (1) the extent to which they have previously obtained or can acquire the basic skills that computer-using and other occupations require, and (2) the likelihood that they can adjust should computers enter their already established worklives.

Youth

The youngest members of the baby boom generation are now in their middle twenties. A peak of over 38 million 16 to 24 year olds was reached in 1980; there are projected to be about 30.8 million 16 to 24 year olds by 1995 -- approximately the same number as in 1969. Youth will then be 15 percent of all persons over age 16, down from 22 percent in 1981.

While the number of all young people is declining, the number and proportion of minority youth are increasing. Minority youth will account for 19 percent of all 16 to 24 year olds by the mid-1990s, up from 16 percent in 1981.(2)

The three different types of computer-using occupations described in Chapter 3 are likely to attract youth with differing levels of educational attainment. High school graduates are more likely to enter those occupations which use standardized computer programs than are young people who complete college. High school graduates looking for their first full time jobs need the "basic skills" -- English and mathematics as well as general problem-solving abilities -- for successful employment; they may need some occupation-specific training as well. Most of these young people probably do not need in-depth computer training in grades K-12, since most of their computer training will take place after they have jobs.

College graduates are more likely than high school graduates to enter those occupations that require either lengthy computer-related training or at least some knowledge of programming. More than basic skills are needed to enter these occupations, and a considerable amount of pre-employment training may be required.

High School Youth It is difficult to judge whether or not young people have received the basic skills necessary to qualify for computer-using or other jobs. A standard approach has been to use the proportion who have a high school diploma as a measure of those who have basic skills.

About 85 percent of young people now complete high school. However, there are wide differences among race and ethnic groups: close to '0 percent of whites, under 75 percent of blacks and a little over half of Hispanic youth obtain a high school diploma by age 24.(3) These differences would indicate that black and Hispanic youth are going to continue to be at a disadvantage in seeking jobs requiring basic skills, whether or not the jobs involve computers.

Measures of high school completion provide information on the amount of schooling youth receive, but not necessarily the quality. Evidence on trends in academic achievement is mixed, with no general conclusion possible at the present time. A Nation at Risk reported that youth's knowledge of the basics has declined.(4) This finding was based on data on test performance, homework effort and academic course completions. There is some recent evidence of an upturn, based on the National Assessment of Educational Progress and on results of Scholastic Aptitude Tests.(5)

Many States are instituting educational reforms in an attempt to upgrade the education young people receive. Putting computers into schools has been proposed as one way to upgrade students' knowledge. The uses and effectiveness of computers in grades K-12 are discussed later in this chapter.

College Youth The number of young people enrolled in institutions of higher learning increased during the past twenty years. For example, almost 6 million young people between 18 and 24 were in post-secondary institutions in 1970; by 1982, this number had risen to over 7 million.(6) This increase reflected the movement of the baby boom generation through their college years. The proportion of people aged 18 to 24 who entered colleges and universities remained close to 20 percent.

An increasing proportion of enrollees over these years were women and minorities. Hispanics and blacks were 9 percent of full-time undergraduate enrollments in 1970, but over 15 percent in 1979. Women were just over 40 percent of full-time enrollees in 1970, but almost 50 percent in 1982.(7)

The decline in the number of youth between 16 and 24, which began in 1981, was first reflected in college enrollments two years later, and is projected to continue into the 1990s. About 6.4 million 18 to 24 year olds are projected to be enrolled in 1987 and 5.9 million in 1992. This decline appears to be due more to general demographic trends than to a fall in the proportion of youth who attend colleges or universities.

Between 15 and 17 percent of college graduates obtain a degree in quantitatively based fields, the physical and biological sciences, computer sciences, engineering, and mathematics. Women and minorities remain underrepresented in these areas even though they have increased their share of total degrees awarded. For example, while women were almost half of all BA recipients in 1979/80, they were less than 30 percent of those who received a degree in computer sciences.

