Chapter 1
The Supply of IT Workers in the United States

William Aspray and Peter A. Freeman

Technology Everywhere
A Campus Agenda for Educating and Managing Workers in the Digital Age

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What is the nature of information technology (IT) workers? Where do they come from? What are some of the political and economic factors and supply issues that are most relevant to an educational institution? The breadth and depth of the higher education system in the United States makes it impossible in this brief chapter to do more than offer a broad sketch of the supply of IT workers in the United States. Yet our experience has been that even a modicum of scholarly rigor can serve to clarify many important discussions that otherwise seem to bog down.

What Is an IT Worker?

In answering the question of what an IT worker is, there are three definitional types to consider: labor-category, skill-set, and work-related.

A *labor-category* definition, such as those used by the U.S. Bureau of Labor Statistics, is necessary for comparison, regulatory purposes, devising specific training programs, and so on. However, the Standard Occupational Categories (SOC) currently used by the BLS are essentially a distillation of job titles, an increasingly out-of-date and inaccurate reflection of what people do or the skills they need. Thus we believe this type of definition, in general, is deeply flawed for understanding strategic issues and for planning.

A *skill-set* definition (what should a worker of type X be able to do?) is obviously useful in devising a training program and helpful in some ways in building or modifying a broader educational program. There is some obvious overlap between skill-set definition and labor-category definition, which is one thing that reduces the broad usefulness of the former. The biggest impediment in our opinion is that it is generally impossible to predict in detail what skill sets will be needed in the future—even next year.

We took the *work-related* approach in a Computing Research Association (CRA) study three years ago (Freeman and Aspray, 1999), returning to basics and looking at the fundamentals of what people are *doing* in their work, independent of the job title or skill set. This permitted us to consider strategic questions much more easily. A recent National Research Council study (Committee on Workforce Needs in Information Technology, 2000) also gave some consideration to fundamentals, but to be able to consider federal data in detail, it basically used a labor-category approach.

Our CRA study report presents a discussion of these definitional types and some previous attempts to define IT workers and then proposes a work-related definition. We extract liberally from that report in the discussion that follows.

A Four-Category Approach (CRA Study)

There are two categorizations that can help with planning and estimation. The first distinguishes IT workers from other kinds who may sometimes use information technology in their jobs. In Figure 1.1, each IT-related occupation is located at a single point on the graph. As one moves from left to right, the occupations require an increasing amount of IT knowledge. As one moves from bottom to top, the occupations require an increasing amount of domain knowledge (knowledge of business practice, industry practice, technical practice, or other kind of knowledge particular to an application domain). The diagonal line separates the IT-related occupations into two classes, depending on whether IT knowledge or domain knowledge is more important. If more than half the value provided by a worker involves his or her IT knowledge, then this person is considered to be an *IT worker.* If the person's occupation involves using information technology but it contributes less than half the value added to the work, then we regard the person as an *IT-enabled worker.* A few occupations are plotted on the figure as examples.

The second categorization focuses only on the IT workers. Exhibit 1.1 differentiates four categories of IT worker, depending on the principal functionality in the occupation. The exhibit includes examples of particular IT occupations that fall under each category: conceptualizers, developers, modifiers/extenders, and supporters/tenders.

