OFFICE OF TECHNOLOGY POLICY

America's New Deficit: The Shortage of Information Technology Workers

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I. INTRODUCTION

The sweep of digital technologies and the transformation to a knowledge-based economy have created robust demand for workers highly skilled in the use of information technology. In the past ten years alone, employment in the U.S. computer and software industries has almost tripled. The demand for workers who can create, apply and use information technology goes beyond these industries, cutting across manufacturing and services, transportation, health care, education and government.

Having led the world into the Information Age, there is substantial evidence that the United States is having trouble keeping up with the demand for new information technology workers. A recent survey of mid- and large-size U.S. companies by the Information Technology Association of America (ITAA) concluded that there are about 190,000 unfilled information technology (IT) jobs in the United States today due to a shortage of qualified workers.[1] In another study, conducted by Coopers and Lybrand, nearly half the CEOs of America's fastest growing companies reported that they had inadequate numbers of information technology workers to staff their operations.[2]

Evidence suggests that job growth in information technology fields now exceeds the production of talent. Between 1994 and 2005, more than a million new computer scientists and engineers, systems analysts, and computer programmers will be required in the United States-an average of 95,000 per year [Figure 1]. One difficulty is that the formal, four-year education system is producing a small proportion of the workers required. Only 24,553 U.S. students earned bachelor's degrees in computer and information sciences in 1994. While many IT workers acquire the needed skills through less formal training paths, it is difficult to determine whether such training can be adequately expanded to meet the demand for IT skills.

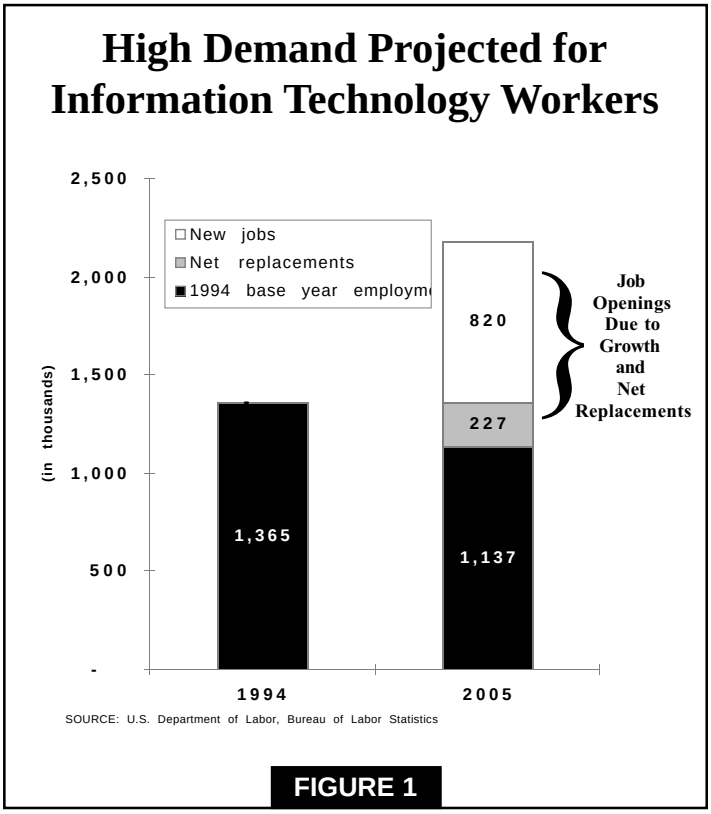


FIGURE 1

This shortage of IT workers is not confined within the borders of the United States. Other studies, including work by the Stanford Computer Industry Project, document that there is a world wide shortage of IT workers. That industries in other nations are facing similar problems exacerbates the U.S. problem since the geographic location of such workers is of decreasing importance to the conduct of the work. U.S. employers will face tough competition from employers around the world in a tight global IT labor pool. Thus, the United States cannot expect to meet its long-term needs through increased immigration or foreign outsourcing, and must rely on retaining and updating the skills of today's IT workers as well as educating and training new ones.

Since information technology is an enabling technology that affects the entire economy, our failure to meet the growing demand for IT professionals could have severe consequences for America's competitiveness, economic growth, and job creation.

This paper is an initial effort to explore this complex and evolving challenge. It begins by considering the different ways in which interested parties have defined the challenge, and reviewing the various ways of defining the IT worker. It considers the state of supply and demand for IT workers and assesses the potential consequences of a failure to meet the country's need for these workers. To lay the foundation for further development of policy responses to this challenge, the paper also highlights some of the measures that companies are taking to meet their short-term and long-term needs for IT workers. Examples of partnerships between industry, government, and educational institutions are also provided with the hope of encouraging improved interactions among concerned groups. In exploring these issues, the paper recognizes that information technology is evolving rapidly, with resulting shifts in labor requirements. Accordingly, this paper is, at best, a snapshot of a rapidly changing phenomenon.

Statistical and Definitional Problems

What is an IT worker? It depends on whom you ask. In a broad sense, the term "information worker" can be applied to data entry personnel, auto mechanics who use computer diagnostic equipment, medical technicians who operate CAT scan equipment, and loan officers who use computers to assess creditworthiness, as well computer programmers, systems analysts, and computer scientists and engineers.

In the context of this report, we present data from several organizations that have looked at the IT worker shortage issue. Each defines an "information technology worker" differently. The following definitions are presented to provide a foundation for understanding the meaning behind the data.

For its study, the ITAA defined "information technology" as the "study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware," and considered the lack of skilled workers available to perform all functions related to its definition.

Others are engaged in the development of software who are not trained software professionals, but who are considered to be IT workers. Stanford University, for example, has observed that those developing software embedded in cars, cellular phones, aircraft, and consumer electronics were far more likely to be mechanical engineers or electrical engineers with minimal training in software development methodology.[3]

A study by the United States International Trade Commission of the competitiveness of the U.S. computer software and services industries referred to only those individuals who have software-related skills that fall into five general categories. These categories are applications software developers, systems software developers, systems integration service providers, outsourcing service providers, and custom programming service providers.[4]

For this report, the Office of Technology Policy analyzed Bureau of Labor Statistics data to determine projected growth rates of core information technology occupations through the year 2005. BLS classifies these occupations as computer scientists and engineers, systems analysts, and computer programmers.

Descriptions of Information Technology Worker Professions

Computer Scientists

Computer scientists generally design computers and conduct research to improve their design or use, and develop and adapt principles for applying computers to new uses. They are distinguished from other computer professionals by the higher level of theoretical expertise and innovation they apply to complex problems and the creation or application of new technology. Computer scientists employed by academic institutions work in areas ranging from theory, to hardware, to language design. Some work on multidisciplinary projects, such as developing and advancing uses for virtual reality. Computer scientists in private industry work in areas such as applying theory, developing specialized languages, or designing programming tools, knowledge-based systems, or computer games.

Computer Engineers

Computer engineers work with the hardware and software aspects of systems design and development. Computer engineers may often work as part of a team that designs new computing devices or computer-related equipment. Software engineers design and develop both packaged and systems software.

Systems Analysts

Systems analysts (SAs) use their knowledge and skills in a problem solving capacity, implementing the means for computer technology to meet the individual needs of an organization. They study business, scientific, or engineering data processing problems and design new solutions using computers. This process may include planning and developing new computer systems or devising ways to apply existing systems to operations still completed manually or by some less efficient method. SAs may design entirely new systems, including both hardware and software, or add a single new software application to harness more of the computer's power. They work to help an organization realize the maximum benefit from its investment in equipment, personnel, and business processes.

Computer Programmers

Computer programmers (CPs) write and maintain the detailed instructions, called "programs" or "software," that list in logical order the steps that computers must execute to perform their functions. In many large organizations, CPs follow descriptions prepared by SAs who have studied the task that the computer systems is going to perform. The transition from a mainframe to a primarily PC-based environment has blurred the once rigid distinction between the programmer and the user. Increasingly adept users are taking over many of the tasks previously performed by CPs. A growing number of sophisticated software packages allow users and SAs to write programs.

Source: Bureau of Labor Statistics, U.S. Department of Labor

II. THE DEMAND FOR WORKERS IN THE INFORMATION TECHNOLOGY-DRIVEN ECONOMY

The Office of Technology Policy analyzed Bureau of Labor Statistics' growth projections for the three core occupational classifications of IT workers—computer scientists and engineers, systems analysts, and computer programmers—to assess future U.S. demand. BLS projections for occupational growth are given in three bands-low, moderate, and high. The following analysis uses the moderate growth figures.