Regardless of their sex, race or ethnicity, young people entering and already in college tend to be flexible in their educational goals: they generally respond to perceived changes in employers' demands. This point is demonstrated by their tendency to enter fields of study which are likely to lead to good job prospects and move out of fields where job prospects are poor. For example, the number of computer programmers and systems analysts increased by 170 percent between 1974 and 1984, about eight times as fast as employment generally. Along with this expansion, the percent of college-bound youth who identified these areas as their preferred field of study rose from 1 percent in 1974 to 10 percent in 1984. The proportion of Bachelor's degrees that were earned in computer and information sciences more than doubled over four academic years, from 1976/77 to 1980/81, indicating that young people were following through on these expressions of interest.

From the Nation's perspective, the willingness of college students to alter their specific education and career plans and actions is as important as their basic skills. Since youth are flexible in college, most shortages in occupations that require sophisticated computer skills should be alleviated relatively quickly -- in less time than the four years required to educate one "generation" of college-age young people. Short response times are important to the economy: while computer-using occupations which require lengthy training account for a small proportion of the workforce, they are critical in terms of the economy's ability to improve the technology and to facilitate its diffusion throughout the workplace.

The large number of youth who graduate each year reinforces the view that spot shortages in computer-using occupations will not last a long time. For example, the number of persons receiving post-secondary degrees in 1982 alone equalled almost 3 percent of the workforce. Combined with other sources of job turnover, even modest shifts in fields of graduation can make a significant difference in the balance between firms' demand for workers and the supply of job applicants. Of course, the ability of students to respond to changes in demand depends in part on the adaptability of educational institutions. This is discussed in a later section.

Adults

Most adults in the workforce are generally well educated, according to standard measures of educational attainment. Almost 85 percent have high school diplomas and almost 25 percent have four or more years of college. Educational attainment is projected to continue to rise since the average educational level of young people who will be entering the workforce is greater than that of workers who will be retiring. About 90 percent of the workforce of 1990 is likely to have at least a high school degree.(8)

Adult workers should not be viewed as "set in their ways," even though they are less likely to change occupations or geographic locations than youth, and are also less likely to (re)enter the formal school system. For example, between 5 and 10 percent of adult workers change occupations every year, compared to around 20 percent of persons aged 20 to 24. Over 50 percent of adult workers have changed occupations at least once in the course of their careers.

Adults' movement among occupations is one way that occupational shortages are reduced, including shortages that may arise in the early stages of a technology's diffusion. In the 1960s, demand grew rapidly for workers in the relatively new computer-related occupations. Because few people had been formally trained for these positions, members of the already experienced workforce moved into many of the jobs. One third of those who entered electronic data processing occupations between 1965 and 1970 had held other positions. Over two thirds of these experienced workers came from occupations that were not related to electronic data processing; only 30 percent had held such positions as engineers, mathematicians or accountants.(9)

Adult education and training is another way to facilitate the spread and efficient use of computers in the workplace. Adults are willing and able to engage in training, as is demonstrated by the fact that a considerable amount of privately financed adult education and training occurs every year. While there are no estimates of the type and extent of computer-related training they take, such training is typically provided either in adult education courses as an adjunct to workers' normal work schedule, through employer- or vendor-sponsored courses (often during work hours), or by enrollment in regular college courses. The first two types of courses are most often geared to using computers in the workers' current jobs.

Despite this generally optimistic picture, there are two groups of adult workers who are likely to continue to have employment problems as computers spread. The first are adults who are "functionally illiterate." Functional illiterates are unlikely to have the basic skills required in most occupations, including those in which computers are used. Because there is no standard definition of functional illiteracy, only a range of estimates of their numbers is possible. Approximately 13 to 25 percent of persons 15 or older may be functional illiterates, as measured by an inability to use written materials and forms common in daily life, such as applications for credit cards and drivers' licenses. The problem is greatest among those groups with disproportionately little formal schooling: blacks, Hispanics, or older workers in general.

