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Chapter 7: Education

There are a variety of ways in which a country can attempt to shape its destiny in the face of offshoring. One is to address the issue through a policy and regulatory approach. For example, a country that is sending software work across its national borders could introduce protectionist tariffs, reform tax law, build a safety net for workers who lose their jobs, or promote innovation through increased research budgets. This policy and regulatory approach is the subject of Chapter 8. Another way to address offshoring at the national level is to adjust the educational system to provide the basis for the labor pool for the employment needs of the country especially in light of the international marketplace. For a developing country, this generally means building up the size and quality of its workforce in order to expand its software export business. For a developed country, this generally means finding ways to educate a workforce that either enables it to compete against low-wage countries or take advantage of partnerships with the low-wage countries.

This chapter addresses education as an enabler and as a response to offshoring. The chapter identifies some challenges, describes the educational systems in four locations (India, China, the United States, and the European Union), and ends with some proposed educational responses. The focus is primarily on higher education, both undergraduate and graduate, but there is also discussion of training opportunities outside of the traditional degree programs.

7.1 Prospects and Challenges of an Educational Response to Offshoring

The educational system must address both new workers who need an initial education to enter the IT field, and incumbent workers who have to keep their skills and knowledge current to do their work effectively in a world that is rapidly changing due to globalization. Most of this chapter focuses on the new workforce, but some of the topics discussed here also apply to the incumbent workforce such as courses on particular technologies, certificate programs, or people returning for a higher degree after working for some years. Chapter 8 addresses another issue related to the incumbent workforce, providing them with retraining if they lose their job through trade.

The educational system for information technology is complex, and it is difficult to determine the most appropriate steps for a country to take if it wants to prepare for a globalized software industry. This is true for countries sending software work as well as those receiving it. There are at least ten reasons why this educational response is so complex and difficult. This is not to suggest that a policy maker should give up trying. Indeed, the final section of the chapter suggests some actions that one might take. But it must be recognized that the issues are complex and no easy fixes are likely to be found.

1. *Many different occupations*. In the medical profession, there is not just one occupation of doctor, but many different kinds of doctors (general practitioners and many different kinds of specialists), nurses, medical technicians, physical therapists, and so on. Each of these occupations has its own set of requirements in terms of skills and knowledge to be able to do the job in a professional manner. The same is true of the IT profession. There are many different IT occupations, ranging from web designer or programmer to

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research computer scientist or computer system architect, and they vary widely in their requisite skills and knowledge. Each occupation is affected differently by globalization.

2. *Multiple degree programs*. Several of the computing professional societies have mapped out model curricula for IT academic degree programs (computer science, computer engineering, software engineering, information systems, and information technology), and these model curricula are followed in many countries. There are numerous variations on these five types of programs and also various kinds of educational experiments with new kinds of degree programs such as information schools. Thus there is a need to consider not one but many different curricula in order to address offshoring.

3. *Multiple non-degree training and education opportunities*. There is a large range of choices in non-degree training and education. These include corporate universities, individual courses and suites of courses from traditional and for-profit universities, and programs of study leading to certifications in various specific technologies.

4. *Multiple career paths*. There are many different career paths to become, for instance, a beginning programmer. One might take an undergraduate degree in computer science, enroll in a few computer science courses while taking a major in another science or engineering discipline, take an associates degree or study in a certificate training program in a particular programming language, learn on the job, and so on. Few physicists have a career path that does not involve formal training in physics; however, the majority of IT workers do not have a formal degree in computer science or information technology.

5. *Multiple application domains*. IT is used in virtually every application domain, from the entertainment industry, to science and engineering, to government, to business. Many IT workers need to know something about the application domain in which they work; for example, many IT workers in drug companies need to know something about the pharmaceutical business not just IT if they are to work effectively. IT workers might also need to learn about how IT systems are integrated into the company's business functions and operations. In contrast, workers in an IT research or development lab might be able to focus more narrowly but be required to draw more deeply on a technical IT education.

All of these complexities make it impossible to give simple prescriptions about what changes to make to a national educational system in order to provide good service to the country in the light of offshoring. But there are also some other features that make it difficult to implement an educational response to offshoring.

6. *Transformation pace*. Traditional universities, at least in the United States and Europe, have been slow to change. This is caused in part by taking a long-term view of education and in part by organizational structure (long-term labor contracts, decentralized power, management by consensus, entrenched bureaucracy). The deliberate approach to curricular reform is one of the strengths of the university system, but it can also be a weakness in a field where technologies becomes obsolete in a year or two and where the demand for workers can rise and fall significantly in a short period of time.

7. *Centralized planning of supply and demand*. While universities in most countries make their own decisions about the number of IT students they enroll, these admission decisions are shaped by national policies and government support in the form of computing equipment, infrastructure funds, research funds, fellowships, and internships. If a government believes that it has a shortage of IT graduates to fulfill its work needs and does not have direct control over university enrolments, it might act indirectly by

increasing funding to universities. Unfortunately, governments do not have a strong track record in their ability to predict trends to match supply to demand. For example, some argue that in the United States, there was a glut of scientists in the mid-1990s after the scientific community convinced Congress there was an impending shortage of scientists, and Congress ramped up support for fellowships and other means to increase the number of scientists (Teitelbaum 2003).

8. *Competing goals of education*. In many cases, preparation for the IT job market is not the only reason for an educational program. It may be designed, for example, to give the student a liberal education or to stretch the student's mind. With competing objectives for a degree program, it is harder to make changes that maximize the training provided for a single one of these objectives such as preparing students to be effective IT workers.

9. *The changing nature of offshoring*. Offshoring is not a single fixed phenomenon. The Indian offshoring industry, for example, includes programmers and system analysts who do software maintenance, testing, or development; workers answering phones in call centers; workers doing accounting services and other back-office business work; workers doing knowledge processing such as reading digitalized X-rays; workers doing research and advanced development; and so on. In India, the growth field of offshoring was once programming to fix Y2K problems. A year later, it was call centers. Two years later, it was IT-enabled services. Today, there is a push towards high-end activities where profit margins are higher such as systems integration and research. Who knows what the growth area will be next year? All of these kinds of offshoring co-exist in India today. Other low-wage countries might have one kind or another of offshoring work today, for example, there are mostly call centers in Africa, mostly programming shops in China, but the mix of tomorrow is uncertain. The type and mix of work is constantly changing, so how is an educational system to plan since one kind of education is needed for someone working in a call center and a very different kind of education is needed for someone working in a research lab? Perhaps it will be possible to build an educational system that takes into consideration the dynamism of the world, but this is a challenge.

10. *Lack of data on the relationship between education and career*. We have no good data on the kinds of careers that people pursue with a given IT education, how successful they are, what the progression of jobs held is, or how long they persist in the IT field. It would be useful to have this data for each of the different degree programs so that they could be compared with one another and against careers in other science, engineering, and professional disciplines.

In a sense, the issue for every country, whether high-wage or low-wage, is the same: to provide an education system that will form the basis for the labor pool for the employment needs of that country. But this is too facile a statement. There are important differences from country to country. Low-wage countries such as China and India, which have rapidly expanding software export industries, need to ramp up their educational systems to meet the rapidly increasing demand for educated workers. Companies in these countries need to hire well-trained employees so that clients have confidence in the quality of the work, and they have to hire enough of them so that clients will give the company large-scale projects. India has an educational system that has been increasingly privatized. The educational system has been agile at adapting to industry's needs, but India faces problems of quality control outside of a few elite institutions, and the education and lucrative careers in IT are out of reach for most of the population. China faces issues about how well central planning will work. Some people in the United States fear that most of the low-skill IT jobs will leave the country. For these people, the question is how to train people for the high-skill IT jobs and what kind of career ladder is possible to get there. Other people believe that the United States will stay strong by increasing its level of innovation. For these people, the question is how to introduce a curriculum that teaches students to be innovative. In Europe, the Bologna Declaration, a joint declaration of the European ministers of education in 1999, is trying to facilitate the movement of labor within Europe. The educational challenge there, in part, is to move from national-style educational systems to a new higher education system that has some uniformity and transportability across Europe. Moreover, Europe is very different from the United States in not having a large global software products industry.

We do not yet know, for any country, how difficult it will be to offer an adequate educational response to the challenges and opportunities of offshoring. Globalization is here to stay, and offshoring looks like it will be a growth industry for at least a few more years. Thus an educational response seems critical if a country is to thrive in the globalized software world. But, to take an example, the United States has faced a stream of knotty educational issues relating to IT. From the first days of the US computer industry in the 1950s, the United States has faced issues concerning computer education. At a national conference in 1954, science policy leaders wrung their hands over how they would find enough PhD. mathematicians to staff the scientific computing projects that existed. In the 1960s, the country struggled with finding adequately trained personnel to teach in their newly formed computer science departments, how to define graduate and later undergraduate education, and what curricula to teach. As business computing emerged beginning in the late 1950s, and as computing filtered down to smaller and smaller businesses as computing price-performance improved in the 1960s and 1970s, there were new educational challenges over forming new academic disciplines (e.g., information systems) to meet business's computing needs. In the early 1980s, doctoral production remained stubbornly low and there were concerns that there would not be enough faculty members to teach the expanding number of undergraduate majors and other computing course-takers.