BLS projections indicate that between 1994 and 2005, the United States will require more than one million new IT workers in these three occupations to fill newly created jobs (820,000) and to replace workers who are leaving these fields (227,000) as a result of retirement, change of professions, or other reasons.

Of the three occupations, the largest job growth is accounted for by systems analysts, which are projected to increase from 483,000 in 1994 to 928,000 in 2005, a 92 percent jump. This compares to a projected increase of 14.5 percent for all occupations. The number of computer engineers and scientists is expected to grow by 90 percent, from 345,000 to 655,000 over the same period, while the number of computer programmer positions is expected to grow at a much slower 12 percent rate, from 537,000 in 1994 to 601,000 in 2005. However, while only 65,000 new computer programmer jobs are projected to be created during this period, 163,000 new programmers will be required to replace those exiting the occupation [Figure 2].

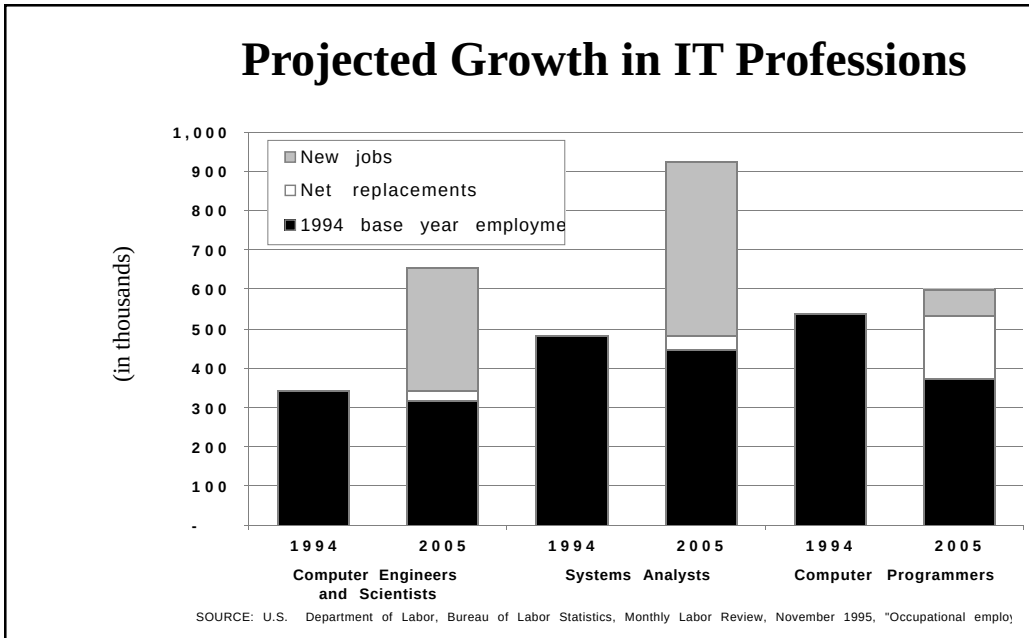


FIGURE 2

The service sector (not including transportation, communications, finance, insurance, real estate, and wholesale and retail trade) is expected to absorb the lion's share of all increases in these core information technology occupations. By 2005, the service sector is expected to increase its employment of computer scientists and engineers by 142 percent, systems analysts by 158 percent, and computer programmers by 37 percent. In contrast, the number of computer scientists and engineers and systems analysts in the manufacturing sector is expected to grow much more slowly (approximately 26 percent and 48 percent, respectively), while the number of computer programmers is expected to decrease by about 26 percent.

Rapid technological change and the growing complexity of information technologies and their applications are accelerating the trend toward outsourcing some computer-related

Industry IT Worker Intensity*

	1994	%		2005 Projection	%
1	Computer and data processing services	33.46	1	Computer and data processing services	43.65
2	Computer and office equipment	14.76	2	Computer and office equipment	18.31
3	Telegraph and communication services, nec	10.03	3	Telegraph and communication services, nec	13.62
4	Guided missiles, space vehicles, and parts	6.13	4	Search and navigation equipment	8.00
5	Life insurance	6.13	5	Life insurance	7.96
6	Medical service and health insurance	6.11	6	Security & commodity exchanges & svcs.	7.70
7	Security & commodity exchanges & svcs.	5.80	7	Guided missiles, space vehicles, and parts	7.57
8	Search and navigation equipment	5.45	8	Medical service and health insurance	7.52
9	Research and testing services	5.33	9	Banking and closely related functions, nec	6.81
10	Banking and closely related functions, nec	5.27	10	Communications equipment	6.53
11	Communications equipment	4.75	11	Research and testing services	6.48
12	Management and public relations	4.62	12	Aircraft and parts	6.10
13	Aircraft and parts	4.27	13	Management and public relations	5.99
14	Fire, marine and casualty insurance	4.26	14	Fire, marine and casualty insurance	5.51
15	Electronic components and accessories	3.84	15	Electronic components and accessories	5.20
16	Engineering and architectural services	3.47	16	Federal government	5.08
17	Federal government	3.32	17	Engineering and architectural services	4.78
18	Crude petroleum, natural gas, & gas liquids	3.19	18	Crude petroleum, natural gas, & gas liquids	4.35
19	Measuring and controlling devices	3.16	19	Measuring and controlling devices	4.10
20	Federal and business credit institutions	3.15	20	Drugs	4.03
21	Drugs	2.95	21	Federal and business credit institutions	3.88
22	Security and commodity brokers and dealers	2.88	22	Holding and other investment offices	3.78
23	Services, nec	2.87	23	Services, nec	3.40
24	Holding and other investment offices	2.86	24	Telephone communications	3.33
25	Pension funds and insurance, nec	2.69	25	Security and commodity brokers and dealers	3.31

* Percent of industry workers that are computer scientists and engineers, systems analysts, and computer programmers.

nec = not elsewhere classified

SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

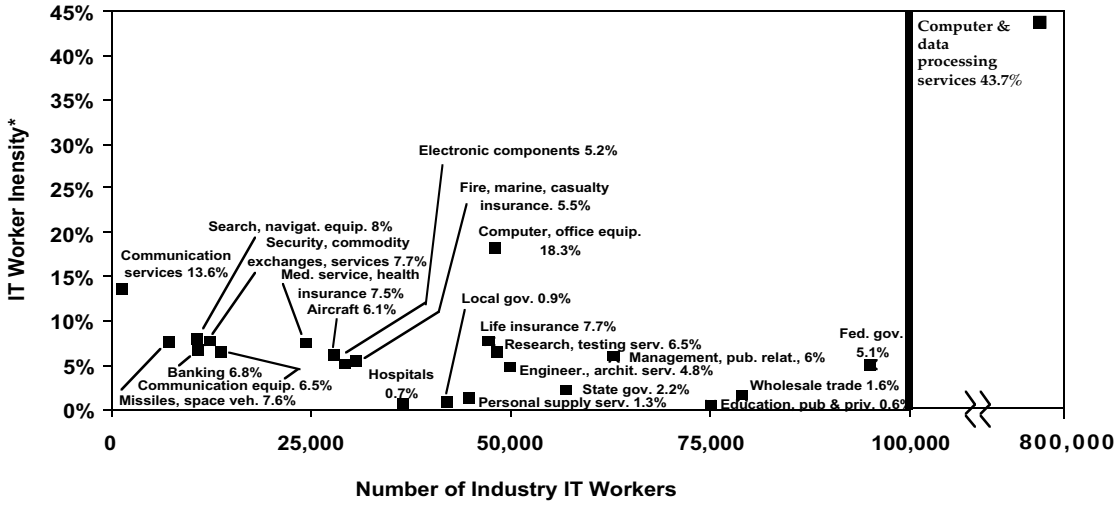
FIGURE 3

functions. Companies recognize the need to rely on outside experts to keep up with the technologies and to assemble multidisciplinary teams to meet the unique needs of each company. This is contributing to the growth of IT workers in services.

Certain industries are more IT worker intensive than others and thus, would be more severely affected by serious shortages of these workers [Figure 3]. And these industries are only growing in their IT worker intensity. In the most IT worker intensive industry—computer and data processing services—it is projected that, by 2005, 43 percent of the industry's employees will be computer programmers, systems analysts, and computer scientists and engineers.