Illiteracy problems are also found among displaced workers. For example, at the Downriver Community College Assistance Center in Michigan about 30 percent of the clients were estimated to read at a sixth grade level, at best. At another center, in Ohio, about 35 percent of the displaced workers were between the fifth and seventh grade in math and reading skills.(10)

Other workers likely to continue to have employment difficulties are those who face financial or other barriers to entering adult education and training programs. The majority of workers who take adult education and training are already doing well, such as managers, and professional and technical workers. Adults least likely to take training are those not doing well in the job market. The Federal Job Training Partnership Act is targeted on this group, including some who may be employed in low wage, "dead end" jobs.

The Role of Educational Institutions

Many types of institutions provide training related to computers and computer-based equipment. Elementary and secondary schools offer students instruction in word processing, programming and other computer applications. Four-year colleges and universities, vocational and technical schools, community or junior colleges and the Armed Forces offer many types of computer-related courses, while professional associations, trade unions, equipment vendors and employers also provide or sponsor training.

This section discusses two specific parts of the educational system: elementary and secondary schools, and four-year colleges and universities. Elementary and secondary schools are examined because of the rapid rise in the numbers of computers they have acquired and the widespread belief that computers are a particularly valuable innovation in education. The discussion focuses on the effectiveness of computers in schools. Colleges and universities are examined with particular attention to their education of the young people who become computer scientists and engineers. The numbers of such workers, and the quality of their education, are critical both to the Nation's ability to improve computer technology and to the equipment's diffusion and effective use throughout the workplace.

Computers in Grades K-12

To use a word much favored by youngsters in school, the increase in the number of microcomputers in public school grades K-12 has been "awesome": from 30,000 in 1981 to more than 630,000 by June 1984. Recent estimates are that the number reached 1.1 million in 1985 and will increase to about 3 million by 1990.(11)

At the start of this period, "computer buff" teachers were the leaders in bringing computers into individual schools and using them in classrooms. Educational administrators and planners have become formally involved in planning for computer use only within the last few years.

The purpose of this section is to discuss the effectiveness of these large numbers of in-school computers. Two key questions about computers in the schools are: How are they being used? and, What steps must be taken to assure that their use contributes both to improving the quality of education that children receive and to preparing them for jobs?

There are five major categories of computer use in schools:

- Computer-assisted instruction, in which a child operates a computer to learn math or some other basic subject;

- Computer-managed instruction, in which a teacher, counsellor or principal uses a computer to diagnose a child's learning difficulties, prescribe appropriate learning materials, manage the curriculum process, etc., so that each child receives individualized instruction;

- Administrative applications, in which a computer is used for such matters as recording attendance, scheduling and test scoring;

- Tool applications/instruction, in which a student is taught word processing or spread sheets, for example;

- Computers as the subject of study, in which the child learns about computers and how to use them. Computer programming is an example of this application.

Each type of use has many options. For example, computer-assisted instruction can employ drill-and-practice programs, considered the least challenging use of the computer, but the most helpful for many students. Alternatively, computer-assisted instruction can use simulation programs, which allow the child to interact imaginatively with the computer. There are a myriad of different software programs within each of these two options. There are, for example, thousands of different drill-and-practice courseware packages. (The term courseware includes the supplementary materials such as workbooks, as well as the program itself).

The number and scope of evaluations of computer effectiveness in education are limited. Many studies predate the type of computer that now predominates in schools (the microcomputer) and the sophisticated, student-controlled software that is increasingly in use. Further, many of the evaluations deal with only one type of computer use -- such as computer-assisted instruction. Others looked at a broader spectrum, but differences in methods and scope of these studies preclude generalizations. Additionally, findings can vary from State to State since each State implements its programs differently. For example, one study found that wealthier school districts are much more likely to have microcomputers than poorer districts, while another study using data from another State obtained the reverse finding.

There are two major conclusions from the evaluations, despite these limitations:

- The computer is a potentially valuable tool for educators; it can be of great assistance in improving the education of some students in some situations.

- The effectiveness of computers in schools is largely determined by the presence of three conditions: good advance planning, extensive teacher training, and high quality software.

Good advance planning allows schools to identify how computers will be incorporated into the educational process, including how they are to be used generally, which students will use them, and for what specific purposes (such as programming, drill-and-practice or word processing).

Extensive teacher training is needed to assure that all the teachers who use computers are knowledgeable about the equipment and what it can do.