More recent times have seen new challenges including dealing with rapid spikes and rapid drop-offs in undergraduate enrolments in the face of the dot-com boom and crash, revitalizing a research agenda and graduate education core that was largely formed in the 1960s and 1970s, enriching research vitality through an interdisciplinary approach to research and greater attention to applications, finding means to handle growing national IT workforce needs especially to accommodate people who did not take the traditional path of formal technical degrees, and handling revolutionary changes in the ways in which IT is used in American business. Generally speaking, the US educational establishment has not been as quick to meet these challenges as some policymakers would like, but they have succeeded well enough to maintain the world's strongest software industry.

Because the IT educational system is so complex and what is happening with offshoring is changing so rapidly, it is impossible to be prescriptive about what any country should do with its educational system. In the next four sections, we describe the current IT educational systems in India, China, the United States, and Europe and the changes taking place in them. In the final section, we draw some conclusions about the educational response to offshoring.

7.2 Indian Education

Higher education is one of the crucial enablers for India to become a powerhouse in offshoring. The higher education and training system continues to be one of India's strategic advantages together with a large English-speaking population, a British-style legal system, and close ties to the English-speaking world through both its colonial roots and the contact of its scientists and engineers with Western Europe and the United States.

Brief History of Education and Trends

In the initial decades after independence in 1947, India tilted its educational investment priorities in favor of higher and technical education in order to realize Nehru's vision of a state-regulated production and distribution machine. This was a period of planned economic development, designed on a Soviet model of modernization. In the first twenty years of planning, higher and technical education received much higher priority than primary education due to the predicted labor requirements of heavy industries. In the next fifteen years, the percentage of India's resources spent on technical education declined, higher education growth stabilized, and elementary education gained a higher percentage of the state investment. In the first twenty-five years after independence, the number of universities in India quadrupled, and the number doubled again over the next twenty-five years.

The Increasing Importance of Higher Education for India

The role of knowledge in economic development has become critical in the last decade and, concomitant with this worldwide trend, the role of higher education has assumed increasing significance. Higher education is underdeveloped in terms of quantity and quality in India. A vast demand was generated for various kinds of human capital, brought about by the opening up and integration of the Indian economy with global markets. The real income level of a sector in Indian society has gone up, enabling people from this sector to participate in higher education. Two factors ultimately raised the demand for higher education: the increasing role of the knowledge economy that requires higher skills, and the globalization trends that opened up new avenues to high-skill jobs. As The World Bank observed, "Higher education has never been as important to the future of the developing world as it is right now. It cannot guarantee rapid economic development - but sustained progress is impossible without it." (World Bank 2000, 19).

India tried to meet the higher education demand through both public and private means. One reason that government has not invested more in higher education is that the resources available to the Indian government are finite, and there is competition for these funds for higher education from other public investments that also have high social return such as clean drinking water. Another reason that the Indian government may not have invested more public funds in higher education is because there has been strong private interest in making these investments since the early 1990s (Jha 2005; Tilak 2002, 2004; Carnoy 1999). During the liberalization of the 1990s, privatization in the higher education sector advanced rapidly. One estimate is that private sector education today accounts for close to 2 percent of Gross Domestic Product (Lall 2005). The private sector accounted for just 15% of the seats in engineering colleges in 1960, while today it is 86.4%.

There seem to have been some problems with the quality of instruction in a number of the private institutions, and the government has been lax in establishing and enforcing accreditation and other quality standards. However, there are some excellent private institutions, such as the Indian School of Business at Hyderabad that provides high-quality executive business education.

The tuition of even the state colleges and universities is beyond the reach of many Indian citizens, and this is part of the reason why only 6% of the population enters higher education. The cost in the private schools is much greater. The Indian School of Business in Hyderabad, for example, charges about US$30,000 for a one-year course of instruction which is five times the per capita income in India. However, there are other more affordable choices of business schools for students of lesser means.

As is discussed later in this chapter, the Indian universities have not made great contributions to scientific and engineering research which goes hand in hand with graduate education. Doctoral training in engineering has dropped significantly in India just as undergraduate capacity has increased. It is likely that the private institutions will be better at producing commodity products (masses of undergraduate engineers and MBAs) than specialized niches such as doctoral-level researchers. Perhaps this is another role for the public universities.

Financing and Demographics of Education

The expenditures in India on education as a percentage of the Gross National Product has risen from about one percent half a century ago to nearly 3.5% today. The average spending on education in the 1950s was 1.8% of GNP, 2.8% in the 1960s, 3.1% in the 1970s, 3.3% in the 1980s, and about 3.5% in the 1990s. The world average is 4.8% with the industrialized countries spending about 5.1% of their GNP on education and the developing world spending about 3.6%. Breaking down the data further, Sub-Sahara Africa is spending 5.4% of GDP on education, Eastern Europe 4.6%, and Latin America and the Caribbean 4.6%. Thus India's spending on education is low compared not only to developed countries but also to a number of developing countries.

In the year 1953, there were 25 universities and 565 colleges in India; in 2004, those numbers were 311 and 15,600, respectively. The number of students in higher education rose during the same period from 230,000 to 9.28 million, while the teaching staff rose from 15,000 to 462,000. Over 2.5 million graduates are produced in India every year. There are serious class, regional, rural-urban, and gender inequities in the demographics of higher education.

Despite the rapid expansion of higher education, enrolment in higher education in India is just 6 percent of the relevant age group (18-23). In comparison, countries in North America are in the 60 to 70 percent range, those in Europe are in the 40 to 60 percent range, while the Asian Tigers (Hong Kong, Singapore, South Korea, and Taiwan) are in the 33 to 55 percent range.

In 2000, the engineering colleges in India were not evenly distributed geographically. Just four states, Andhra Pradesh, Karnataka, Maharashtra, and Tamil Nadu, accounted for 64% of the engineer-degree intake with just 28% percent of the population. In the state of Tamil Nadu, there were over 40 engineering colleges for every 10 million people, while it is less than 1 per 10 million people in the state of Bihar. However, response to market forces by private organizations has begun recently to even out the distribution.

In 2000, India produced 11,100 PhDs of which 5300 were in the sciences and engineering. The total number of engineering institutions as of 2002 was 1215; 253 more were to be added in 2003-04.

Higher Education: Its Development and Present Status

Some excellent centers of higher education have been created in India. The foremost and best known are the five Indian Institutes of Technology (IIT). Other strong educational institutions include the Indian Institutes of Management (IIM), and the Indian Institute of Science (IISc). There are other institutions of academic and research excellence which come under the ambit of the Council of Scientific and Industrial Research (CSIR). In addition to these public sector institutions, the private sector has contributed the Indian Institute of Science, Tata Institute of Fundamental Research, and the Birla Institute of Technology and Science among others.

Most of the graduates of these institutions found there was a paucity of good jobs for them in India, at least in the years from 1953 until 1998. The economic growth rate that the original planners envisioned did not come about so many of these graduates could not find good, full-time employment in the profession for which they had trained. Because of this lack of opportunity at home, many of the IIT graduates started migrating to the Western countries, particularly the United States. Over one-third of the graduates of the

IITs have settled outside India, mostly in the United States. Thus the vastly qualified human capital created at considerable cost to India has remained underutilized until recently.

Development of the IT Sector

When circumstances changed in the mid-1980s and particularly in the 1990s with the onset of the IT boom and the Y2K problem, the major investments made in the higher education sector started paying off for India. This investment enabled the rapid maturity of India into a significant IT player in the world. With this background, let us consider the higher education system in place in India today.

The key driver for the Indian IT industry has been the availability of skilled computing professionals who are inexpensive (relative to other countries) and fluent in the English language which is the language in which most systems and applications software is written. In the last fifty years, the annual growth rate in science education in India has been 11 percent in terms of number of graduates and 9 percent in terms of institutions. The number graduating annually in science and engineering, including computing, has been in excess of 150,000. The polytechnics annually produce about 200,000 diploma graduates; these polytechnic colleges provide technical training that is vocationally oriented. In addition to this, there are the thousands of private training institutions that offer both short- and long-term courses in programming and software engineering.

As far back as the late 1970s, information technology education received attention in India based in part on a belief by the government that this technology would become pervasive and require large numbers of qualified workers (Maheshwari 2004). The government planned a three-year MCA (Master in Computer Applications) program. The engineering colleges were encouraged to start the B.Tech (Bachelor of Technology) programs in computer science and engineering. Private initiatives in functional training in the use of software packages also began at this time.

In the late 1980s and early 1990s, the rise in software exports caught the imagination of people and various estimates of the anticipated shortages in the availability of skilled workers were publicized. Personnel planning for IT was similar to an emergency operation, with large shortages foreseen in skilled workers. Most universities either started or expanded their degree-level programs in IT in this period. There was a major expansion of the certificate and diploma courses offered by private organizations. Soon IT education was a massive industry, including both public and private initiatives.

Where does IT education stand in the country today? Out of the 700 plus engineering colleges, about 500 run B.Tech programs in electronics, computer science and engineering, or IT. The MCA program is found in over 300 universities or colleges. The BCA (Bachelor of Computer Applications) and BIT (Bachelor of Information Technology), which are three- or four-year programs, have been introduced recently in a number of universities. These B.Tech, BE, and MCA programs together can produce around 75,000 graduates per year. This number falls short of meeting the national demand for IT workers. As in other countries, however, employers who are seeking technical IT workers do not restrict themselves to graduates with IT degrees. They are also likely to hire students who majored in other scientific or engineering disciplinesand who learned a significant amount about IT as part of their degree program. Thus the number of technically-trained graduates is higher than 75,000 but hard to count exactly.