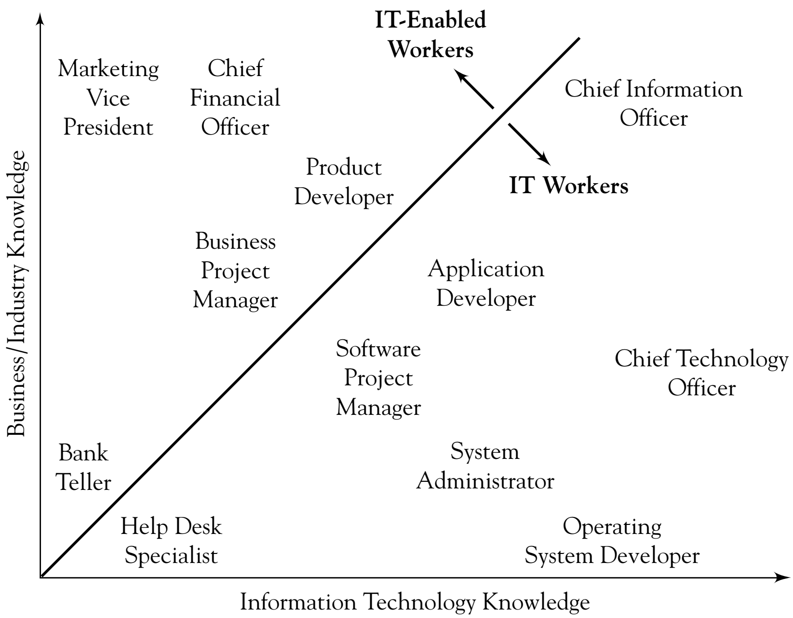

Figure 1.1. Distinguishing IT Workers from IT-Enabled Workers

Source: Computing Research Association, Intersociety Study Group on Information Technology Workers, published in Freeman and Aspray, 1999.

Exhibit 1.1. Categorization of IT Jobs

Conceptualizers are those who conceive of and sketch out the basic nature of a computer system artifact:
- Entrepreneur
- Product designer
- Research engineer
- Systems analyst
- Computer science researcher
- Requirements analyst
- System architect

Developers are those who work on specifying, designing, constructing, and testing an information technology artifact:
- System designer
- Programmer
- Software engineer
- Tester
- Computer engineer
- Microprocessor designer
- Chip designer

Modifiers/extenders are those who modify or add on to an information technology artifact:
- Maintenance programmer
- Programmer
- Software engineer
- Computer engineer
- Database administrator

Supporters/tenders are those who deliver, install, operate, maintain, or repair an information technology artifact:
- System consultant
- Customer support specialist
- Help desk specialist
- Hardware maintenance specialist
- Network installer
- Network administrator

Source: Computing Research Association, Intersociety Study Group on Information Technology Workers, published in Freeman and Aspray, 1999.

The categorization is built from a developmental perspective of the world. It is based on experience and familiarity with the IT industry, where the workers are responsible for creating IT artifacts. However, this categorization applies reasonably well to all kinds of IT worker in all sectors of the economy, including universities.

We believe there is a reasonably good match between level of formal education and category of worker. Table 1.1 maps formal education onto the four categories. There is no exact one-to-one

Table 1.1. Typical Educational Preparation for IT Jobs

	Highest Degree Attained				
	High School Diploma	Associate Degree	Bachelor's Degree	Master's Degree	Doctorate
Conceptualizers	✓	✓	✔	✔	✔
Developers			✔	✔	✓
Modifiers		✓	✔	✔	✓
Supporters	✓	✔	✔		

Note: Blank cell = unlikely; ✓ = occasional; ✔ = common; ✔ = frequent.

Source: Computing Research Association, Intersociety Study Group on Information Technology Workers, published in Freeman and Aspray, 1999.

correspondence between educational degree and category of work; however, the table clearly shows a correlation. (This correlation breaks down in the case of the earliest stage of conceptualization of an IT system, where the initial functional idea often comes from people with little IT education but great application knowledge.) Occupations that fall under the *conceptualizer* category are commonly populated with recipients of a master's degree or doctorate. Occupations that fall under the *developer* or *modifier* categories are usually filled by people with a bachelor's or master's degree—and in the case of the modifier category, sometimes by a person with an associate's degree. Supporter occupations tend to be filled most commonly with people holding an associate's degree, or perhaps only a high school diploma.

A Two-Category Approach (NRC Study)

The 2000 National Research Council study, *Building a Workforce for the Information Economy*, also returns to the fundamentals of the work done, in a fashion similar to our study. The NRC study group differentiates between IT workers and those whose primary job is *enabled* by using IT. Thus they define IT workers as "those persons engaged primarily in the conception, design, development, adaptation, implementation, deployment, training, support, documentation, and management of information technology systems, components, or applications" (p. 44).

After careful examination, the study committee found that two categories were sufficient for their analysis. Work in category one involves "the development, creation, specification, design, and testing of an IT artifact, or the development of system-wide applications for services; it also involves IT research" and thus corresponds broadly to the categories of *conceptualizer* and *developer* in the CRA study. Category two work primarily involves the "application, adaptation, configuration, support, or implementation of IT products or services designed or developed by others" and thus corresponds to the categories *modifier/extender* and *supporter/tender.*

The NRC study does a good job of explicating the interaction between these categories of work, the skill and knowledge requirements for various types of worker, and the nature of the existing workforce. If your need for a categorization system is deep, then we recommend that you read the NRC study (at least its second chapter). If your need is less detailed, then either categorization scheme serves as a framework for analysis and planning.