However, IT worker intensity does not tell the whole story. The size of an industry's IT work force is an important consideration. For example, while the Federal government is projected to be less IT worker-intensive in 2005 than many other industries, the sheer size of its IT work force would make shortages of computer programmers, systems analysts, and computer scientists and engineers a troubling problem. When IT worker intensity and size of IT work force are taken together, a picture emerges as to which industries' competitive performance would be most adversely affected by severe IT worker shortages [Figure 4]. The computer and data processing services industry stands out starkly as an industry with much at stake in the supply of IT workers.

Projected IT Intensity and Size of IT Work Force for Selected Industries in 2005



* "IT worker intensity" is the percentage of a given industry's workers that are computer programmers, system analysts, and computer scientists and engineers.
Source: U.S. Department of Labor, Bureau of Labor Statistics, Moderate Projection.

FIGURE 4

The Growing Importance of the Computer and Data Processing Services Industry

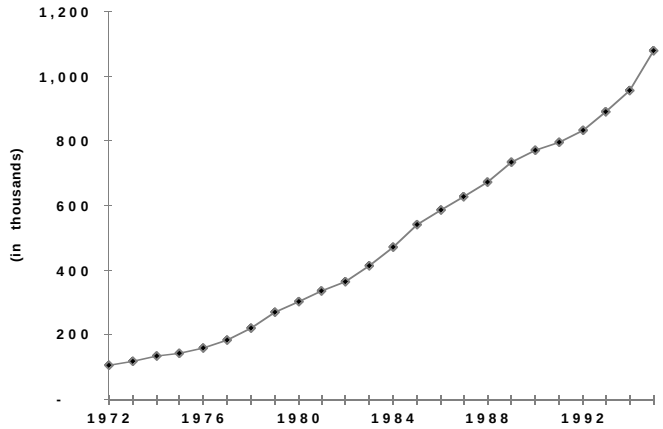
The size and influence of the computer and data processing services (CDPS) industry have expanded rapidly over the past decade. Between 1988 and 1995, CDPS sales grew 14 percent in constant dollars, compared to only 4 percent for all industries that conduct research and development.

Along with its phenomenal sales growth, CDPS employment has grown rapidly since the mid-1970s, as shown below. This growth is fueled not only by the rapid diffusion of information technologies throughout the economy, but also by the tendency of firms in all industries increasingly to outsource both routine and complex information activities in order to concentrate on the core business. Accordingly, increasing numbers of CDPS and management consulting firms are providing clients specialized information technology services more rapidly and less expensively than if the contracting firm did it themselves.

The shift to an information-based economy and the increasing concentration of information functions in information service firms is reflected in projected employment trends for "core" IT workers in the industry. By 2005, BLS projects that computer programmers, systems analysts, and computer scientists and engineers will constitute 43.7 percent of all 1.61 million CDPS workers (up from 0.95 million in 1994). Between 1994 and 2005, the CDPS share of total U.S. industry IT workers is expected to move up substantially with the computer programmer share rising from 30 to 41 percent, the share of systems analysts moving up from 20 to 29 percent, and the share of computer scientists and engineers increasing from 24 to 34 percent. Engineering and management services and personal supply services also increase their share of these workers, while most other services and all other major sectors of the economy (in particular manufacturing) decrease their shares.

As a consequence, the CDPS has, by far, the greatest stake in the adequacy of the supply of IT workers. Continuation of employment growth to a projected 1.6 million workers in 2005, with 702,862 "core" information technology workers, depends critically upon the existence of a well trained workforce. As U.S. industry increasingly depends upon the CDPS to provide many specialized information services, any adverse effects resulting from serious bottlenecks in the supply of new IT workers would reverberate across the economy.

Employment in Computer Services Has Grown Rapidly Since 1972



SOURCE: Current Employment Statistics Program, Bureau of Labor Statistics

The Millennium Problem

Many computer professionals have been diverted to correct the so-called Year 2000 problem. Some of the most important computer software used in industry and government may not work correctly starting in the year 2000 because it can only recognize two-digit dates that represent the year. For example, 97 is recognized as 1997. This means that these computers may not recognize a change to the new century and, thus, generate erroneous data in a wide range of computer activities, such as financial transactions, logistics, production, and communications. Many of the computers involved are older mainframe computers, which has placed a premium on computer professionals skilled in the older computer language of COBOL. It has been estimated by the Gartner Group that it may cost as much as $600 billion worldwide to fix the problem.

Rapid Growth Expected for Systems Analysts

With an expected growth rate of 92 percent to the year 2005, systems analysts are among the most dynamic of occupations, working at the nexus of rapid change in technology and business organization. Composed largely of young workers, unlike computer programmers, only a small percentage of systems analysts are expected to exit the occupation by the year 2005.

Responsible for matching computer/information systems to the special needs of companies and systems, many systems analysts must not only have an understanding of information technologies, but also business, scientific, manufacturing, or engineering problems. According to BLS, for jobs in the business environment, employers usually want systems analysts with backgrounds in business management or closely related fields. Many information service and consulting firms are looking for educated, computer savvy, individuals with a variety of college and graduate degrees to fill systems analyst positions. A number of consulting firms, which are rapidly expanding their information services, prefer hires with degrees in management, business, public policy, etc., over those with more narrow computer specialization. These firms provide whatever additional training is necessary to fill out computer/systems skills. With a wide variety of skilled IT workers to draw upon, information service firms can quickly assemble the precise teams necessary to meet the needs of their diverse clientele.

The projected dramatic growth in systems analysts contrasts sharply with the expected net growth in computer programmers. Systems analysts may contribute to this slow growth as they assume more and more computer programming responsibilities, aided by the introduction of a variety of programming software which simplify and extend the programming process. Some additional factors may further slow the growth in computer programmers. These include economies of scale associated with increased outsourcing of information functions and increased reliance by organizations on prepackaged software rather than wholly customized data systems; overseas outsourcing of computer programming; and the focus on enterprise-wide system integration which is consolidating stand-alone computer systems and islands of automation.

III. IS THERE AN ADEQUATE SUPPLY OF IT WORKERS?

Current statistical frameworks and mechanisms for measuring labor supply do not allow for precise identification of IT workers shortages. However, evidence does suggest a problem may be emerging.

Upward Pressure on Salaries

The strongest evidence that a shortage exists is upward pressure on salaries. The competition for skilled IT workers has contributed to substantial salary increases in many IT professions. A compensation survey conducted by William M. Mercer showed that average hourly compensation for operating systems/software architects and consultants rose nearly 20 percent from 1995 to 1996. A survey conducted by the Deloitte & Touche Consulting Group revealed that salaries for computer network professionals rose an average of 7.4 percent from 1996 to 1997. Computerworld's annual survey found that in 11 of 26 positions tracked, average salaries increased more than 10 percent from 1996 to 1997. For example, systems analysts' salaries were up 15 percent, programmer/analysts' salaries were up 11 percent, and directors of systems development received an average increase of 10 percent. Starting salaries for graduates with bachelor's degrees in computer science have nudged up to an average of $36,666[5], while experienced programmers can command salaries ranging from $45,000 - $75,000.[6]

ITAA Survey

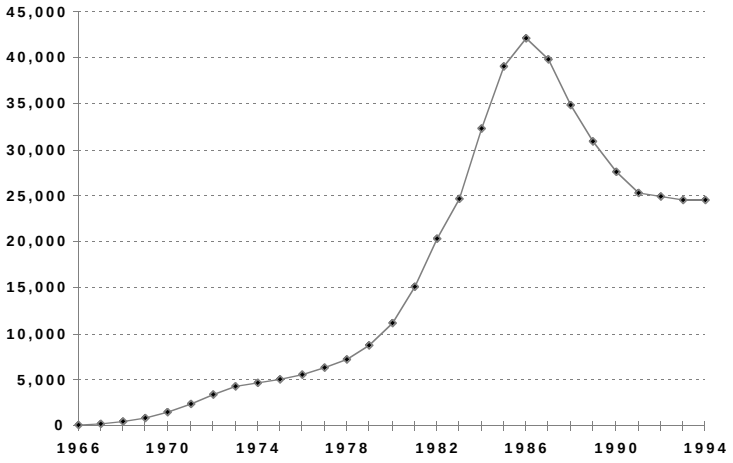
A recent survey of mid- and large-size companies, both information technology-related and non-information technology-related, conducted by the Information Technology Association of America found approximately 190,000 unfilled information technology jobs in the United States due to a shortage of qualified workers. According to this survey, shortages are likely to worsen. ITAA found that 82 percent of the information technology companies responding to the survey expect to increase their IT staffing in the coming year, while more than half of the non-information technology companies planned IT staff increases.