Formal technical degrees and the demand for them is only part of the story. There is also a large demand for workers familiar with IT who have done courses less rigorous than the formal degree programs mentioned. These less highly-trained workers can fill the demand for workers in call centers and back office/IT-enabled services. This sector has over 5000 training institutions, and its growth rate is around 20% per year. Major private players include NIIT Technologies and Aptech, as well as the DOEACC Society, an autonomous body set up by the federal Ministry of Information and Communications Technology. These institutions offer a large number of courses and provide short-term, skills-oriented programs. They enable university students who could not get admitted to degree programs in IT to pick up IT skills while doing some other course of study unrelated to IT at the university. It is believed that as many as 500,000 students are getting some sort of IT training through these non-formal channels each year.

There is competition for trained IT workers from other IT fields in India. There are at least two important areas that require IT workers. The first is the growing hardware sector. One estimate puts the demand by the hardware industry for trained workers with university degrees or diplomas at 180,000 by 2008 (NASSCOM 2005). The second is the large number of workers who will be required to teach IT in the schools. There are about 100,000 secondary schools teaching about 28 million students today. One of the ways that IT education will be promoted is through the teaching of computer science as a formal subject which will require an additional 100,000 qualified teachers. Estimates for 2008 place demand at 1.4 million formally-trained degree holders in an IT discipline, and an additional 1.1 million workers for the IT-enabled services (ITES) area (NASSCOM 2005).

What are the pressing problems for the IT education sector today? Even with the vast initiatives in both the public and private sectors, some policymakers are concerned that supply may not be able to cope with the demand, which is expected to balloon. (But one study by NASSCOM, discussed later in this section, disagrees.) The second problem is the quality of the tertiary sector of computer science and IT education. One study estimates that 70 percent of the workers with formal post-secondary training are not up to par as far as industry's requirements are concerned (Balatchandirane 2004). The third area of concern is that PhD enrolments in computer science are practically nil which could seriously impair the prospects of India moving up the value chain in IT exports. An alternative to indigenous production of computer science doctorates would entail an effort to attract Indian and other students who received their IT doctorates in another country, most likely the United States or the United Kingdom. There has been a recent increase among Indian students taking doctorates in the United States in the number who return to their homeland, but there are still questions of compensation and working conditions to consider if the Indian universities want to attract these people as faculty.

Around 290,000 engineering degree and diploma holders enter the workforce annually. Most of them enter the IT industry. Most have received their education in English. Table 1 summarizes the pool of graduates in India.

Table 7-1: Graduate Pool in India, FY 2003-04

(nos)	**Engineering Degree Holders**	**Engineering Diploma Holders**	**Arts Degree Holders**	**Science Degree Holders**	**Commerce Degree Holders**	**Total Graduates**
Graduates (through 2003)	1,200,000	1,750,000	11,500,000	4,985,000	5,933,000	21,986,000
2004 graduates (estimate)	155,000	130,000	1,150,000	540,000	480,000	2,460,000

Source NASSCOM (2005)

The number of IT and ITES professionals employed in India has grown from 284,000 in 1999-2000 to an estimated 813,500 in 2003-04. Most of the new recruits are recent graduates with various academic backgrounds. Turning to the worker demand and supply for the IT sector, NASSCOM estimates that the supply of IT professionals will in fact outstrip demand by 48,000 in 2008. The number of professionals who would be joining the IT workforce from various academic disciplines is given in Table 2.

Table 7-2: Indian IT Sector; Labor Supply

(in '000)	**2003-04**	**2004-05**
Number of engineering graduates	215	284
Degree (4-year course)	112	155
Diploma (3-year course)	103	129
Number of IT (Computer Science, Electronics, Telecom) Professionals	141	165
Engineering IT graduates (Degree)	95	100
Engineering IT graduates (Diploma)	46	65
Number of IT professionals entering the workforce	80	94
Engineering IT graduates (degree)	55	58
Engineering IT graduates (diploma)	25	36
Number of non-IT engineers entering the IT workforce	40	40
Number of graduates (other disciplines)	30	30
Total fresh IT labor supply	150	164

Source NASSCOM (2005)

Training Programs

Even though there is a large population available to enter the IT workforce generally, there may still be shortages in particular IT occupations such as programmers or web developers. Different people in the work pool have different training and not all of them are prepared for all the IT occupations. By and large, engineering graduates are prepared for many technical IT occupations. However, some of them need to take a few software courses after they enter the workforce in order to be able to function more efficiently in the IT industry. Students from other disciplines, such as the sciences and arts, often need rigorous training in software development. Some Indian educational policymakers are advocating that software-related courses be added to these other curricula, even if the software courses are not fundamental to the principal subject of study, for the specific vocational purpose of preparing students concentrating in these other disciplines for IT sector entry.

English-language skills are a problem for many students in Indian graduate and vocational schools. The image of India churning out a large number of graduates fluent in the English language is not really accurate. Students are entering the IT job market with a wide range of skills in the English language, but the IT industry expects fluency. Some of these graduates need additional language training. This is particularly so in the ITES industry that requires skill profiles that are different from those for the software industry. Those employed in the ITES industry need not only language skills, but also familiarity with the particular functions and domains of knowledge of the field to which IT is being applied.

It is ultimately the quality of the human capital that determines the growth of the Indian offshoring industry. Without the creation of high-quality human capital, other advantages are not going to be of much help. Education is important, but training may be even more important. Preparing workers for this career involves more than a one-time investment effort; it involves a dynamic, ongoing process that is flexible and quick to respond to market signals, while at the same time incorporating an overall philosophy of matching the basic human capital to the additional incremental skills that are demanded by the market.

Thus the training programs need to be innovative and dynamic with course curricula designed on the move. This differs markedly from the curricular reform process used by universities where it can take years to design a course that is solid and can stand the test of time. The nature of the training that is expected in the IT industry is difficult to predict since it is based on ever-changing demands for particular new skills in the international marketplace. Like most universities and governments around the world, Indian public-sector universities are not well suited to this kind of flexibility and rapid change. In fact, it has been the private sector that has been by and large responsible for most of the meaningful training programs in this industry. The biggest training institution in Bangalore today is not in a university, however, but at the company, Infosys. The company is setting up a huge facility at Chennai, where as many as 10,000 of its computer professional employees can be given specialized training each year. Another industry leader, Wipro, also has a large training facility. These companies are two of the largest training institutions in Bangalore today. As many as 33 percent of the world's SEI-CMM Level 5 companies (the Software Engineering Institute Capability Maturity Model of Carnegie Mellon University), the highest level of international quality certification, are to be found in Bangalore today, a fact made possible by the high-quality training of its professionals (NASSCOM-KPMG 2004).

There are also a number of courses or institutions created for industry. IIM Bangalore runs courses intended to meet the need of the hour. There is a specialized program in Masters in Business Administration designed especially for IT professionals. The interesting aspect is that, while IIM Bangalore interacts with industry and accepts large donations from industry, it retains its autonomy. Private industry cannot control or decide on the kind of course that will be run or how to run it. IIM Bangalore decides completely on its own about the form and content of its courses, and yet the program remains highly sought after. Similarly, the Indian School of Business at Hyderabad, funded by private sector initiative, is turning out to be a world-class institution for training managers with additional skills. Both these institutions fall outside the regular university system in India. They do not receive certification from the University Grants Commission (UGC), the autonomous body of the government of India that monitors, certifies, and funds institutions of higher learning in India. These institutions and others, such as the Indian Institute of Information Technology (IIIT), are of very high quality and brand equity.

Another model is the scenario where some companies pay large sums of money to a university or other educational institution for a specific course to be started. The company gets to place some of its managers in the program every year, but the course content is controlled by the educational institution. For example, Wipro has made large contributions to Birla Institute of Technology and Science for this purpose.

There are other industry/academic interfaces. In a number of engineering/IT courses, the student is expected to do project work that involves studying and collecting data from an industry over a period of three to six months. This gives the student a first-hand opportunity to get to know about the industry, even before graduation. Companies that encounter bright students in this way let the students know informally that opportunities are available for them on the completion of the course. A number of companies recruit on campus. They visit campus to meet students a semester or two away from graduation and explain to them about their company and career opportunities for the students, and they make offers to promising students after interviewing them. Faculty members are present to advise the students. In this way, students can receive job placements before they complete their study, and the companies are assured of good quality computer specialists. Another area of cooperation is in providing foreign language skills to qualified IT professionals. Many companies are turning towards the Far East market. Since fluency in Chinese, Japanese, or Korean is essential for the Indian IT professional who works in the Far East in order to communicate and write software, these companies have interacted with universities to provide special courses in these languages for its professionals. Alternatively, they have selected bright foreign language students and given them IT training in their own companies and then placed them in their offices abroad.

Some of the pertinent points about training to emerge from a study done by NASSCOM and Hewitt Associates are listed in the Table 3 (NASSCOM 2004). They indicate the importance attached to training by the Indian IT companies.

Table 7-3: Training by Indian Companies

1. Nearly all companies (95%) have a formal development and learning needs analysis program.
2. The most commonly used mechanisms to support continuous learning and development for employees are organizational libraries, assessment of skills/knowledge/abilities, and job postings/internal transfer systems.
3. The median number of training hours per employee per year is 40. The distribution of training hours across behavioral and technical training programs varies with level of employees. Senior employees get more behavioral training, up to 60% of the training is either on managerial topics or in interpersonal skill enhancement.
4. 98% of the companies have a formal training feedback mechanism.