Which scheme you use is probably dictated by what you are trying to achieve. Trying to plan for the proper balance of academic programs on a campus, for example, is likely to be well served by the (slightly) more detailed scheme of the CRA report. An early field test of the scheme for this purpose has substantiated its usefulness. On the other hand, if you are simply trying to determine which jobs on a campus should be placed on an "in short supply" list, then the two-category scheme of the NRC report is probably sufficient.

The Supply System

As we suggested in our study report (Freeman and Aspray, 1999), the traditional, formal educational system remains critically important to the supply of IT workers. Jobs of various kinds within the IT field, however, require quite different skill sets and levels of knowledge; thus IT jobs vary greatly in the kind and level of education they require. This is a critical point that was often largely overlooked in the early days of the IT boom, when we heard calls for producing hundreds of thousands of highly educated people. What was actually needed was an increase in the supply of a range of workers, most of whom did not need extensive education.

Formal programs leading to associate's, bachelor's, master's, and doctoral degrees in IT-related fields all have their place in the supply system. An associate degree trains a person for certain kinds of entry-level position that may involve maintaining or tending IT products, whereas a doctorate might prepare a person to create entirely new information technologies. None of the relations between training, education, and particular IT occupations are hard and fast, though.

Associate's and master's degree programs are an important supply source for IT workers because they tend to be more vocationally oriented than bachelor's or doctoral programs. However, bachelor's degree programs have produced the largest number of graduates for the IT workforce, and the doctoral programs are critical in producing trained workers for occupations involving conceptualization and advanced development as well as faculty positions that educate the next generation of IT workers. The most popular IT-related major is computer science, followed by computer engineering and management information systems. However, one author has identified twenty IT-related degree disciplines offered in the United States, and new ones are being created all the time (Denning, 1998). What these programs teach is more important than what they are called. Indeed, program names are often confusing, and it can be difficult to establish similarity or difference between programs solely on the basis of their names.

One of the least known yet most important facts is that the vast majority of IT workers do not obtain a formal degree in an IT-related discipline. Perhaps the most common of the many training paths to an IT career is a bachelor's degree in some technical field nominally unrelated to information technology, accompanied by some course work in either an IT subject or a closely related preparatory field, such as mathematics, electrical engineering, or business.

We would note, however, that the scene is changing rapidly. The proliferation of new majors, and options in existing majors, now give many students a variety of choices. Students and counselors now better understand that one does not always need a computer science or computer engineering degree to enter the IT field and succeed. Traditional majors—such as electrical engineering, industrial engineering, or operations research—are in some cases morphing into majors that essentially produce IT workers.

All of this means that the earlier statements about where most IT workers come from may be obsolete in a few years. More important, in a pluralistic and decentralized university where an individual department can more or less redefine itself and its majors, any attempt at central planning is difficult at best.

At the same time, certain IT occupations do demand a particular kind of formal education. An advanced researcher, such as a faculty member in a research university or a principal scientist in an industrial research laboratory, almost always has a doctorate in an IT-related discipline, usually computer science or computer engineering (or occasionally in a closely related field, such as physics, mathematics, psychology, or electrical engineering).

Over the past decade, there have been vast changes in the characteristics of IT work and preparation for it. Traditionally, higher education served as the basis for one's career, although some of the larger IT companies had training programs for their employees. Today, higher education is an entry ramp into a job, but it is not expected to carry one through a career. Taking advantage of on-the-job experience and various kinds of continuing education, the IT employee is today expected to engage in a life-long retraining effort, which is intended to keep the worker up to date in this rapidly changing field.

Many groups supply this continuing education. The higher educational system has a major role, offering seminars, short courses, and groups of courses that lead to a certificate in a specialized aspect of information technology such as network administration or biocomputing. Universities often attract the mid-career employee who goes back to earn an additional degree, perhaps a computer science degree for someone who majored in humanities or a master's degree in business administration for the computer engineer. Every level of the higher education system participates, but the training is most likely to come at the associate or master's level.