The Education Pipeline for IT Workers

Over the last ten years, there has been a decline in the number of students receiving university degrees in computer science. These graduates come from four-year degree-granting universities which focus on computer theory; that is, operating systems, languages, distributed systems, computer architecture and compilers. According to the U.S. Department of Education, the number of bachelor-level computer science degrees awarded by U.S. universities declined more than 40 percent between 1986 and 1994, from 42,195 to 24,553 [Figure 5].[7] The

significant decline in bachelor-level computer science degrees is, however, an imperfect indicator of declining labor supply, given that many IT workers acquire their skills through alternative education and training paths.

Bachelor's Degrees in Computer Science Down More Than 40 Percent Since 1986



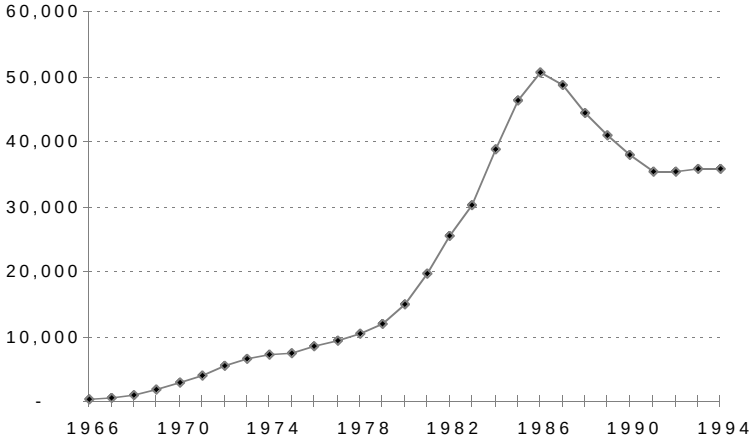
SOURCES: National Science Foundation; U.S. Department of Education, National Center for Education Statistics

FIGURE 5

While there have been some increases in the award of computer science masters and doctoral degrees, overall computer science degrees awarded have dropped from a high of 50,000 in 1986 to 36,000 in 1994 [Figure 6].

In addition, foreign students make up a significant share of U.S. computer science graduates. Of the 36,000 individuals awarded graduate and undergraduate computer science degrees in 1994, about 18 percent were foreign nationals. For advanced degrees, the proportion of foreign nationals increases, reaching more than 50 percent for doctorates.[8] The Computer Research Association estimates that foreign nationals comprise nearly 50 percent of computer engineering students in the United States.[9] The high proportion of foreign nationals in the graduate population would indicate that American industry cannot count on capturing all new graduates.[10]

Computer Science Degrees Earned
Bachelor's • Master's • Doctoral



SOURCES: National Science Foundation; U.S. Department of Education, National Center for Education Statistics

FIGURE 6

IT workers also obtain their skills from training providers other than four-

Training, Other Qualifications, and Advancement

Computer Programmers

There are no universal training requirements for programmers because employers' needs are so varied. Computer applications have become so widespread that computer programming is taught at most public and private vocational schools, community and junior colleges, and universities. Although some programmers obtain two-year degrees or certificates, bachelor's degrees are now commonly required. In the absence of a degree, substantial specialized experience or expertise may be needed.

The majority of programmers hold a four-year degree. Of these, some hold a B.A. or B.S. in computer science or information systems while others have taken special courses in computer programming to supplement their study in fields such as accounting, inventory control, or other business areas. College graduates who are interested in changing careers or developing an area of expertise may return to a junior college or technical school for more training.

Employers using computers for scientific or engineering applications prefer college graduates who have degrees in computer or information science, mathematics, engineering, or the physical sciences. Graduate degrees are required for some jobs. Employers who use computers for business applications prefer to hire people who have had college courses in management information systems (MIS) and business, and who possess strong programming skills. Knowledge of FORTRAN, COBOL, C, Fourth Generation Languages (4GL), CASE tools, systems programming, C++, Smalltalk, and other object oriented programming languages is highly desirable. General business skills and experience related to the operations of the firm are preferred by employers as well.

Most systems programmers hold a four-year degree in computer science. Extensive knowledge of a variety of operating systems is essential. This includes being able to configure the operating system to work with different types of hardware, and adapting the operating system to best meet the needs of the particular organization. They also must be able to work with database systems such as DB2, Oracle, or Sybase.

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Training, Other Qualifications, and Advancement—continued

Computer Scientists and Engineers, and Systems Analysts

There is no universally accepted way to prepare for a job as a computer professional because employers' preferences depend on the work to be done. Prior work experience is very important. Many people develop advanced computer skills in other occupations in which they work extensively with computers and then transfer into computer occupations. For example, an accountant may become a systems analyst specializing in accounting systems development, or an individual may move into a systems analyst job after working as a computer programmer.

Employers almost always seek college graduates for computer professional positions; for some of the more complex jobs, persons with graduate degrees are preferred. Generally, a Ph.D., or at least a master's degree in computer science or engineering, is required for computer scientist jobs in research laboratories or academic institutions. Some computer scientists are able to gain sufficient experience for this type of position with only a bachelor's degree, but this is difficult. Computer engineers generally require a bachelor's degree in computer engineering, electrical engineering, or math.

For systems analysts, many employers seek applicants who have a bachelor's degree in computer science, information science, computer information systems, or data processing. Regardless of college major, employers generally look for people who are familiar with programming languages and have broad knowledge of and experience with computer systems and technologies. Courses in computer programming or systems design offer good preparation for a job in this field. For jobs in a business environment, employers usually want systems analysts to have a background in business management or a closely related field, while a background in the physical sciences, applied mathematics, or engineering is preferred for work in scientifically oriented organizations.

Technological advances come so rapidly in the computer field that continuous study is necessary to keep skills up to date. Continuing education is usually offered by employers, hardware and software vendors, colleges and universities, or private training institutions. Additional training may come from professional development seminars offered by professional computing societies.

Source: Bureau of Labor Statistics, U.S. Department of Labor

year degree-granting universities. These include:

- two-year associate-degree-granting community colleges which provide grounding in applications (especially in new computer programs and hot areas such as "the year 2000 problem) as well as basic theory, and vocational technical education programs
- special university/community college one-year programs designed to upgrade the skills of IT workers already in the work force (new applications) or those with backgrounds in other technical fields who are looking for a fast track entry into the IT profession
- private-sector computer learning centers which typically offer courses to people with little or no computer background who are interested in discovering whether they have the aptitude to make it in the computer-related professions
- in-house company training to upgrade employee skills (e.g. client/server-based tools and architectures, C++ and Visual Basic) or to assist in the transition from one skill set (e.g. computer hardware engineers) to another (e.g. computer software engineers)
- computer user groups, Internet forums, and company-sponsored help sites also offer knowledge that can help expand or update computer skills

In addition to those earning four-year degrees in computer and information sciences, in 1994, 15,187 degrees and awards in computer and information sciences below the bachelors level were earned.

Offshore Sourcing and Recruiting

Some companies are drawing upon talent pools outside the United States to meet their demands for IT workers. India, with more than 200,000 programmers, in conjunction with predominantly U.S. partners, has developed into one of the world's largest exporters of software. In 1996-97, outsourced software development accounted for 41 percent of India's software exports. Companies are also searching for IT workers in foreign labor markets--in Russia, Eastern Europe, East Asia, and South Africa--using direct recruiting efforts, Internet techniques, and international recruiting agencies.[11]

The Global Shortage of IT Workers

As in the United States, data limitations make it difficult to assess and compare the supply and demand for IT workers in foreign countries. Nevertheless, executive surveys and anecdotal evidence suggest that IT workers are in increasingly short supply in other countries as well.

A survey of some 1,500 chief information officers (CIOs) in 21 countries, conducted by Deloitte and Touche Consulting Group, suggests that IT managers throughout the world are experiencing a difficult combination of unprecedented demand for IT workers and high turnover rates. According to the survey, companies are finding it especially difficult to retain employees in four key areas—client/server architecture, data modeling, distributed databases, and particular packaged software applications such as SAP. Turnover rates in these areas range from 35 to 45 percent.