Source: NASSCOM and Hewitt Associates (2004)

Observations

Using the previous discussion as background information, here are some observations and recommendations about IT education in India.

1. It is ultimately the quality of the human capital that determines the growth of this industry. Without the creation of high-quality human capital, other advantages are not going to be of much help. One advantage of India is that it has adapted very rapidly, if not perfectly, to this need. A country that wants to be a significant IT player has to have a strong higher education sector. Recently, in India the private sector has predominantly played this role. The demand for a strong higher education system presents a great challenge for India. For example, for India to bring its total investment in education up to 4.8%, which is the level of developed nations, would require almost US$9 billion additional annually. If every penny of the extra funding was spent on primary education, it would still not be enough to give all Indian children an eighth-grade education. Thus there is tremendous demand for funding even within public education itself which competes with the called-for investments in higher education.
2. Training courses for IT professionals have to be continually created to keep abreast of market demands. The private schools are more motivated and better positioned to do this, but the public universities could improve at this as well.

3. There are bound to be gaps between the supply and demand for IT professionals. Any projection of supply and demand is at best an approximation of the present understanding of future realities. The future reality could be drastically affected if there are some changes in the international economic or political environment. New IT players could rise, displacing others who have dominance now. Since a country cannot control the external environment, and since changes in IT occur rapidly, the demand for IT products and services can change very quickly. Along with this risk are great opportunities in that the international market for IT products and services is huge and expanding. How responsive each country's education and training systems (both public and private) are and how quickly they adapt and exploit these opportunities will separate the winners from the also-rans.
4. Despite advantages of location, cost, and time-zone differences, what ultimately matters is quality. One reason why India could succeed is the fact that it has the largest concentration of IT companies with the highest level of quality certifications in the world in Bangalore and Hyderabad.
5. The low level of R&D investment and shortage of R&D workers in India leads to a low level of technological innovation. India employs just 150 R&D personnel per 1 million people. Among these, those holding doctorates represent just 13 percent, while graduates are 17 percent, and the remaining 70 percent are still undergraduates or diploma holders (NASSCOM 2005).
6. The quality of the Indian university system is a concern. There is not a single Indian university among the top ten Asian universities. While 280,000 engineers are produced in India every year, only 10,000 (less than five percent) are of top international quality (NASSCOM 2005). If one were to remove the well-known Indian Institutes of Technology and Indian Institutes of Management, the average quality of the remaining higher education institutions drops steeply.
7. The demand for higher education in India will balloon due to a number of factors. First is the rising need for skilled labor due to globalization. Second is the large increase in the number of young people in India and the large rise in people with primary and secondary education. An increasing share of them are moving on to higher-education levels, raising the demand for higher education.
8. With the developed world constantly raising the stakes by pushing the knowledge frontier further, India will have to constantly raise the quality of its higher-education systems to prevent the widening of the gap. This might mean greater investment in the public universities, but it should also mean greater quality control through government regulation of the private education providers who now provide a majority of the educated workers.
9. Salary levels for university teachers are low. It is typical for students who graduate from the top institutions to receive a compensation package that is greater than what a teacher receives. The best of these teachers are tempted by jobs abroad as well as by jobs in the private sector. It is becoming increasingly difficult to get bright people to enter the academic profession. It may be that the private sector is better positioned to provide adequate salaries to attract quality faculty, but the public universities could also improve the salaries and working conditions of their faculty.
10. Various documents of the World Bank of late have focused on the importance of the knowledge society and how post-secondary education needs to rapidly grow in the developing world (World Bank 2002). As the higher education systems are inadequate in the developing countries, they are open to selling by the developed countries who are moving in to sell education in countries such as India.

11. In most universities, there is a resources crunch for research. In many universities, salaries alone take up 95% of the total allocations, and there is a tremendous infrastructure shortage as a result.

7.3 Chinese Education

During the last two decades, the Chinese economy has grown rapidly (compound annual growth rate in excess of 7%), while shifting from a largely agricultural country to a major industrial power. China has developed a substantial technological base, although Chinese industry is still dependent upon imports of advanced production equipment, technology in the form of licenses, and the uncompensated usage of intellectual property. Chinese performance in innovation is improving dramatically. For example, in 1986, in terms of patents filed at the US Patent Office, China was 57th globally; by 2003, it had advanced to 18t and, by all accounts, continues to improve its global ranking (Pluvinage 2005). This section draws heavily from Chen and Kenney (2005).

A Brief History of Chinese Higher Education

In China, respect for education is rooted in Confucianism. When the Communist Party came to power, it was committed ideologically to education and the use of science and technology for economic development. The new government also massively increased its investment in basic education, creating a broadly educated public. With the establishment of the People's Republic of China in 1949, the Western powers pursued a policy of isolating China; a by-product of this was China's adoption of the Soviet Union's model of comprehensive and specialized universities and a large network of research institutes. In 1978, the Chinese university model was again reformed to one that more resembled that of the United States and emphasized comprehensive universities (Pepper 1996; Wang 2000). However, the government research institutes are still enormous and have an important role in graduate education. Despite these changes, until recently only a very few universities undertook research; their most important priority was pedagogy.

When the Chinese economy opened to overseas investment, the earlier investment in elementary and secondary education provided a pool of literate and capable factory workers. For those seeking further education, national examinations identified the most capable students, and these students were allowed to continue for massively subsidized post-secondary education. This meant that even children from impoverished backgrounds could, in theory, receive higher education. The result has been enough educated people in the general populace, together with a well-educated elite, to provide an adequate supply of trained engineers and scientists for the country. After the opening to the West in the 1980s, the final element of the Chinese education system was put in place: going abroad, preferably to the United States, for post-secondary education. As with the IITs in India, graduates in engineering or the sciences from elite universities, such as Peking or Tsinghua, are nearly certain to be able to secure admission and financial support to a foreign university.

The Current Chinese Higher Education System

As in the case of India, Chinese universities graduate a large number of students every year. For example, in 2001 (the most recent date for which data was available from the US National Science Board), 567,000 students received their first degree. In total, there were 337,000 graduates in science and engineering; of these, 219,000 were in engineering (National Science Board 2004). The quality of these graduates varies dramatically, but the sheer volume means that China has a large reservoir of technically- trained individuals.

Since the educational reforms of the 1980s, Chinese universities and research institutions (URIs) have developed an unusual mode of interacting with industry. Chinese URI personnel have established firms that are, in effect, university subsidiaries. These firms undertake a variety of activities, ranging from serving meals in university cafeterias to technology development. Lenovo, which recently bought IBM's PC business (Lan 2005; Eun et al. 2005), is an example of such a firm. Chinese universities are also willing to undertake mundane technology development for firms that US universities are generally unwilling to do. This general pattern of university/industry interaction is true for the software industry as it is for other industries.

There is disagreement about the size of the Chinese software workforce. Joseph (2001) reports that there were 30,000 to 35,000 high-level software professionals in China and about 400,000 workers employed at the various levels of the software industry. Pollice (2005), on the other hand, reports that in 2002, only about 250,000 people were employed in information technology jobs in China. He expected this number to increase five to tenfold during the next few years. Universities and research institutes provide 71 percent of all the software engineers in China, with training organizations as the next most important source (12%), followed by professional schools (7%), on-the-job training (6%), and overseas-trained Chinese (4%) (Liu 2004). Liu also states that foreign firms, such as IBM and Microsoft, have established training facilities in China. The Indian for-profit firm, NIIT, has established 100 software training centers in China and developed partnerships with various Chinese institutions (Menon).

Although there had been earlier interest in hardware engineering, Chinese universities largely neglected software studies as an academic discipline until 2001 (Pollice 2005). At the end of the 1990s, the Chinese government recognized that it had a shortage of trained software personnel. The Tenth Five-Year Plan called for a dramatic improvement in Chinese software capabilities. In response, beginning in 2001, 51 Chinese universities established Masters degrees in software engineering. The degree quickly attracted students. For example, beginning in 2002, Peking University Software Institute had an enrolment of approximately 1,000 students. "This is in addition to the number of undergraduates and programmers trained in other trade school curricula . . . [and it] brings the yearly entry total of … employees [trained for some kind of IT occupation] to more than 100,000." (Pollice 2005)

Even though Chinese universities have become interested in software training only recently, the Chinese software industry has benefited from URI and government spinoffs in the formation of some of the more recent software firms (Tschang and Xue 2005). Under government prodding, they have rapidly increased the numbers of software engineers they are training. Although the shortage of software professionals is starting to be addressed, problems remain in educating these professionals to be creative and innovative. Most Chinese technology start-ups appear to be "me-too" firms that clone a Western business model for the Chinese market or use fairly unoriginal technology. For example, of the 24 Chinese technology start-ups that have listed on the NASDAQ Stock Exchange, all appear to be copies of firms that already exist in developed countries (Kenney and Patton 2005). According to Xielin Liu (2004) of the National Research Center for Science and Technology for Development, the education and training of software engineering in China is still "very weak." The courses emphasize "theoretical knowledge" and do "not offer the students a good operational experience." Liu concludes that "both professors and Chinese business engineers are not familiar with international standards" and "lots of Chinese are good in textbook learning and poor in practical learning." Whether or not this rather dismal assessment is fully justified (and a more recent survey in People's Daily 2005 appears to confirm it), given the rapid growth in the economy, there are shortages of qualified and innovative software engineers.