High quality software is needed to achieve educational and administrative objectives with a minimum number of "bugs" and a maximum amount of challenge for students.

It is the presence of these conditions that creates the success stories and it is their absence that creates the failures. For example, the administration of special education programs is viewed as one of the more successful applications of computers in schools. The equipment is used to develop and update Federally-mandated Individualized Education Plans. The role of the computer has been clearly defined, teachers understand its capabilities and how to use it, and high quality programs are available.

A less successful computer application has been the use of computer-aided instruction to teach English to students for whom English is their second language. The lack of success appears to be directly related to a lack of quality software -- there are few programs currently available and teachers reject about 80 percent of them.

"Computer literacy" is one area in which success or failure has yet to be determined. This phrase was originally coined as a "catch-all" term. It has taken on a life of its own to the point where many States are mandating that their high school graduates be "computer literate." Because there is no standard definition of the phrase, computer literates from different States have very different levels of knowledge about computers. This knowledge requirement can range from basic familiarity with the equipment to an in-depth understanding of computer science.

Establishing a nationally standardized definition of the term and mandating that all high school graduates be computer literate would be ill-advised, however. Computers are likely to be only one component of a newly emerging and much broader concept of "technology literacy," and the term "computer literacy" may well become obsolete in a few years. Furthermore, educational resources might be better allocated to teaching the basic skills rather than intensive computer or technology skills, if the majority of jobs continue to require strong basic skills, but only minimal computer training.

Part of the planning process for computers in schools involves deciding who receives which kind of computer training. Computers are currently being used in many of the same ways as traditional educational materials. As a consequence, such usage appears to be perpetuating some historical inequities. For example, more boys than girls are enrolled in computer-based education programs; when girls are enrolled in computer-based programs, they are often being prepared for lower-paying jobs, such as word processing. Similarly, there is evidence that students in compensatory education programs use less sophisticated software than other students, and thus have less opportunity to develop higher-level computer skills. On the positive side, computers are being used quite effectively in particular applications, such as developing special education plans, where the three criteria of planning, training and good software are met. The challenge is to extend these areas of success, both across the country and across computer applications.

The Post-Secondary Education System

The post-secondary system, and especially four-year colleges and universities, provide the advanced training required for people in the highly technical, computer-related occupations. Several events over the coming years are likely to present new challenges to these institutions. These events will be occurring just as educators are seeking to alter or upgrade educational offerings in response to changes in technology and, at the same time, are trying to maintain or improve the quality of their graduates. This section discusses these challenges.

The post-secondary education system consists of over 9,000 institutions: almost 2,000 are four-year colleges or universities; the remainder are two-year colleges and non-collegiate schools. Schools within the post-secondary system responded to needed change over the past several decades. They increased the number of opportunities for study in different fields and also offered more part-time opportunities in response to changes in students' preferences. They also accommodated a doubling of the number of students -- 12.4 million enrollees in 1981, up from 6.4 million in 1966 -- and they adjusted to changes in the composition of the student population, by age, sex, race, and ethnicity.

The system was able to accommodate these changes for several reasons:

- The system has a large number of institutions, as indicated above. Changes in demand could be spread among them; no undue burden was placed on any one.
- There is such variety in the types of institutions within the system that at least some schools will likely be able to respond to new demands even if others cannot. These different types of institutions vary in the extent

to which they are publicly or privately funded. For example, 25 percent of the four-year colleges, 60 percent of the universities, and almost 75 percent of the two-year colleges are public institutions. Because privately funded institutions are less constrained in their actions by government procedures, rules and regulations than are public institutions, they can respond to change more quickly, as their endowments and fund-raising capabilities permit.

- There are overlaps in course offerings among the different types of institutions. Changes in demand for various fields of study can be accommodated by more than one type of school.

Two-year colleges Enrollments in two-year institutions have accounted for the bulk of the enrollment growth in post-secondary education over the past fifteen years. These institutions appear particularly attractive to two groups of students: high school graduates with average or below average grades, and adults returning to school.