Others provide continuing education and retraining as well. For-profit educational companies, such as DeVry or the University of Phoenix, offer formal degree programs and certificate programs. Private consultants and private training companies offer specialized seminars, as well as customized training programs for individual companies. Companies themselves are getting into the training business for their own employees (and sometimes for others), forming "corporate universities" that they may develop on their own or in partnership with one of the other traditional or for-profit suppliers. The corporate university not only teaches IT technical materials but also develops communications and interpersonal skills and imparts knowledge of business and industry practices. It is believed that there are between fifteen hundred and two thousand corporate universities today, in addition to countless training departments.

The need for continual retraining has made it necessary to rethink how education is delivered. It has to be made available at a time and place, and in a style, that accommodates the employee's work and personal life. This requires more frequent offerings on evenings and weekends, scattered around numerous geographical locations. Even better, in some cases, is use of teaching methods that free the student from a specific time and place. Computer, Internet, and broadcast technologies are being used to develop various kinds of distance learning, some of which can be engaged by the student asynchronously—that is, when the student wants the training, not when a teacher is scheduled to give a lecture. These technologies are available in a rudimentary form today, but their development continues and they are being put into practice at a rapid pace.

It is clear that distance learning offers some interesting new approaches, but just where and how to use them is not clear at all. Predictions of the imminent demise of the traditional university because of these new technologies have proven to be premature, while at the same time the plethora of experimentation with new approaches has yet to show us the best way to proceed. Because of the demand for people and the expectation that IT students should be more comfortable with technological approaches, the supply system for IT workers is a primary laboratory for distance learning.

The university has traditionally been where people turned for continuing education, and even distance education (remember correspondence courses?). But the newer providers in many cases have taken the lead in offering this much-needed (and profitable) service to IT workers and those who want to be IT workers. In some areas, this is entirely appropriate (a research university should not be wasting resources teaching low-level skills), but in other areas the university is now scrambling to remain relevant.

Shortages and Market Tightness

There has been a great deal of discussion over the past several years of a shortage of IT workers in the United States. Various studies, such as those released by the Information Technology Association of America (ITAA) and the Department of Commerce, quantify the size of that shortage—typically in the hundreds of thousands of people. These claims have been used as principal evidence when companies and industry trade associations have requested changes in immigration law to allow more foreign IT workers to enter the United States. Yet the CRA and NRC studies on IT workers have found that the evidence for a shortage is less than compelling. These studies instead point to tightness in the labor market.

According to the Department of Labor definition, a *shortage* occurs when there is a disequilibrium between supply and demand. Thus, to be able to claim a shortage, one must be able to count the supply and the demand with reasonable precision and demonstrate that there is a greater demand than supply. Unfortunately, this task presents several serious challenges to the objective analyst.

First, there are problems with defining an IT worker—no matter which definition one chooses to use. Many jobs are borderline as to whether they are IT or not, and companies respond to surveys differently when they count IT workers. Many surveys focus only on workers needed for the IT industry; others are broader. Thus it is hard to get a count on the number of filled and unfilled IT jobs on the demand side.

There is also a problem in counting the supply. There are reasonably accurate figures on the number of people who graduate each year with various formal degrees—from associate through doctorate—in computing-related fields (computer science, computer engineering, management information science, and so forth). However, historically only a small percentage of IT workers received a formal degree in the field, and there is little reason to believe this will change any time soon. In fact, the supply pool comes from many sources, only a small part of which is determined by formal education.

Another problem is that supply and demand are not necessarily measured most effectively at the national level. If there were an excess of IT workers in Boston and a deficit of IT workers in San Francisco, it would not necessarily mean that the labor markets in the two places would equalize. There are often constraints on the ability and interest of IT workers to relocate from one part of the country to another.

Not only is there geographical segregation of the IT labor market, there is also job-type segregation. IT work encompasses a large number of jobs with wide variability in the skill set and knowledge required to do the work. Some jobs require an advanced computer science degree; there are others (as at a computer help desk) for which a computer science doctorate would be ill-suited. Thus, in figuring out the actual market place match between supply and demand, one cannot legitimately talk about IT work as a whole but instead must talk about various jobs.

There are also problems with the data. The federal data tend to be the most complete and objective, but often several years out of date—much too old for use in making decisions in this rapidly changing field. Supply data from the Department of Education are hard to match up with demand and employment data from the Bureau of Labor. Some national data, such as those supplied by the Department of Commerce and the ITAA, have been called into question on methodological grounds (small sample size, how the data were collected). It is hard to generalize from location-specific or occupation-specific statistical studies, such as those of the Washington Software Alliance.