Chinese Research and Development Parks

Even as the central government strives to increase the number of software engineers, local and provincial governments are also actively pursuing software as part of their economic development priorities. Local universities are central to these efforts. For example, Dalian, a large city on China's northern coast, is establishing itself as a center to supply software services to Japan and the rest of the Asia Pacific. The Dalian Software Park (DSP) advertises itself as located in the Higher Education and Culture Zone of Dalian and surrounded by numerous universities and research institutes (DSP 2005). These universities appear to have begun developing a curriculum geared toward providing well-educated employees for the software services industry.

The centrality of Chinese URIs in the development of Beijing and its Zhongguancun Science Park, in particular, has been remarkable (Wu, Yan, Wang 2004). (Although Zhongguancun Science Park is termed a science park, it is more properly a technology park, as few firms within it are doing cutting-edge science like that undertaken by U.S. biotechnology firms.) For example, a number of Beijing's high technology and software firms can be traced directly to elite educational institutions such as the Chinese Academy of Sciences (CAS) and Peking and Tsinghua Universities (Chen and Kenney 2005). Lenovo, a CAS spinoff, experienced its first success by commercializing a Chinese-language word processing system (Lu 2000: 66-68). (For further discussion on the importance of science parks to offshoring, see Chapters 3 and 8.)

Conclusions About the Chinese Higher Educational System

The Chinese educational system has provided a well-educated population and a large and well-trained cadre of engineers that have been important to the growth of Chinese industry. In the software field, the record by Chinese universities has been more mixed, but this is largely because the Chinese government did not see software as a priority until recently. Since 2001, the Chinese government's attitude has changed drastically, and it is emphasizing software as an area for growth. As a result, the university system has responded, although there remains the issue of teaching workers to be innovative.

There are open questions about the most desirable relationship between Chinese universities, firms, and society (Chen and Kenney 2005). Is it desirable for universities and their students to do mundane development work for firms? Should universities own and even manage private sector firms? As the Chinese economy develops and matures, how should universities evolve?

In summary, the Chinese educational system has experienced rapid change as the country industrializes and embarks on an effort to become more knowledge based. In the process, there is a massive effort underway to transform the elite universities from emphasizing teaching to a greater balance between teaching and research. For example, Peking University, in an effort to become a global-class research university, has reorganized its personnel processes to emphasize research and publications and ensure more rigorous standards for promotion and tenure (Yimin and Lei 2003). China has an enormous asset in the form of Chinese engineers and scientists who went abroad, and their return or involvement in the maturation of the Chinese educational system can contribute significantly to the continuing development not only of the Chinese software industry, but also to the Chinese university system. These efforts will be important for China, and will position the country to increase its contributions to the international science and engineering community.

Much of the effort to develop the Chinese software industry is directed at serving the emerging domestic market which is expected to be enormous. Nevertheless, China has participated in and will continue to develop an export market as well, especially to Japan but also to the United States. It is not yet clear how these multiple goals of domestic and export markets will play outso far as education is concerned. Large efforts to localize international software, for example, may call for skills that are not readily transferable to export market work.

7-4 US Education

The US IT educational system is complex and regularly changing. Because the IT market is so large and varied, the United States can support a number of different types of educational programs. There are, for example, five major types of undergraduate degrees alone. More traditional baccalaureate degrees in computer science, computer engineering, and information systems have been joined recently by degree programs in software engineering and information technology. A number of universities are experimenting with new interdisciplinary programs at both the graduate and undergraduate levels. For-profit universities, corporate universities, and certificate programs also play important roles in this complex educational system.

Mainstream Education

Educational programs at many levels prepare graduates for computing jobs. Terminal associate degrees are typically vocationally oriented, often leading to certification in the use of particular technologies. At the other end of the spectrum, doctoral programs prepare graduates for research careers and advanced development. Masters degree programs run the spectrum from the vocationally oriented to serving as a precursor to doctoral study. But in the United States, a baccalaureate computing degree is the typical preparatory program for entry into the computing profession, producing the largest number of graduates. Therefore, we focus most of our attention on these programs.

In 2001-02, the last year for which comprehensive degree production statistics are available, there were 47,299 bachelors degrees conferred in computer and information sciences, a category that includes mainly computer science degrees but also degrees in other computing areas (Zweben 2005). During the same year, there were 30,965 associate, 16,113 masters, and 750 doctoral degrees conferred.

Baccalaureate computing degrees exist under many different titles. The different names frequently invite confusion among students, employers, and the general public. These can be boiled down to five major types: Computer Science (CS), Information Systems (IS), Information Technology (IT), Software Engineering (SE), and Computer Engineering (CE). The computing professional societies have drafted influential model curricula for these five undergraduate degree programs, which have some commonalities, as indicated in Table 4. Accreditation criteria related to computing are in general accord with the model curricula.

While Table 4 shows the similarities of these baccalaureate programs, Table 5 compares their distinguishing features. We can see that there are overlaps between these five programs but each has its own distinctive characteristics.

How well do these programs keep up to date with current needs? Individual computing programs undergo regular change within their respective institutions. Annually, programs incorporate new areas and update course content in existing areas of their curricula. These changes tend not to change the overall character of the program, but they do keep the program up to date with technical developments.

Model curriculum updates have been less frequent. These model curricula, prepared by committees of the computing professional societies (e.g., Association for Computing Machinery, IEEE Computer Society, Association for Information Systems), have been updated about once a decade. The updating process typically takes several years of work and involves scores of people. The process contains many review points. Input is solicited not only from the academic community but also from industry. International input has also been provided in most of the more recent curriculum efforts. Nevertheless, the updating process is largely driven by members of the US academic community and, when completed, reflects mainly the concerns and interests of that community. Curriculum updates tend not to change the fundamental character of the programs. The most recent update adds two new program areas, software engineering and information technology. It also incorporates newer topic areas into the three existing programs. The review process results in many useful changes that address both content (such as new emphasis on networks and databases and reduced attention to compilers) and pedagogy (such as a new emphasis on breadth in the introductory course). These changes help to keep the curriculum more up to date, but the overall structure of the program areas tends to bear great similarity to their predecessors. That is not to say the process is broken. It seems reasonable that many fundamentals remain unaltered from one update to the next.

Table 7-4: Common Skills and Topics in Computing Baccalaureate Programs

- **A foundation in both concepts and skills related to computer programming (understanding of the concept of an algorithm, an ability to implement an algorithm, basic software engineering principles);**
- **An understanding of the possibilities and limitations of computing technology (what current technologies can and cannot accomplish, limitations of computing, impact of technology on individuals, organizations, and society);**
- **The concept of the life cycle of a computing system; the relationship between quality and life cycle management;**
- **The concept of process, both computing process and professional process involving human resource deployment;**
- **Development of interpersonal communication skills, team skills, and appropriate management skills;**
- **Exposure to an appropriate range of case studies and applications;**
- **Attention to professional, legal, and ethical issues;**
- **A capstone project experience.**

Source: The Joint Task Force for ComputingCurricula (2005)

Table 7-5: Characteristics of Different Baccalaureate Computing Programs

Type	Definition	Emphases	History	Number in US
Computer science	Define and implement software, devise new ways to use computers, develop effective ways to solve computing problems	Algorithms, complexity, programming languages, mathematical foundations, programming fundamentals	Began in 1960s. Commonly emerged out of math or electrical engineering, occasionally out of business schools	At almost every college and university (more than 2,000 accredited)

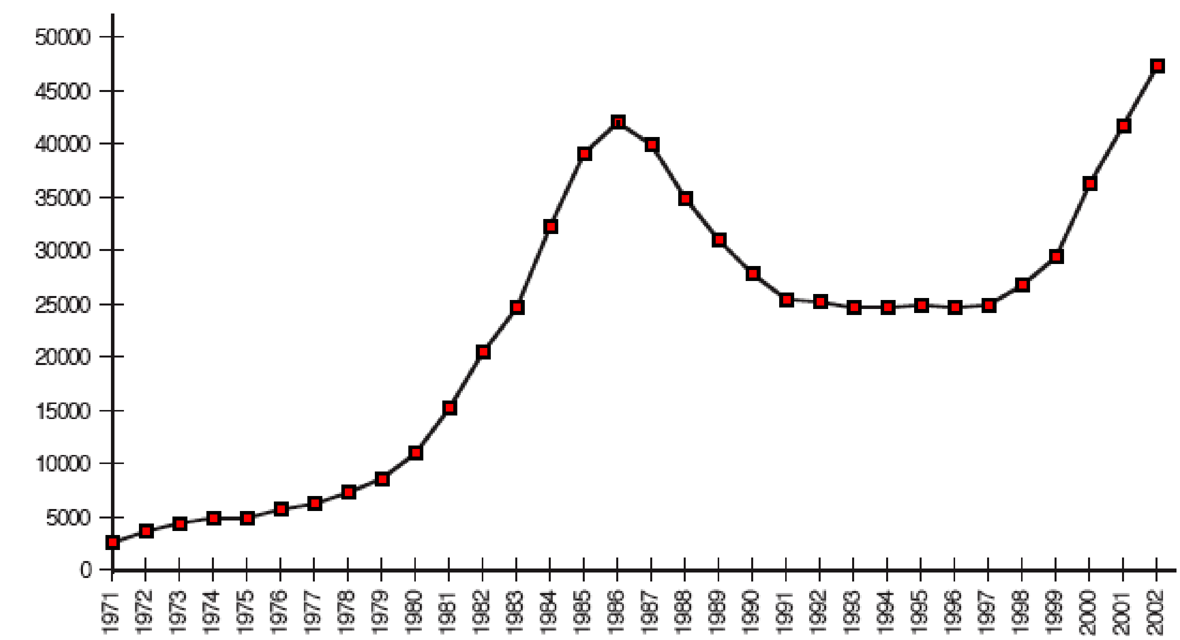
Information systems	Integrate IT solutions and business processes to meet the information needs of businesses and other enterprises	Information, incorporating technology as an instrument to generate, store, and distribute information; business processes related to information	Began in the 1960s. Most emerged from business schools.	1,000
Computer engineering	Design and construction of computers and computer-based systems	Hardware, software, communications and their interactions; computer architecture, computer systems engineering, circuits and systems, electronics	Originated in the 1970s and 1980s. Emerged typically from electrical engineering departments	175 ABET accredited departments
Software engineering	Development and maintenance of software systems so they behave reliably and efficiently, and are affordable to develop and maintain	Programming fundamentals, software design, software modeling, software validation, project management	First departments in the 1990s. Emerged typically from CS departments.	30 (6 accredited)
Information technology	Meeting the needs of end users with business, government, healthcare, schools, and other organizations	Technology, societal and end user context, practical issues of operating computing systems	Most departments formed since 2000.	70 (just beginning accreditation process)