In the advanced industrial economies, strong growth rates in the IT sector continue to propel demand for IT workers. Canada's IT sector has been growing by 10 percent annually; estimates of the shortfall in IT employees range from 20,000 to 30,000. Given Canada's proximity and relatively high level of integration with the United States, U.S. firms often can recruit Canadian IT workers by offering more generous compensation packages than are available locally. While Canadian universities have not experienced a sharp drop in computer science enrollment, the Canadian government has responded to the increased demand for IT workers through several channels: it established the Software Human Resources Council to help develop the IT workforce; improved immigration policies; and encouraged universities to augment standard degree programs with 3 to 9 month IT training programs.

In some developing economies, IT-based economic growth strategies, combined with other sources of demand for IT workers, may overwhelm the supply of skilled personnel. In India, for example, the software industry has been growing at over 40 percent per year. Exports account for approximately half of the industry's revenues, due in large part to the outsourcing activities of U.S.-based software companies. Given the country's skilled workforce, high quality standards, relatively low labor costs, widespread use of English, and available communication links, India is a particularly attractive outsourcing site for Western software companies. In addition, the Indian government has implemented a variety of programs and policies designed to expand the country's software industry, largely through Software Technology Parks of India (STPI).

Although various institutions are producing 55,000 students annually, India's highly skilled software professionals—numbering approximately 160,000 in 1996-1997—are not expected to keep pace with the country's rapidly growing software industry. The country's large software firms are attempting to solve the problem through internal training and education programs, combined with support from the country's universities, colleges, and private educational institutions. In addition, the industry's main trade association, the National Association of Software and Service Companies (NASSCOM), established the Institute of Computer Software Professionals of India (ICSPI) to assist with the problem.

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Global Shortage—continued

In other countries, local IT development strategies alone are creating a gap between the supply and demand for skilled IT professionals. Malaysia's long-term economic development strategy relies heavily on creating a "multimedia super corridor" (MSC),a 9 by 30 mile IT center that is expected to lead the country to a new level of economic and technological development. Through tax breaks and other investment-related incentives, the Malaysian government is actively seeking to attract foreign IT firms. However, these efforts may outstrip the supply of skilled personnel: Malaysia's universities are producing less than 6,000 IT engineers per year, far fewer than the estimated annual demand of 10,000. In addition, many skilled workers have been seeking higher wages in countries like Singapore. To address the problem, the Malaysian government has included a university within its MSC plan, is exploring university-industry partnerships to train workers outside of the college track, and is seeking to reduce any barriers to hiring foreign workers. Indeed, comparative economic developing studies suggest the importance of education, training, and skill flexibility for countries, like Malaysia, that are pursuing IT-based economic development trajectories.

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IV. COMPETITIVENESS ISSUES

Information technologies are the most important enabling technologies in the economy today. They affect every sector and industry in the United States, in terms of digitally-based products, services, and production and work processes. Thus, severe shortages of workers who can apply and use information technologies could undermine U.S. innovation, productivity, and competitiveness in world markets.

Productivity and the Cost of Doing Business

Competitive pressures have driven businesses to adopt a wide range of computer systems to improve productivity, manage production, improve both internal and external communications and to offer customers new services. Private sector investment in enterprise-wide applications alone was estimated to be $42 billion in 1996.[12] The service sector, now representing 70 percent of U.S. GDP, is increasingly information technology intensive. Manufacturing also relies heavily on information technology from computer aided design and computer numerically controlled machine tools to computer-based systems for inventory control, production planning, and statistical process control. In short, computer-based information systems have become an indispensable part of managing information, workflow, and transactions in both the public and private sector. Therefore, a shortage of IT workers affects directly the ability to develop and implement systems that a wide variety of users need to enhance their performance and control costs. A recent survey by Deloitte & Touche Consulting reported that worker shortages are causing many companies to delay information technology projects.

As competition for IT workers heats up, rising salary levels increase the cost of doing business. For example, Electronic Data Systems Corp. (EDS) recently reported that IT worker shortages have contributed to pushing workers' compensation up by 15 to 20 percent annually. The company reported in April 1997 that it may reduce its work force by thousands to cut labor costs and maintain profits. Many computer companies faced with rising labor costs have passed those increases along to their customers. However, EDS and similar companies rely on long-term fixed contracts to develop and manage large computer systems and have less flexibility to pass increased costs to customers.[13]

Shortage-driven increases in salaries for both skilled IT managers and IT workers also increase the amount of venture capital investment required by start-up companies in information technology-related businesses. For example, new software technology start-ups—which have benefitted substantially from private venture capital and are IT worker-intensive—could require greater venture capital investment in the future to cover salary costs. These rising labor

costs could result in venture capital seeking growth opportunities elsewhere, constraining the emergence and growth of many promising new companies.

Government and non-profit organizations may increasingly be squeezed out of the competition for IT talent. For example, while average starting salaries for graduates with bachelor's degrees in computer engineering grew to more than $34,000 in 1995, the Federal government's entry level salary for computer professionals with bachelor's degrees ranged from about $18,700 to $23,200 that year. The Department of Defense is already having difficulty retaining IT employees; it appears industry is offering them more attractive compensation packages. The U.S. Air Force Communications Agency reports a loss rate of 42 to 45 percent of systems administrators from 1993-1995.

Industry Growth

High-tech industries, particularly leading-edge electronics and information technology industries, are driving economic growth not only in the United States but around the world. According to industry estimates, the markets for computer and communications hardware and services, and for software have grown to one trillion dollars.[14] With the current annual growth rate estimated at 10 percent, the global market for these products and services may be growing by $100 billion annually. These industries are IT worker intensive and shortages of critical skills would inhibit their performance and growth potential.

In the ITAA survey, 50 percent of the information technology company executives cited lack of skilled/trained workers as "the most significant barrier" to their companies' growth during the next year-a problem viewed as significantly greater than economic conditions, profitability, lack of capital investment, taxes, or regulation. An additional 20 percent of the IT company executives identified the shortage of these workers as "a barrier" to their companies' growth during the next year.

Innovation

The United States is a leader in the development of new products and services, and many important consumer and industrial innovations-from computers, consumer electronic products, and telecommunications services to automotive electronics, aerospace products, and advanced industrial systems-have been made possible by information technologies. Information technologies are expected to continue to form the basis of many of the most important products, services, and processes of the future. For example, it is expected that in less than a decade, electronics will account for about one-fifth of an automobile's value.[15] Shortages of IT workers could inhibit the nation's ability to develop leading-edge products and services, and raise their costs which, in turn, would reduce U.S. competitiveness and constrain economic growth.

Trade

The shortage of IT workers could undermine U.S. performance in global markets. The global market for computer software and computer services reached $277 billion in 1994. The United States is both the predominant supplier of and the primary consumer for these goods and services.[16] Ranked in terms of global market share in 1994, eight of the world's top ten applications software vendors and seven of the top ten systems software vendors are U.S. firms. Both of these markets are growing rapidly, with the computer software market growing 12 percent annually, and the computer services market growing 11 percent annually, reaching $420 billion by 1998, a 50 percent increase just between 1994 and 1998. Aerospace, another IT worker intensive industry is also a global market leader for the United States, and is the Nation's leading net exporter of manufactured goods. An adequate supply of IT workers is essential to America's continued strength in these markets.

High-Wage Jobs

A shortage of qualified IT workers could also prevent the United States from taking full advantage of high-wage job creation. Many information technology jobs are high-wage jobs. Workers in the software industry earn more than twice the national average. A William M. Mercer compensation study shows that the average hourly compensation† in 1996 for an intermediate customer support technician was $40.80; software development architect, $77.70; operating systems software architect/consultant, $85.60, and operating systems/software programming analyst manager, $92.20. Even if shortages ease and upward pressure on salaries is reduced, the IT professions have traditionally been high-wage jobs.

† Note: The text in the paragraph above appears as originally published. The figures, however, are actually "average **annual** compensation," not "average **hourly** compensation."

V. FACTORS AFFECTING THE SUPPLY OF INFORMATION TECHNOLOGY WORKERS

A number of factors may contribute to constraints in the supply of IT workers with the skills employers want.

Underlying Causes of Decline in Computer and Information Sciences Degrees

A number of reasons have been offered for the declining number of U.S. students entering and earning degrees in computer and information sciences (a 42 percent decrease between 1986 and 1994):

- despite rapid gains in the last decade, only about half of all high school graduates complete algebra II or chemistry, which are prerequisites for college mathematics and science;[17]
- defense industry cutbacks and corporate downsizing have left many students with the impression that there are fewer job opportunities in the computer field;[18]
- many students believe that universities do not provide proper training for the marketplace, particularly with respect to understanding the software development process in an industrial setting;[19] and
- on-the-job training is increasingly substituting for formal four-year university education in computer science.[20]

It should be noted that computer science is not a particularly popular choice of academic study. Only 1.1 percent of women and 3.3 percent of men earning bachelor's degrees in 1994 earned them in computer science.