A significant number of students in two-year colleges transfer to four-year colleges. This occurs particularly in the West, where the community college network is most extensive. To the extent that transfers represent a second round of sorting by academic ability, it reinforces the perception that students in two-year colleges are typically of lower academic ability than those in four-year colleges. In the context of this project, this would mean that students in two-year schools are more likely to be candidates for jobs in the third group of computer-using occupations.

The second major group of students in two-year colleges are those who do not go to college right after high school, but rather start working, enter the Armed Forces, begin families or defer additional schooling for other reasons. Adult learners may have considerable work experience, but if they are displaced from their jobs, or decide they need more education as a way of forestalling displacement, they seem to find two-year colleges more receptive than four-year institutions. They too are more likely to be interested in and qualified for jobs in the third group of computer-using occupations.(12)

Four-year colleges and universities A combination of events, largely outside the control of colleges and universities, may lead to challenges in the coming years. The challenges are expected to be greater for four-year college and universities than for other post-secondary institutions.

One of the events is the decline in enrollment mentioned earlier. The student population began to decline in 1983 and is projected to continue to decrease into the 1990s. Declines in enrollment reduce the number of faculty required for classes of given sizes. They also cause financial pressures that make it difficult for institutions to alter the composition of their faculties by hiring, or promoting into tenured positions, teachers who are newly trained and most likely to be up-to-date in their professions. A decline in the number of required faculty is projected to be greater among four-year than two-year institutions -- while there were an estimated 513,000 faculty members in 1982, approximately 457,000 are projected to be employed in four-year colleges and universities by 1992.

Second, because of the slowdown in hiring new teachers, the average age of the faculty at four-year colleges and universities is rising: by 1990 almost 50 percent of the faculty will be between the ages of 56 and 65, up from 20 percent in 1980. Their increasing average age, in combination with the tenure system, may pose problems as institutions seek to reorient individual course offerings or entire curricula.

The challenge to adapt to change and to assure quality education will be difficult to meet. While the system's own actions will largely determine its ability to meet these challenges, actions taken by elementary and secondary schools are also important. Their responsibility is to provide colleges and universities with students who have a solid basic education upon which the post-secondary system can build.

The goal for both systems is to assure that the changes made in educational services are in fact those that are required to produce the desired results. There is a continuing need for quality teacher-training, motivated teachers, and good educational materials, good planning and good administration, especially with respect to the integration of computers into the educational process. Schools at all levels need to learn how to teach students about computers and how to use computers to help students learn. This, on a foundation of mastery of basic skills, will help both students of today and workers of tomorrow be ready for changes that can only be imperfectly foreseen. The final chapter focuses on this need to prepare for new conditions.

ENDNOTES

1. Drawing a sharp line between youth and adults in this way is clearly an oversimplification. The division largely reflects data availability; large numbers of people older than 24 are in school, while many people have established worklives well before reaching that age.

2. These data come from Gregory Spencer, Projections of the Population of the United States by Age, Sex, and Race: 1983 to 2080, Current Population Reports, Population Estimates and Projections, Series P-25, No. 952 (Washington, D.C.: U.S. Department of Commerce, Bureau of the Census, May 1984), and from U.S. Department of Labor, Bureau of Labor Statistics, Labor Force Statistics Derived From the Current Population Survey: A Databook, Volume I, Bulletin 2096 (Washington, D.C.: U.S. Department of Labor, September 1982).

3. U.S. Department of Labor, Bureau of Labor Statistics, "Educational Level of U.S. Workforce Up Sharply Over Decade," News Release USDL 85-355, September 1985.

4. National Commission on Excellence in Education, A Nation at Risk (Washington, D.C.: National Commission on Excellence in Education, 1984).

5. For example, see "SAT Scores Rise for Fourth Year," The Washington Post, 24 September 1985, p. A-6.

6. These data come from Valena White Plisko, ed. The Condition of Education, 1984 Edition (Washington, D.C.: U.S. Department of Education, National Center for Education Statistics, 1984) and Spencer, Projections.

7. The sources for the data in this paragraph and the next come from Spencer, Projections and U.S. Department of Labor, Bureau of Labor Statistics, Labor Force Statistics.