Sources: The Joint Task Force for Computing Curricula (2001; 2004a; 2004b; 2005), Gorgone (2002), ABET (2004), CAC and CSAB Criteria Committees (2005), Zweben (2005)

The most recent updates to the model computing curricula began just before 2000. The computer science curriculum was revised in 2001, information systems in 2002, and computer engineering in 2004. The first software engineering model curriculum was introduced in 2004, and the first IT curriculum is currently under review. Thus a lot of progress has been made in the past few years. However, during this update period, the job market has changed considerably. For example, the dot-com boom ended and the offshoring of jobs became a public concern during a period of economic recovery that was creating new jobs at a historically low rate (the so-called jobless recovery). These updated curricula do not directly address the offshoring issue.

Perhaps the most notable change has been the serious drop-off in student enrollments in undergraduate computing programs in the United States. Figure 1 shows national enrollment data for computer and information science bachelor degrees from 1971 through 2002 (the most recent year for which this data is available). It is apparent that there were periods of rapid growth in the first half of the 1980s and again in the late 1990s, while the late 1980s had a significant drop-off in computing bachelor degrees awarded.

Figure 7.1: Baccalaureate degrees in computer and information science.

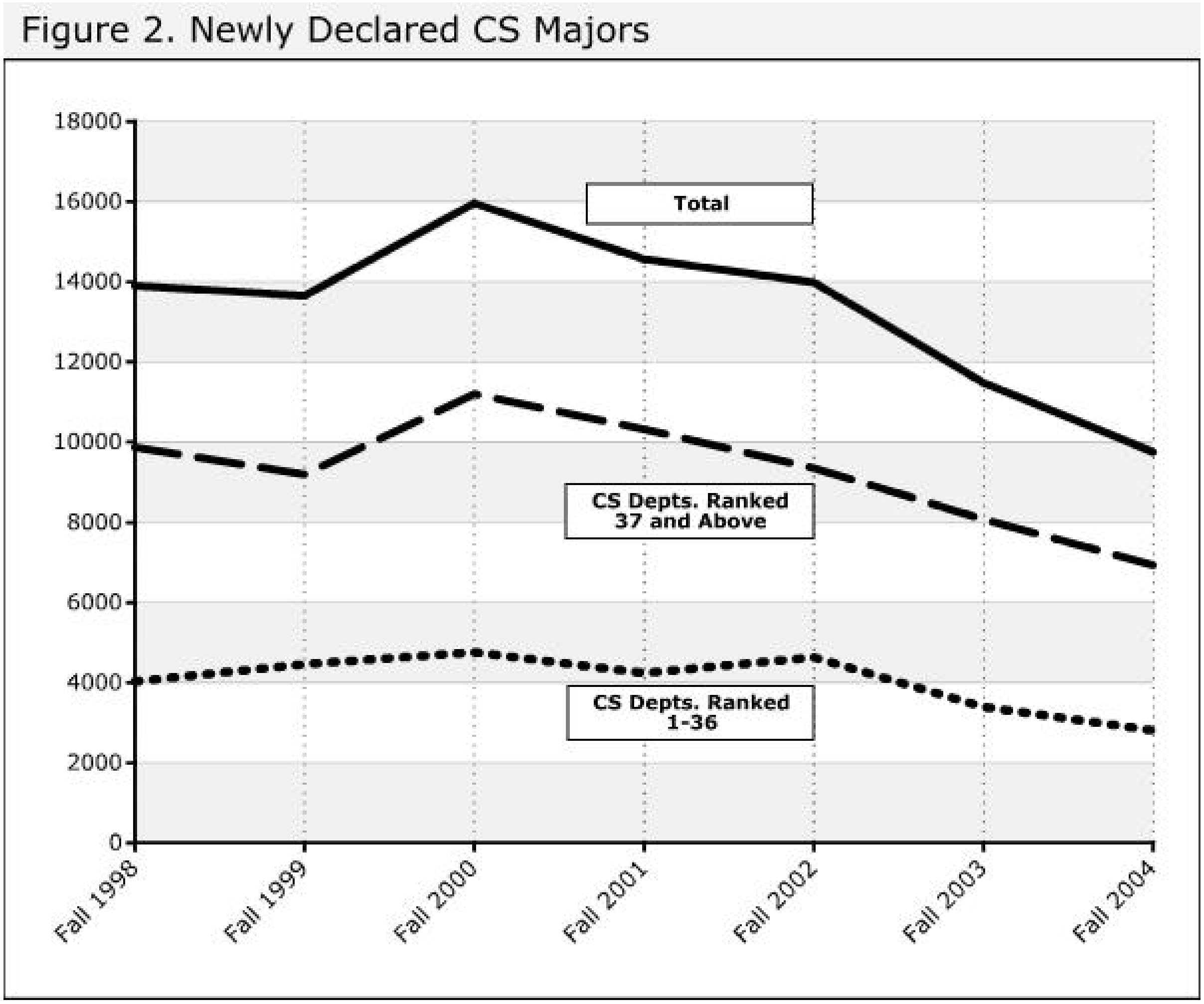


Source: National Center for Education Statistics, *Digest of Educational Statistics 2003*, Table 252.

To gain an idea of what has happened more recently, one needs to consider a different data set. The Computing Research Association Taulbee Survey provides data on baccalaureate degrees awarded by PhD.-granting computing departments in the United States. A historical comparison of national (NCES) and Taulbee data shows that the numbers reported by the Taulbee survey closely match the up and down paths of the national data over time, with the Taulbee numbers amounting to approximately one-third of the national numbers; thus one would expect trends in one would be mirrored in the other. The advantage of the Taulbee data is that it is more up to date. The recent Taulbee data, as presented in Figure 2, shows a serious decline in students entering US computer science baccalaureate programs at PhD-granting Institutions from Fall 2000 to Fall 2004.

Further evidence of the loss of student interest in computing careers is shown in a national survey of college freshmen that is regularly conducted by UCLA, as reported in Figure 3. It shows a precipitous drop in interest among freshman in selecting computer science as their major.

Figure 7.2: Newly declared CS majors.



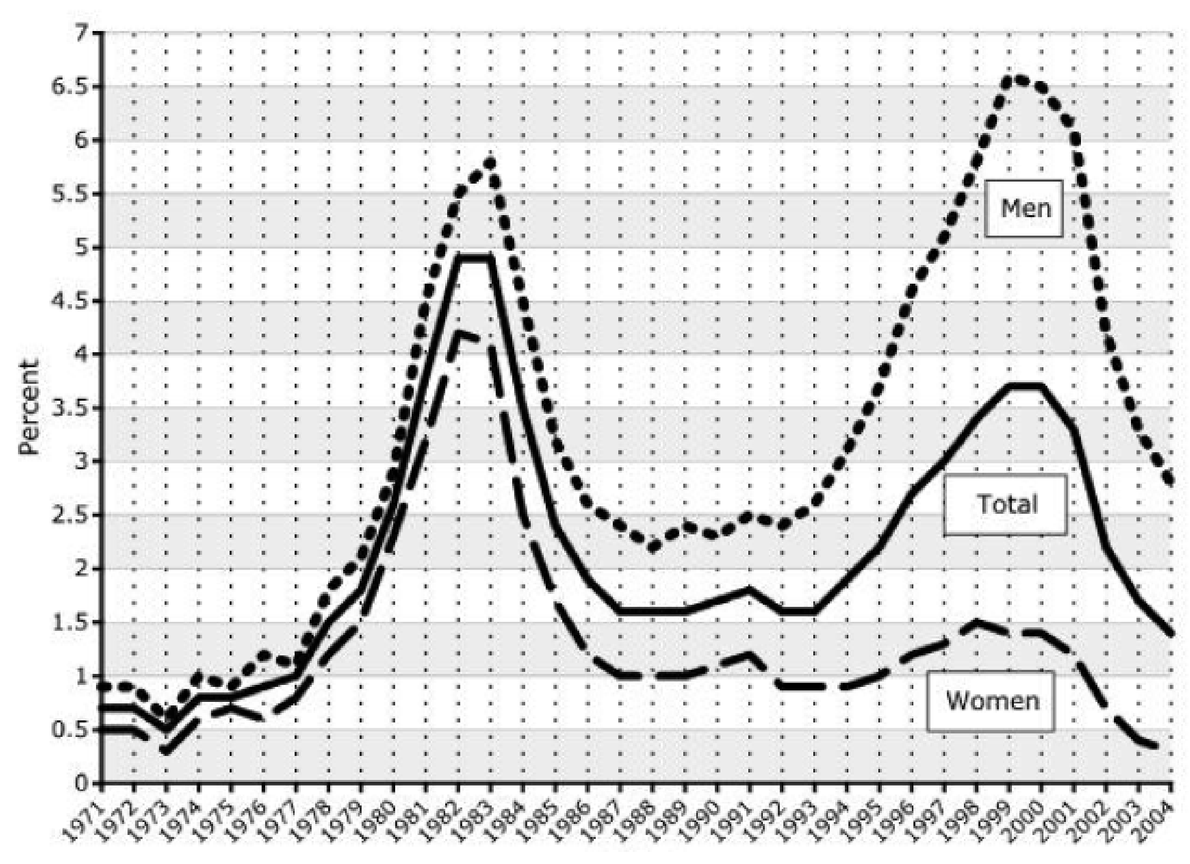
Source: Computing Research Association

The data in Figure 3 is principally about computer science programs. Less reliable reports indicate that information science and computer engineering undergraduate enrolments grew in the late 1990s and fell in the past several years. Software engineering and information technology programs have not witnessed such declines as far as we know, but they are recently created and still in the process on growing in number and size.