Mismatches between what universities teach and what industry needs

While workers with degrees from two- and four-year computer science programs are attractive to potential employers, many employers have found some skill sets lacking in many of these graduates. For example, graduates may be superb computer theorists, but employers are looking for IT workers skilled in networking/distributed computer environments and large software projects, who have real world experience, and who are capable in business and industrial settings.

Industry Practices and Expectations

Information technology is advancing rapidly, causing frequent changes in skill requirements. A decade ago, the Internet was a tool used mostly by researchers at American universities. Today the Internet and the World Wide Web are information tools for the masses, which

has driven up the demand for skills needed to create and support on-line information services.[21] According to one estimate, 760,000 persons are now working at Internet-related companies.[22]

Even within established segments of the software discipline, such as software programming, change is rapid. Software market leaders constantly update their programs used in a wide range of work place applications, causing employers to demand that new hires have the latest skills.[23]

A critical factor affecting the IT labor market is the volatility introduced into a company's work stream by the appearance of new versions of software products in shorter cycle times — in some cases every six months. Some have suggested that this rapid change in software leads companies to unrealistic expectations on potential hires, as well as on their own staff in terms of keeping their skills up-to-date.[24] Companies may advertise positions as requiring specific skills sets, even before training on the new software is generally available. They may also recruit on the basis of computer program-specific skills, rather than looking more broadly at applicants' basic understanding of computing concepts, experience with programming, and ability to learn new technologies.

In addition, businesses often define skill sets for IT jobs very narrowly-for example, skill in a specific programming language-but developers of computing technologies come from a wide variety of backgrounds, including electrical engineering and the humanities. Electrical engineers led the way in the development of computer graphics. Linguists and electrical engineers built the first machine translation and speech understanding and production systems.

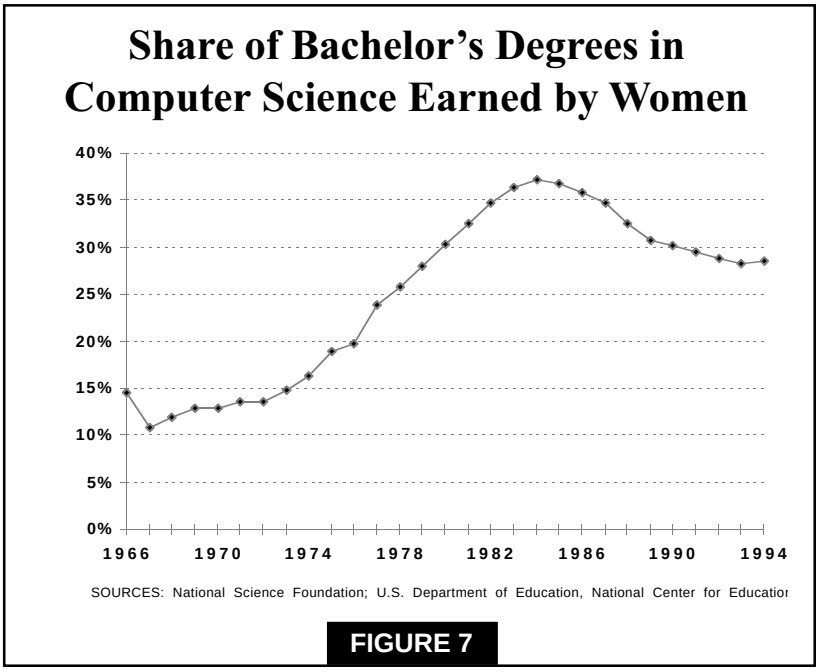
The Need to Retrain Workers

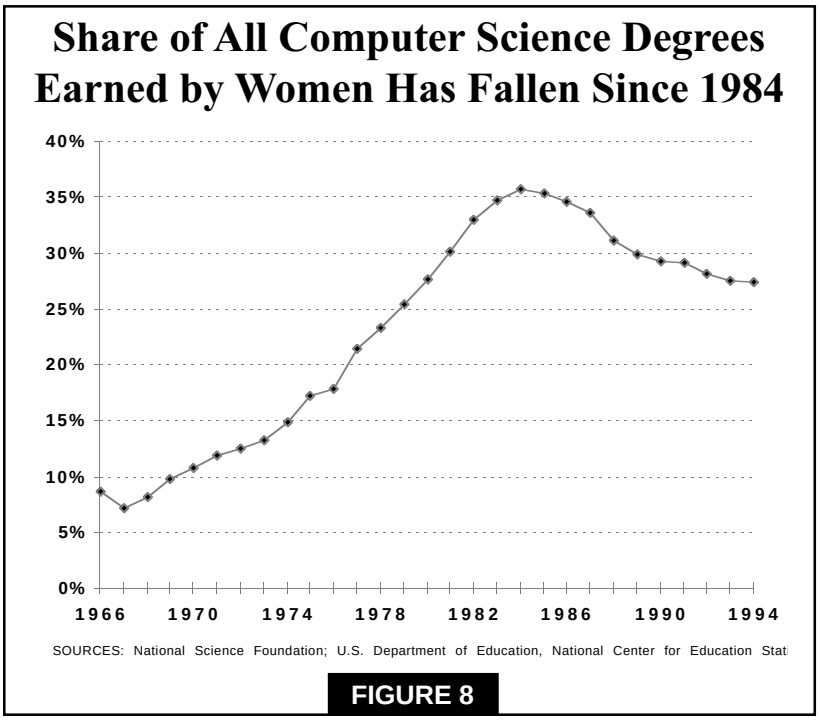
Many of the unfilled IT jobs such as managerial positions, require specific skills and significant experience. Retraining existing employees could play an important role in meeting the growing skills needs of companies. Some suggest that companies play a larger role in cultivating and updating information technology skills among their employees.[25]

ITAA does note, and anecdotal evidence confirms, that most IT companies provide training to their IT employees.[26] However, highly trained workers can easily leave an employer after receiving extensive and expensive training and, in a tightening labor market, they frequently do. Nevertheless, while upgrading the skills of existing employees is important for companies seeking to meet their needs for skilled IT workers, employer provided training alone is unlikely to satisfy the increasing demand.[27]

Underrepresentation of Women and Minorities in the Computer Science Education Pipeline

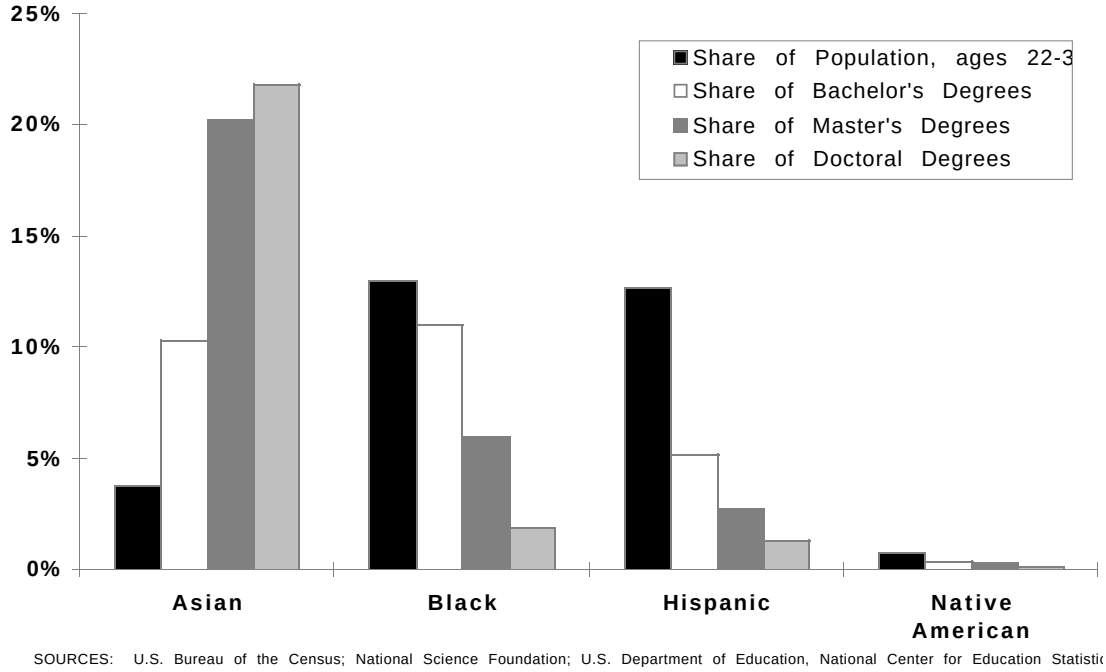
Women and some minorities are underrepresented in the computer and information sciences education pipeline. Women—who comprise 51 percent of the population and earn more than half of all bachelor-level degrees awarded—earn about one-quarter of the bachelor-level computer and information sciences degrees awarded by U.S. academic institutions [Figure 7]. More disturbing is the trend line: the share of all computer science degrees awarded to women in the United States has fallen steadily from a peak of 35.8 percent in 1984, to only 27.5 percent in 1994—the lowest level since 1979 [Figure 8].[28] This trend, coupled with the dramatic downturn in the number of computer science degrees awarded, has cut the number of women receiving bachelor's degrees in computer science by more than half, from a high of 15,126 in 1986 to 7,020 in 1994. In 1994, men were three times more likely to choose computer science as a field of study than women.