For these reasons and others, the CRA and NRC studies both claim that we have insufficient evidence to assert there is actually a shortage of IT workers in the United states, much less to quantify that shortage.

Both the CRA and NRC studies do, however, observe tightness in the market. Evidence is in a variety of corporate actions (more recruiting, increase in salaries and benefits, more contracting out of IT work) and greater job churning (that is, growth in the number of resignations and hirings as IT workers hop from one job to another). Beyond this tightness in the labor market, it is hard to make any claims.

Political Issues

Because of the cries from industry over the past several years, legislators at the local, state, and especially the federal levels have been seeking political means to increase the IT labor pool. There have been state-funded regional efforts at economic development, such as the successful Yamacraw project in Georgia, which include workforce development. There are programs, such as one in northern Virginia to increase the production of low-end IT workers through increased access to an associate's degree, especially for people who previously were on the disadvantaged side of the Digital Divide. The final results of these programs for low-end workers are not yet in, but they seem to have had at best mixed success. Attempts have been made at the state and federal levels to give tax relief to companies that offer training for technical workers. This legislation may have a chance of success at the state level, but it is unlikely to be passed at the federal level.

Employers want more workers now, not sometime in the distant future. Thus political attention has been focused primarily on short-term solutions. Some federal agencies, such as the National Science Foundation, the Department of Education, and the Department of Commerce, have worked on Digital Divide and K–12 and higher education programs to a limited extent. There has also been modest focus on underrepresented groups such as women and some ethnic minorities. But the main focus has been on a quick fix—in particular on immigration.

The immigration issue has focused primarily on the H-1B visa program. The H-1B is a temporary visa that resulted from some major legislative changes in U.S. immigration law of the 1980s and is modeled after a temporary visa program (H-1A) for nurses of 1989. The H-1A program, incidentally, proved to be of only short-term success in alleviating the nursing shortage, and then only for a few regions (notably New York City).

The H-1B program enables specialty occupation workers such as foreign specialty cooks, physical therapists, fashion models, and high-tech workers to enter the United States. In the first half of the 1990s, no more than about twenty-five thousand high-tech workers entered the United States under this program each year. In the late 1990s, the demand for IT workers under this program grew dramatically, and the annual cap of 65,000 visas was reached well before the end of the federal fiscal year. Two later revisions of the

H-1B legislation raised the cap (it is now 195,000). The revisions also include two exemptions from the cap that have a special impact on universities: for those who hold a graduate degree and those who are employed in a university.

There are many problems with the H-1B visa program. Many people have criticized the management of the program by the Immigration and Naturalization Service for delays in processing applications and inability to keep track of how many H-1B visas have been awarded in a given year. Many of the workers who enter the United States under this temporary visa program would like to remain here permanently, and many apply for a permanent visa. Unfortunately, these new applications for permanent visa exacerbate an already overtaxed INS; the typical applicant waits many years for a decision on permanent visa status—often not receiving a decision before the temporary visa expires.

Labor unions and some groups supporting minorities and the elderly have been opposed to the H-1B program, noting that these visas take safe, high-paying, high-skill jobs out of the hands of American workers. These criticisms have been somewhat louder over the past year, in the wake of the dot-com crash. Others have criticized the program because it removes the incentive to find a long-term solution to ramping up our educational system to produce an adequate number of indigenous American IT workers, and that it does not force the country to find ways to better enfranchise underrepresented groups.

For an immigration strategy to work, there must be qualified IT workers in other countries willing to come to the United States. But Canada and most of western Europe have their own shortage of IT workers. Some of the original sources of foreign IT workers (Ireland, Israel) have dried up. The main source of H-1B workers is now India. Some people complain about a visa program directed primarily at one country, and about Indian-owned companies in the United States that manipulate the visa system to bring Indian workers as indentured servants to work in consulting firms under subpar conditions. Other countries are now competing with the United States for these foreign IT workers. Early results indicate that green-card programs to attract foreign IT workers are not succeeding in other countries—especially in Germany, where the program is seriously undersubscribed and the foreign workers often feel unwelcome.