Rapid increases or rapid decreases in enrollment are difficult for most universities to handle because of the long-term employment contracts to faculty and the sunk costs in infrastructure and laboratories which are overtaxed/underutilized in times of rapid student enrollment growth/decline. Students receiving computing degrees represent only one part (estimated at about a third) of the IT workforce in the United States (Wardle 2002, chart: Employment as a Function of Training and Area), but they are the most important source of IT workers because they not only represent the largest single source of these workers but also overwhelmingly fill the high-skill technical jobs.

Because of the importance of rapid undergraduate computing enrollment shifts (either up or down) to university planning and national worker supply, a number of groups have studied the causes for these rapid changes (Freeman and Aspray 1999; NRC 2001). The rapid growth in student enrollment in the early 1980s and late 1990s has closely followed the rise of the personal computer and the commercial Internet. Thus it might be that students' personal knowledge of and enthusiasm for these technologies drove the steep ramp-up in student enrollments.

Figure 7.3: Freshman intention to major in Computer Science.



Source: Higher Education Research Institute at UCLA, as cited in Computing Research News, May 2005.

Another possible explanation is that many of the students are vocationally motivated in their choice of major, and the increase in enrollment in the late 1990s was tied to the possibility of a good job, or the lure of wealth through stock options during the dot-com era. We hear various anecdotal reports of high-achieving students claiming there are better opportunities elsewhere than in IT, for example, in law, finance, entertainment, medicine, or some other professional field. The vocational reason works better than the knowledge/interest reason at explaining the drop-off in enrollments between 2000 and 2004. There are at least two possible reasons why students would believe their vocational opportunities in IT are not strong and, therefore, would not choose a computing major. One is the highly publicized dot-com crash that gives students and parents the impression that there no longer are jobs available in high tech start-ups. Another possible explanation is the press reports of Americans losing their jobs through offshoring.

The evidence about why students perceive a lack of career opportunity in IT is not strong. A 2004 survey of over 1000 high school teachers by the Computer Science Teacher Association revealed that teachers believe offshoring is the biggest reason for student disenchantment with a computing career. But this is the teachers' perception of student beliefs not a survey taken of the students themselves. A report by Andrea Foster in *The*

Chronicle of Higher Education (May 27, 2005) states that "undergraduates blame the field's anemia mostly on news-media reports of the technology jobs moving to developing countries." However, Foster seems to have based this claim on the UCLA (HERI) report cited (see Figure 3) which reports intentions but not reasons for them, and on some anecdotal remarks, not on solid research.

Another reason sometimes put forward for the low undergraduate computer science enrollments is the response from computer science departments to rapid enrollment growth in the late 1990s. Departments had trouble coping with the higher demand and, in response, set higher grade point averages for admission, made introductory courses more demanding, or established other filters or barriers to enrollment. These barriers are still in place in many departments, despite lower demand.

One final possible explanation has to do with the quality of teaching and the nature of the material that is taught. High school curricula have changed in the last decade to focus on languages (primarily Java) and paradigms (object-oriented programming). The introductory college computing course also typically focuses on teaching the more modern object-oriented style of programming such as Java, in part because students who mastered these tools could readily find employment (at least in the 1990s). However, these tools are somewhat difficult for faculty to teach and students to learn especially compared to tools and skills taught in introductory courses in other science and engineering disciplines. The preparation of high school teachers who are teaching computer science has been an issue for many years, but the complication introduced by these new programming languages has made the quality of instruction even more problematic. Many high schools have eliminated computer science courses perhaps because it is so hard to teach, but there may be other reasons as well such as not being part of the performance canon under the No Child Left Behind initiative, and not being sanctioned as part of the core college preparatory curriculum.

We do not have good data to sort out how significant these different reasons are. It is likely the reasons vary from student to student, and that multiple reasons are in effect as students make decisions about their college major and career. As we showed in Chapter 1, this perception of decreasing job opportunities in IT does not match the actual numbers of jobs existing between 1999 and 2004, nor is it consistent with the Bureau of Labor Statistics projections for job growth over the coming decade. The BLS data suggests strong job opportunities now and in the future.

Bill Gates, in his tour of several universities during the past year, expressed concern about the future availability of skilled workers in the face of these declining enrollments. Companies such as Microsoft that are developers of computing technology used throughout industry have an ongoing need for workers with strong technical skills. Computing programs that are strong on the technical side such as those in computer science, software engineering, and computer engineering are likely to continue to be of interest to such companies. Jobs in the IT sector account for only about ten percent of the IT jobs in the United States. There are, however, numerous technically oriented jobs in IT departments in companies in other sectors of the American economy.

Innovative Approaches to Computing and IT Education in the United States

The previous section discussed the traditional courses of study in computing in US higher education. Beyond these academic departments, a variety of new academic units at the school or college level that are related to computing and information technology have begun to emerge in the United States, largely in the last decade. A wide range of motivations exists for the formation of these units. Two primary motivations seem to be:

- Structural. This includes computer science departments that have become sufficiently large or diverse enough to evolve into schools or colleges, as well as existing schools or colleges with a different mission (particularly library schools) that transform themselves into something more oriented to modern information technology.

- Innovation. This generally involves creating a new unit to meet new educational and research needs.

In almost all cases, however, whether curricular innovation or meeting new educational needs were the initial driving factors behind the formation of these new units, they are turning out to develop new curricular approaches which are impacting the breadth of computing and information technology education in the United States.

The remainder of this section presents a simple categorization of these new academic units related to computing and information technology in the United States. For each category, we list a small number of examples, and briefly mention curricular programs that characterize some of them at the undergraduate and/or graduate level. The categorization used here is arbitrary and others are possible. The point of this material is not the categorization but the examples of new educational approaches that are contained among them.

1. Schools and colleges of computing, computer science, computer and information science, and related names that include the degree programs in computer science as one component. In a number of cases, these units evolved directly from departments of computer science that either grew large enough to become separate colleges or had a vision to broaden their scope. Among the major US research universities, leading examples include the School of Computer Science at Carnegie Mellon University, the College of Computing at Georgia Tech, the Faculty of Computing and Information Science at Cornell, and the Donald Bren School of Information and Computer Sciences at the University of California, Irvine. Many additional examples exist, some of which are motivated by collaborations with local software and data processing industries, such as the College of Information Technology at the University of North Carolina, Charlotte, and the College of Information Science and Technology at the University of Nebraska, Omaha.

2. In all of these units, either initially or over time, the curriculum and undergraduate or graduate degree programs have expanded beyond traditional computer science offerings. For example, the School of Computer Science at Carnegie Mellon, in addition to its Department of Computer Science, contains a number of institutes and centers in areas including robotics, human-computer interaction, language technologies, and entertainment technology. Each of these centers offers academic programs, including an undergraduate major in human-computer interaction, a masters in entertainment technology, and masters and doctoral programs in robotics, language technologies, and human-computer interaction. Georgia Tech's College of Computing includes (beyond computer science degrees) an undergraduate major in computational media offered jointly with the School of Literature, Communication and Culture, a Masters degree in information security, a Masters degree in human-computer interaction, and a doctoral degree in human-centered computing. The School of Information and Computer Sciences at UC Irvine includes undergraduate degrees in informatics and in information and computer science, in addition to computer science, and computer science and engineering. At the graduate level, beyond the standard computer science degrees, it includes a large set of specialized masters degrees: in arts, computation and engineering, embedded systems, knowledge discovery in data, and network systems, and a doctoral degree in network systems. The College of Information Technology at UNC Charlotte offers degrees at all three levels in computer science and in software and

information systems. These examples are indicative of the breadth of curriculum that is emerging from these types of academic units.

3. New schools and colleges that are separate from computer science (and information science) programs and fill an additional need in the computing and information technology space. Two examples of recently formed units at major research universities include the School of Informatics at Indiana University's Bloomington and Indianapolis campuses, and the School of Information Sciences and Technologies at Penn State University. The School of Informatics at Indiana includes an undergraduate major in informatics that combines core courses in informatics or computer science with the study of a cognate area chosen from a broad range including biology, communication and culture, fine arts, psychology, and many others. It also includes masters programs in bioinformatics, chemical informatics, human-computer interaction design, and music informatics, and a PhD. in informatics that includes these and other areas of research including cyber security, social study of information technology, and health informatics. Penn State offers an undergraduate major, as well as masters and doctoral degrees in information sciences and technology that are aimed at blending technology, applications, and human, social, and organization factors.