8. Bureau of Labor Statistics, "Educational Level."

9. Sheldon Haber and Robert S. Goldfarb, "Labor Market Responses for Computer Occupations," Industrial Relations, (February 1978), pp. 53-63.

10. Paula Duggan, Literacy at Work: Developing Adult Basic Skills for Employment, Education-Economic Development Series No. 2, (Washington, D.C.: Northeast-Midwest Institute: The Center for Regional Policy, 1985), p. 4.

11. Interview with a Representative of Education TURNKEY Systems Inc., Falls Church, Va., September, 1985.

12. Data supporting the text statements are in Plisko, ed., The Condition of Education, Tables 2.2 and 5.4.

Chapter 5

PREPARING FOR A CHANGE

Computers and computer-based equipment are one of the new technologies that are changing what we do and how we do it. Whether the process is termed "revolutionary" or "evolutionary" is largely a matter of personal and historical perspective rather than of fact. If your job is abolished or dramatically altered when new equipment is introduced into the workplace, it is a personal revolution, even if you are retrained to work with the new equipment or can move to another occupation. From a broader perspective, however, technological change is a continuous process, and the diffusion of computer-based equipment appears more evolutionary, as has been the case with other innovations.

Computerization is one of the forces causing permanent structural change in the economy, in contrast to cyclical changes, which tend to be reversed as economic conditions vary. A useful analogy is the distinction between changes in the weather (cyclical) and changes in the climate (structural). Most studies of the economy are like weather forecasts, whereas the goal of this project was to investigate the extent to which the climate is changing. Our conclusion is that while structural change is proceeding irreversibly, it is at a rate which is manageable given intelligent and well-informed preparation. Part of this preparation is the provision of information on the extent and implications of technological change, a need addressed by the Commission-sponsored studies underlying this report.

The conclusion that structural adjustment is manageable means that individuals and firms should use this time to plan and adjust to new labor market realities. The political, educational and social institutions which play their own roles in the labor market, such as government agencies, schools and unions, must also use this time to adjust. Employment opportunities and job requirements will change regardless of whether this planning takes place: the hope is that preparation will reduce distress and delay.

This report finds that an important part of individuals' preparation is for them to obtain, or sharpen, their own basic skills. Parents have a special responsibility: in order that their children can become educated for a changing environment, parents will need to be aware of what is happening in the schools, in terms of both basic curriculum and the role played by computers.

Education and training institutions also have a major role to play in helping workers prepare for the labor market changes due to advances in technology. Obtaining the new equipment has proved to be easier than integrating it into curricula: specifying what the student will be doing with the computer is more important (and more difficult) than just putting a computer in the classroom. Many schools will have to redefine their notions of who should be students, too, and work with people past the traditional schooling age range. Further, in an era of limited resources, coordination of programs among employers, schools and other training providers has an even higher value than in times of program expansion.

New technologies in general, and computers in particular, can only be implemented by human decisions. Human decisions are also central in the distribution of the benefits of change, including the economic growth made possible by greater productivity, and the improved quality of work life in safer and more pleasant surroundings. Some of these implementation decisions have imposed significant costs on the people least able to bear them, in the form of extended unemployment and reduced earnings prospects. Displaced workers are only the most obvious manifestations of these costs of change. Decisions which take human resource impacts into account would reduce these costs and redistribute them more in accordance with the distribution of the benefits of change, which could also be made more equitable.

Many other nations share with the United States the realization that change needs to be managed, not reversed. If an industry is to be viable in world competiton, it must adopt world class technology. Aid to industries and individuals making the transition to the new technologies can be a legitimate policy instrument of governments at all levels. Those aided, however, also have the responsibility to make conscientious use of public and private resources to prepare themselves for the new environment into which we are moving. When the waters are uncharted, it is wise to know how to swim.

APPENDIX A: Commission-Sponsored Research on Computers in the Workplace

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Barnow, Burt (ICF, Inc.)	The Education, Training, and Work Experience of the Adult Labor Force from 1984 to 1995.	85-10
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83

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