African-Americans, Native Americans and Hispanics are also underrepresented in computer science education [Figure 9], though the share of degrees in these fields received by each of these groups has climbed substantially since 1977. These groups also are underrepresented in higher

Distribution of Degrees in Computer Science by Race and Ethnic Heritage



SOURCES: U.S. Bureau of the Census; National Science Foundation; U.S. Department of Education, National Center for Education Statistic

FIGURE 9

education generally. Comparing the number of bachelor's, master's, and doctoral degrees granted in 1994 to students of each race and ethnic group to their share of the U.S. population of 22-30 year olds, we found the percentage earned by Whites (5.2 percent) and Asians (5.5 percent) to be significantly higher than Native Americans (2.9 percent), African-Americans (2.4 percent), and Hispanics (1.4 percent). Nevertheless, Asians, African-Americans, and Hispanics who earn bachelor's degrees choose computer science as a field of study at higher rates than White and Native American students [Figure 10].

Computer Science Selection Rate, by Race

	All Bachelor's Degrees	Bachelor's Degrees in Computer Science	Percent Choosing Computer Science
White	947,309	20,503	2.2%
Asian	51,463	3,592	7.0%
Black	77,872	2,773	3.6%
Hispanic	45,376	1,311	2.9%
Native American	5,671	97	1.7%

SOURCES: National Science Foundation; U.S. Department of Education, National Center for Education Statistics

FIGURE 10

Efforts are underway in both the private and public sectors to increase women's and minorities' participation in technical fields. The National Science Foundation sponsors programs to encourage minorities and women to enter the fields of science and technology. Professional organizations also support such efforts. Members of the Association of Women in Computing, for example, participate in a National Science Foundation sponsored telementoring program aimed at encouraging young women to enter technical fields.

Limitations on Immigration of Skilled Workers

A number of U.S. companies have resorted to recruiting foreign nationals to fill skilled information technology jobs. Under the H-1B non-immigrant category of U.S. immigration law, 65,000 professional foreign workers may be sponsored by U.S. employers each year. These foreign workers must have a professional undergraduate degree or substantial work experience, and may work in the United States for six years.[29]

Some companies and industry representatives believe the current cap is too restrictive and have expressed concerns about proposals to make it more difficult or costly to recruit foreign workers. They say foreign nationals are needed to fill open IT jobs and, unless they can hire more foreign workers, they may move some of their operations to locations outside of the United States where labor markets are believed to be less tight.[30]

Some professional engineering societies believe the shortage of IT workers is exaggerated. They fear that easing visa restrictions would create an over supply of IT workers, which could eventually lead to layoffs. The Institute of Electrical and Electronics Engineers (IEEE) has questioned the IT industry's contention. IEEE suggests the shortage is a skills mismatch created by rapidly changing technology and the difficulty of keeping worker skills up-to-date to keep pace. IEEE advocates a focus on retraining the current work force, including engineers laid off in defense downsizing.[31]

Regardless of which view is correct, the emergence of a world-wide shortage of IT workers indicates that U.S. employers cannot rely on increased immigration or even outsourcing to foreign countries to meet any significant IT skill shortages. Instead, the United States—as well as other industrialized countries— will be forced to rely increasingly on policies and strategies directed at educating, training, and retraining their domestic work forces in IT skills.

VI. CURRENT RESPONSES TO THE SHORTAGE

Companies, universities and governments are taking steps to increase the U.S. supply of adequately trained IT workers. For example, Senator John Warner recently introduced a bill to establish a federal commission to recommend ways to increase the U.S. pool of IT workers.

Industry Responses

Since there has been no comprehensive, systematic survey of industry responses to the tightening IT labor market, much of the information on how U.S. industry has adapted to meet its needs is anecdotal. Based on this information, it appears that companies are pursuing aggressive recruitment strategies to fill their IT slots. This includes attracting top performers from other companies.[32] Others pay bonuses to their employees who provide hiring leads.[33] Still others attract employees with signing bonuses of $2,000-$3,000 or more.[34] Stock options in the signing package are becoming routine.[35] Other carrots designed to attract workers include flexible work hours, telecommuting, day care centers, and on-site health clubs. Companies are also expanding their recruiting to other parts of the world such as Russia, Eastern Europe, East Asia, and South Africa.[36]

Companies are also finding ways to overcome the decline in graduates with university computer science degrees. Some hire graduates from other academic disciplines and provide training in computer skills.[37] Similarly, other companies have found the practice of retraining existing staff to be sufficient in fulfilling their IT skill requirements. Many employees with no prior background and skills in computing are able to learn and apply new information technologies.

Companies are broadening their approach to recruiting from colleges and universities. Students at less prominent schools are sought out. Job offers are made as early as a year before graduation. Firms hope that student internships will pave the way to full-time employment, and provide future job candidates with real world experience.

Companies are tapping foreign pools of skilled labor, recruiting foreign nationals and outsourcing more work to contractors in other parts of the world.[38] Geographic location is an insignificant barrier since development of software products does not require that various members of the development team be in one location. By taking advantage of the Internet, electronic blackboard technologies, and videoconferencing, some companies are able to manage teams around the globe that collaborate on projects, sometimes around the clock.

Public Private Partnerships

Public-private partnerships have been forged to help ensure that more workers will be equipped with information technology-related skills. Most have focused on revamping the U.S. educational system to reflect the changing needs of industry. *Industry's Role in the Reform of Mathematics, Science and Technology Education* is one publication that resulted from such an effort by the Triangle Coalition for Science and Technology, a partnership among business, education, engineering, industry, and science and technology-related organizations that work both nationally and locally to improve science, mathematics, and technical education.[39] The ITAA has proposed that the current education paradigm be examined with an eye toward the knowledge-based economy, both by the education community and the employers of IT workers.[40]

There is some evidence that a new paradigm is emerging. For example, a committee composed of the Association of IS Professionals, the Association for Computing, and the Association for Information Systems developed an Information Systems (IS) model curriculum to enhance the ability of the U.S. educational system to meet the needs of employers. The curriculum is designed to equip students with a strong mix of computing, business, and communications skills, and includes classes on computer languages. It is being implemented by the University of Minnesota's Carlson School of Management.[41]

Similarly, companies are forming partnerships with community colleges to develop curricula that are more reflective of industry's needs, especially the need for information technology-related skills.[42] Also, community colleges are working closely with employers in retraining efforts for current employees. Broome Community College in upstate New York, for example, is working with local companies to provide appropriate training to upgrade the skills of the current work force.[43]

The Software Publishers Association has encouraged the principal stakeholders--Federal, state, and local governments, as well as the private and nonprofit sectors--to assume responsibility for producing a world-class, Information Age work force.[44] They advocate the reengineering of K-12 public education, a process that has already started. Many companies, driven by the need to ensure a talent pool from which to draw in the future, have formed strategic partnerships with the schools to improve science and mathematics education at the K-12 levels. Some companies are offering their own in-house expertise and resources to help teachers and students sharpen such skills. For example, in July of 1997, Boeing sponsored a Space Academy for Educators aimed at helping teachers inspire and motivate students in mathematics and science.[45] Since 1992, Boeing has also conducted a Discover Engineering Summer Science Camp in which several hundred children take part in "hands-on" science, mathematics and engineering workshops taught by Boeing engineers.[46]

Professional organizations are also involved in supporting science and technology education in the schools. Since 1979, the New York Academy of Sciences' Education Department has worked to enrich and improve mathematics, science and technology education in New York City. The American Association for the Advancement of Science (AAAS) sponsors a grassroots program, called Project 2061, designed to improve science education programs in American schools. This project has developed books, CD-ROMs, and on-line tools to assist teachers in making all high school graduates science literate.[47]

Regional Cooperation

Regional cooperation is also being forged to address IT worker shortages in certain geographic areas. In the metropolitan Washington, D.C. area, representatives of regional business groups, area universities and the technology councils of Northern Virginia, suburban Maryland, and Baltimore are establishing an alliance to address the area's shortage of workers with information technology skills.[48]

Federal Initiatives to Raise the Technical Skills of the American Work Force

Technology has fundamentally changed the skills Americans need to flourish in the world of work. For example, most work places rely heavily on computer and telecommunications technologies. The Clinton Administration has promoted policies and programs to help prepare today's and tomorrow's work force for a technology-intensive, 21st century economy.