Special Issues for the Education Sector

Campus IT staff have been under extreme pressure in recent years as technology changed rapidly, demand increased exponentially, and the lure of quick riches (or even simply a competitive salary) in industry beckoned. These pressures have been addressed in a number of ways that can best be addressed by others, but in the context of a discussion of the supply of IT workers we want to point out a special opportunity and responsibility for the campus IT support organization.

Though already widely used, there may be opportunities in many areas to make better use of students in staffing an IT organization. It takes creative and flexible management and a degree of cooperation between academic departments and support units that too often is missing. The obvious advantages of working at an educational institution (flexibility, good environment, reduced tuition, challenging work, and so on), if properly exploited, can significantly reduce the competitive disadvantage of generally lower salaries and benefits.

At the same time, campus IT support organizations can play a larger and useful role in extending real-world experience to IT students. Again, it takes creative management on both the support and the academic side, but if done well it can be a great boon to academic programs, students, and support organizations alike.

The responsibility (among others) of the educational institution in providing a supply of well-trained and educated IT workers for society is well known, but that is not the subject of this short chapter. An educational institution, especially a large one, is similar to other organizations in needing a variety of IT workers. A special kind of IT worker (the IT-related professor) is desperately needed by many educational institutions at all levels. Without them, there is no supply chain of IT workers.

The proper balance and staffing of the IT-related professorate is a critical issue for campus leaders, but not the focus of this volume. We note, however, the continuing concern of the research community and others that we may be "eating our seed corn" as IT professors are siphoned off into other careers (usually in industry).

Campus IT policies do play a key role, however, in helping attract and retain good educators and researchers—to say nothing of students—in all fields. In IT, these policies and their implementation are critical. Without proper IT systems in place for their education and research programs, IT professors rapidly become frustrated and leave. Most of the research-oriented institutions that we are personally familiar with have solved this problem (at least partially) by dealing with computing support for IT-intensive programs separately from general campus policies. Some aspects of this may always be necessary for good reasons (a computer science professor can't be allowed to experiment with the campus backbone network!), but campus IT policies that do not support IT-related professors are increasingly irrelevant. To end this discussion on a positive note, those responsible for campus IT policies have a special opportunity to help address the issue of producing sufficient IT workers for society.

Women, Minority, and Older Workers

Several groups of Americans are represented in the IT workforce in percentages that are far lower than the percentage in the population as a whole: women, African Americans, Hispanic Americans, and Native Americans. It is probably also true of older workers, but the figures are not available to demonstrate this.

Statistics on participation in higher education in IT-related majors give some indication of the underrepresentation. According to the Department of Commerce, only 1.1 percent of undergraduate women choose an IT-related discipline, compared to 3.3 percent of undergraduate men. Only about 150 African Americans have received doctorates in computer science and engineering in the United States since computing became a recognized academic discipline in the early 1960s. Tables 1.2 and 1.3 show the number and percentage of degrees awarded to women and minorities in the field over time. One of the most depressing observations that can be made from these tables is that the percentage of women receiving degrees has been steadily declining since the mid-1980s. This is in contrast to the progress made in the late 1970s and early 1980s in attracting women to the field. It is also in contrast to the trend in other scientific and engineering disciplines over the past two decades, during which there has generally been an increase in the percentage of women enrolled and graduating.

For purposes of brevity, this discussion is restricted to the issue of women. Many of the same issues discussed later for women apparently apply to underrepresented minorities, but there are also additional issues at play for minorities.

There is not yet hard empirical evidence about why women are underrepresented in this field. The National Science Foundation is funding a number of such studies currently under its IT workforce initiative, and we should begin seeing the first results in the next year or two. However, there has been substantial speculation about this phenomenon. Here are some of the reasons commonly adduced:

- Use of computers in high school (when students are first introduced to them) for playing aggressive and violent games, which turns girls off
- Lack of high school teachers and counselors who can explain the nature of IT education and careers and show the attractions to young women students