Mathematics and Science Education. Technical skills are built on a foundation of mathematics and science education that begins in a student's early years. The Goals 2000 Educate American Act of 1994—designed to raise U.S. students' competencies—set an ambitious national goal: "U.S. students will be first in the world in science and mathematics achievement." While much of the responsibility for achieving this goal rests with school systems at the state and local levels, the Federal government plays a role in encouraging improvements. Federal investments for improvements in mathematics and science education at the pre K-12 education levels focus on enhancing teacher skills, improving science and mathematics curricula, promoting system reforms, and other areas.

The Federal government also works as a catalyst to inject new vitality into U.S. undergraduate science, mathematics, engineering, and technology education by investing in organizational reform, faculty enhancement, curriculum improvement programs, and student support. The Federal government is also a major supporter of graduate education, financing fellowships and traineeships in pre- and post-doctoral programs. Federal research grants also support graduate students by providing funds for assistantships.

Opening the Doors to College. Over half of the new jobs created in the last three years require higher-level skills and training beyond what a high school diploma affords. To help prepare Americans for such jobs, the President set a goal of making two years of college—the 13th and 14th years of education—as universal for young Americans as the first 12 are today. To support this goal, the President initiated a strategy to make college more accessible and affordable. With Hope Scholarships, for students in the first two years of college, most taxpayers will be eligible for a tax credit equal to 100 percent of the first $1,000 of tuition and fees and 50 percent of the second $1,000. With the Lifetime Learning Credit, for those beyond the first two years of college or taking classes part-time to upgrade their job skills, most families will receive a 20 percent tax credit for the first $5,000 of tuition and fees through 2002, and for the first $10,000 thereafter.

School-to-Work Opportunities. The School to Work Opportunities Initiative is serving as the catalyst for the creation of state and local systems to better prepare all students for college and careers. School-to-Work funding is being used to create systems that integrate academic and vocational learning, expose students to a range of career possibilities, expand opportunities for students to engage in internships or other work experiences, and forge links between high schools and post-secondary education institutions.

(continued on next page)

Federal Initiatives—continued

Technological Literacy. Today, technological literacy—the ability to use computers and other technology to improve learning, productivity, and performance—is a new basic that our students must master. Yet, American schools are not prepared for the technological era. About half of all teachers have little or no experience with technology in the classroom. Only 4 percent of schools have a computer for every five students—a ratio that allows regular use by each student. Only 9 percent of classrooms have connections to the Internet.

In 1995, President Clinton challenged the Nation's parents, teachers, and government, community, and business leaders to work together to ensure that all children in American are technologically literate by the dawn of the 21st century. Four goals guide the technology literacy agenda:

1. Connect every school and classroom in America to the information superhighway.
2. Provide access to modern computers for all teachers and students.
3. Develop effective and engaging software and on-line learning resources as an integral part of the school curriculum.
4. Provide all teachers the training and support they need to help students learn through computers and the information superhighway.

America's Technology Literacy Challenge: In his 1996 State of the Union Address, President Clinton asked Congress to fund a $2 billion, five-year Technology Literacy Challenge to catalyze state, local and private sector partnerships in each state to achieve the four educational technology goals. Congress supported the President's request for first-year funding and appropriated $200 million for grants to states to launch this challenge.

The Technology Innovation Challenge Grants: This component of the technology literacy challenge invites school systems, colleges, universities, and private businesses to form partnerships to development creative new ways to use technology for learning. Each Federal dollar is matched by more than 3 to 1 by local and private funds.

Universal and Affordable Access to Advanced Telecommunications: The Telecommunications Act of 1996 states that schools and libraries should have affordable access to telecommunications services for educational purposes. In May 1997, the Federal Communications Commission released a Report and Order on Universal Service which makes most elementary and secondary schools eligible for discounts ranging from 20 to 90 percent on all commercially available telecommunications services, Internet access, and internal connections.

TIIAP: The U.S. Department of Commerce's Telecommunications and Information Infrastructure Assistant Program is merit-based and provides matching grants to nonprofit organizations such as schools and libraries. The grants are used to purchase equipment for connection to networks, including computers, video conference systems, network routers, and telephones; to buy software for organizing and processing information; to train staff, users, and others in the use of equipment and software; and to purchase Internet access.

VII. SUMMARY AND FURTHER ACTIONS

Just a few years ago, Java was coffee, C was a passing grade, and web masters had eight legs. Today, experts in Java computing and C programming command a premium in the labor market, and an army of human web masters keeps information updated on the rapidly expanding World Wide Web. The labor market for IT workers is expanding and shifting rapidly, driven by the unrelenting advancement and diffusion of information technology. New skills are constantly in demand, and IT occupations are evolving in new directions. As a result, employers are having difficulty obtaining the numbers of adequately trained IT workers they need.

The United States has much at stake in ensuring an adequate supply of IT workers; severe shortages would compromise organizational productivity and the Nation's ability to develop leading-edge products and services, as well as the growth and global competitiveness of important U.S. industries.

In a tight labor market, employers are resorting to a number of strategies to fulfill their IT skill needs, such as aggressive recruiting programs that include financial and quality of working life sweeteners, tapping foreign sources of labor, retraining existing staff in IT skills, and forming partnerships with the academic community to expand the pool of IT workers.

As the Office of Technology Policy worked to develop this snapshot of a rapidly moving situation, we found the information and data inadequate to completely characterize the dynamics of the IT labor market. For example, information is lacking on the supply of IT workers flowing from employer provided training and from academic programs other than computer and information sciences, both believed to be important training grounds for the U.S. IT work force.

Improving our understanding of one of the country's most critical labor markets is an important goal for the United States. Accurate and timely information is essential for the efficient functioning of labor markets-for potential employees who need to know where the jobs are and what skills are needed, for employers who need to identify and recruit highly trained workers, and for the educators and trainers who are responsible for work force development.

A Need for Better Indicators and Statistics

Better information about where computer and information science graduates go, what kind of jobs they find, and what skills they need in those jobs would help educators do a better job of curriculum development and career counseling, and provide students with a roadmap for plotting their educational and career paths.[49] The report, *Leading, Concurrent, or Lagging: The Knowledge Content of Computer Science in Higher Education and the Labor Market*, released by the U.S. Department of Education and the National Institute for Science Education in May of 1997, is a step towards making such information widely known.

In addition, since information technology continues to play an ever increasing role in global competition and economic growth, there may be a need to develop new economic indicators that relate to the information technology-related production, capacity, and evolutionary stage of advanced and industrializing countries that would provide a new view of each country's current competitive position and potential.[50]

The Need for a Better Understanding of Linkages

More data is needed on linkages between engineering, science and technology education and training, and work place needs. The National Science Foundation recently published a report, based on surveys of technical education in two year colleges, which begins to document linkages between their programs and local businesses. Such analysis could be extended to four-year degree granting universities.

The Need To Better Understand the IT Training Industry

Many IT workers currently obtain their skills through a rapidly emerging IT training industry that has developed largely outside the formal educational system. More data is needed on the structure of this IT training industry, how it responds to rapidly changing technology, what the costs are to obtain significant IT skills, and whether workers interested in obtaining such training are able to obtain the financial assistance through existing student aid programs.

The Need For Stakeholder Partnerships

A number of stakeholders from industry and the academic community have begun to address the need to increase the supply of highly skilled IT workers. However, a broader range of public-private partnerships at both the national and regional levels may be needed to erase any long-term shortages of critical IT skills that would constrain business and organizational performance, the ability of Americans to fill high-wage jobs, and growth of the U.S. economy.

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