Table 1.2. Number of Degrees Awarded in Computer and Information Sciences

	Ph.D.'s		M.S. Degrees		B.A. or B.S. Degrees	
Academic Year	Number Awarded	Percentage Women	Number Awarded	Percentage Women	Number Awarded	Percentage Women
1984–85	248	10.1	7,101	28.7	38,878	36.8
1985–86	344	13.1	8,070	29.9	41,889	35.7
1986–87	374	13.9	8,481	29.4	39,589	34.7
1987–88	428	11.2	9,197	26.9	34,523	32.4
1988–89	551	15.4	9,414	28.0	30,454	30.8
1989–90	627	14.8	9,677	28.1	27,257	29.9
1990–91	676	13.6	9,324	29.6	25,083	29.3
1991–92	772	13.3	9,530	27.8	24,557	28.7
1992–93	805	14.4	10,163	27.1	24,200	28.1
1993–94	810	15.4	10,416	25.8	24,200	28.4
1994–95	884	18.2	10,326	26.1	24,404	28.4
1995–96	867	14.5	10,151	26.7	24,098	27.5
1996–97	857	15.9	10,098	28.2	24,768	27.2
1997–98	858	16.3	11,246	29.0	26,852	26.7

Source: National Center for Education Statistics, 2000.

Table 1.3. Degrees Awarded in Computer Science and Computer Engineering, by Level and Gender

	Ph.D.'s		M.S. Degrees		B.A. or B.S. Degrees	
Academic Year	Number Awarded	Percentage Women	Number Awarded	Percentage Women	Number Awarded	Percentage Women
1984–85	326	11.0				
1985–86	383	13.1				
1986–87	559	9.7				
1987–88	744	9.0				
1988–89	807	13.3				
1989–90	907	12.6				
1990–91	1,074	12.1				
1991–92	1,113	11.3				
1992–93	999	13.6				
1993–94	1,005	15.6	5,179	19.1	8,216	17.9
1994–95	1,006	16.2	4,425	19.7	7,561	18.1
1995–96	906	11.8	4,170	20.4	8,028	16.6
1996–97	892	14.5	4,359	22.7	7,335	17.2
1997–98	933	14.0	4,842	22.6	9,341	16.8
1998–99	852	14.6	5,576	26.3	11,461	17.0
1999–2000	868	15.1	6,181	25.7	13,721	19.2

Source: Computing Research Association, Taulbee Survey, published in Freeman and Aspray, 1999.

- The image of computing as a lifestyle that is not well-rounded or conducive to family life
- Differences in socialization of men and women as to whether they are performing well academically, which may encourage men and discourage women from studying information technology—even when the male and female students are performing equally well academically
- A perception of computing as a solitary occupation, not well integrated into social discourse or social institutions
- A perception that software jobs are not family-friendly (long hours, lack of awareness of the opportunity for telecommuting and other flexible schedules)
- Courses in mathematics and science that are requirements for an IT degree program, which women have not been encouraged to pursue on the basis of outdated stereotypes of aptitude and interest
- The lack of women role models

Although we await the outcome of these empirical studies on the causes, expert groups have made a number of recommendations about how to recruit women and underrepresented minorities into the field (Cuny and Aspray, 2001; Aspray and Bernat, 2000). Some of the recommendations are to give students research experience, establish mentoring programs, make sure there are suitable role models, build a community of underrepresented students so that the students do not feel so isolated, be more accommodating to students who interrupt their academic career or who have a background outside of the current norm, and generally make sure that academic programs are student-friendly.

Conclusion

The United States continues to lead the world in creating new information technology and in finding innovative and productive ways to employ it in all aspects of modern society *because* we have such a broad and deep supply of IT workers. The issues we face today are thus primarily of improvement, not initiation. Within that broad perspective, we believe that this discussion, augmented by the studies in the references, creates a good context for more specific discussion.

References

Aspray, W., and Bernat, A. *Recruitment and Retention of Underrepresented Minority Graduate Students in Computer Science*. Washington, D.C.: Computing Research Association, 2000.

Committee on Workforce Needs in Information Technology. *Building a Workforce for the Information Economy*. Washington, D.C.: National Research Council, 2000.

Cuny, J., and Aspray, W. *Recruitment and Retention of Women Graduate Students in Computer Science and Engineering*. Washington, D.C.: Computing Research Association, 2001.

Denning, P. J. "Computing the Profession." *Educom Review*, Nov. 1998, pp. 26ff. [www.educause.edu/ir/library/html/erm9862.html]

Freeman, P. A., and Aspray, W. *The Supply of Information Technology Workers in the United States*. Washington, D.C.: Computing Research Association, 1999. [www.cra.org/reports/wits/cra.wits.html]

National Center for Education Statistics, *Digest of Statistics*, 2000. [nces.ed.gov/pubs2001/digest]