4. Information schools which, in almost all cases, evolved from library schools. Many major universities have transformed or converted a previous school of library science, or a similarly named and focused school, into a school that studies information, information and library science, or the like. There are over a dozen examples in the United States, including the School of Information Management and Systems at the University of California, Berkeley, the College of Information Science and Technology at Drexel University, the School of Information and Library Science at the University of North Carolina, the College of Information Studies at the University of Maryland, the School of Information at the University of Michigan, the School of Information Studies at Syracuse University, the School of Information at the University of Texas, Austin, and the Information School at the University of Washington, simply to demonstrate both the geographic scope and the range of names.

   Many of these programs had a heritage of offering masters degree programs and are evolving to offer a broader range of curricula and degrees. Two examples give some sense of the scope and areas these academic units cover. Generally speaking, these programs tend to cover library and information science and management, and other areas including human-computer interaction, information retrieval, and social study of information and information technology. The University of Michigan's School of Information offers a masters in library and information services; archives and records management; information economics, management and policy; and human-computer interaction. It also offers a PhD that allows research specialization in any of these areas as well as on topics including digital libraries and digital publishing. The Information School at the University of Washington has developed an undergraduate major in informatics and a PhD degree in information science; these supplement masters degrees in library and information science, and information management.

5. Campus-wide multidisciplinary information technology institutes aimed at fostering collaboration of faculty and students across departments, and complementing students' traditional educational programs. Examples include the ATLAS (Alliance for Technology, Learning and Society) Institute at the University of Colorado, Boulder, and the Renaissance Computing Institute at the University of North Carolina at Chapel Hill, operated jointly by Duke University and North Carolina State University. The ATLAS Institute offers a certificate in Technology, Arts and Media that is available to students in all majors, and is developing an interdisciplinary PhD in Technology, Media, and Society.

It is premature to know what impact, collectively, these new or transformed academic units and their new educational programs will have on the software and information technology industries. As a gross generalization, these programs represent an approach to educating students at the cross-section of information technology, a wide range of applications, and human factors. The typical student in these programs does not receive as much technical training as the typical student in computer science or computer engineering, but the mix of skills and perspectives they contain appears likely to produce students well-suited for upper-level jobs involving the application of IT to a business or some other application area. Thus, they are likely to become a useful educational option from the perspective of both students and employers.

It is interesting to consider why this educational innovation could not take place in the traditional departments. While there is some of this kind of innovation in traditional academic departments, they are usually organized to reflect disciplinary boundaries that have as much to do with methodology and approach as with the problem domain. Computer science departments that emerged from engineering or mathematics departments typically retain a preference for quantitative methodologies based on well-established theoretical underpinnings. Such departments find it hard to understand, much less evaluate, the work of faculty whose disciplinary traditions involve human factors (such as human-computer interaction) and where the underlying methods are from design and social science more than from engineering or mathematics. Thus, people who work in areas such as human-computer interaction or the more business-oriented side of IT have difficulty getting hired and promoted by those departments, reducing the level of breadth and flexibility those departments can achieve. Introducing larger structures such as schools of computing in which this large dynamic range of methodologies can be accommodated offers institutions a strategy for getting beyond this problem. Nevertheless, it should be noted that some computer science departments have embraced the broader view of computer science and have welcomed faculty members in human-computer interaction and other less traditional areas of computer science.

Alternative Education

Degree programs in traditional colleges and universities are not the only kind of IT education in the United States. There are non-degree courses offered by traditional colleges and for-profit organizations, certificate programs, training associated with specific technologies, and corporate training programs, for example. There are also degree programs offered by for-profit universities. These alternatives to traditional degree programs appear to be growing rapidly, but it is difficult to quantify their extent or growth. Students enroll in these non-traditional programs to achieve many different goals: training for a specific IT career, career advancement within the IT field, move from a non-professional to professional IT job, continuing education to keep technical skills current, or gaining specific product information or usage skills. For more information on these programs, see Freeman and Aspray (1999, chapter 6).

The success of these institutions clearly indicates a demand for technical education that the more traditional higher education system is not meeting. That these programs have had strong success in technical areas presumably is due to at least the following four factors.

1. The short-term return on technical training is easy for potential students to recognize. The DeVry University web page claims that "for the 10-year period ending June 2004, 91 percent of DeVry graduates who actively pursued employment or who were already employed when they graduated, held positions in their chosen fields within six months of graduation." In terms of immediate employment prospects, this record presumably seems good in comparison, for example, to graduates in the humanities from an Ivy League college. Particularly in an economy that seems increasingly focused on

maximizing short-term gains, the fact that students do the same is not surprising. There are questions, however, about whether that short-term focus is likely to bolster the development of the kind of knowledge and habits of mind that are useful over the full expanse of a career.

2. There is high demand in industry for people with the skills these institutions provide. The for-profit universities could not survive in the marketplace unless there were jobs available for their graduates. The growth in the marketplace and the projected growth over the coming decade is discussed in Chapter 1.
3. Traditional institutions lack the capacity to meet the demand for technical training. The niche that the for-profit universities occupy in technical areas certainly emerges in part from the inability of universities and other components of the traditional educational system to keep up with the demand. It also comes from a university culture that discourages programs whose main goal is the development of specific skills whose value is likely to be short-lived.
4. These institutions are able to respond more rapidly than traditional universities to market demands, both in terms of numbers of students (whether the numbers are increasing or decreasing) and also the demand for new topics to be taught. Most of these non-traditional education providers do not have long-term fixed labor contracts, for example, nor do they have time-consuming review processes for new courses.

There are more than 1,000 corporate universities in the United States. They help provide life-long learning to their employees and to their suppliers and customers. Offerings of the corporate universities differ from the basic training offered by traditional universities; instead they provide education and training in the skills that the company believes these people need most at that particular time. It might be technical training, background information about the company or its industry, or core competencies such as learning skills, communication and collaboration, creative thinking and problem solving, global leadership, or career self-management. Sometimes the corporate universities offer courses themselves, sometimes they arrange for approved vendors (specific universities or private training companies) to offer courses on their behalf, often online through the company intranet. For more information on this subject, see Meister (1998).

A recent study by the American Association for the Advancement of Science and the Commission on Professionals in Science and Technology (Malcom et al. 2005) provides useful information about non-traditional educational pathways to an IT career, including the for-profit universities such as Strayer University, DeVry University, and University of Phoenix. Their study cites one report that as many as 1.5 million higher education students, 1 in 12 students now studying, are in for-profit universities rather than traditional colleges and universities although only about one-sixth of the students in these for-profit institutions are enrolled in four-year-degree programs. The for-profit universities are growing in enrollment about three times as fast as traditional colleges and universities. In 2001, six of the ten schools that produced the most bachelor degrees in information technology and computer science in the United States were for-profit universities. This is completely unlike the situation in other science and engineering disciplines; the largest producers of baccalaureates in physical science, biological science, or engineering tend to be the large, research-oriented state universities.

The for-profit universities have a different profile and mission than the traditional universities. For-profits are usually accredited by regional higher education organizations, attesting to the fact that the institution meets minimum standards for university-wide infrastructure and practices, but not by technical accrediting bodies such as ABET which check on the minimum standards of quality for particular degree programs. There is more of a focus on technical training than on broad-based education, but many do offer four-year information technology or computer science degrees. Instead of retaining a full-time faculty, the for-profit schools generally hire faculty on a course-by-course basis. There is no tenure system and no research conducted. The previously mentioned AAAS-CPST study quotes a New York Times article describing what the students seek in attending the for-profit schools: "quick-and-to-the-point coursework, customer service, small classes, convenience, and an education that leads to employment."

The for-profit universities advertise heavily for non-traditional students. According to the Department of Education (as described in the AAAS-CPST study), non-traditional students have one or more of the following characteristics: delayed enrollment, part-time attendance, full-time employment, dependents, and six or more years to complete a degree. These programs have higher percentages of women and minorities than the traditional programs do, and the student population tends to be older, more mature, and have attended at least one other college or university previously. Statistics show that the students at for-profits tend to work for companies that are not in the IT sector. Students with this profile often used to matriculate at two-year public community colleges but competition for admission to the community colleges is getting stiffer with traditional students trying to save money by completing the first two years of their baccalaureate degree there.

Although it is difficult to get good data, certification training is an important and growing part of the IT education and training marketplace. Certification indicates that an individual has achieved a certain level of proficiency in a narrowly-defined technology area. It became popular with employers during the dot-com boom because it was a way to provide training within a focused area at lower cost and in a shorter time compared to traditional education. Many individuals enroll in certification training programs for the training, not the credential, and in fact, in 2000, only about one quarter of those who were trained ended up being certified (Gartner survey as reported in Prometric 2001). As of 2002, there were approximately 100 vendors, offering at least 670 separate certifications in information technology according to the National Research Center for Career and Technical Education (Moncarz 2002). There are also numerous community colleges and four-year colleges offering certificate programs. National Center for Education Statistics data shows that awards for study lasting less than one year grew almost 400 percent between 1990 and 2000.

Certification tends to be of two types. Most commonly it is focused on a particular vendor's product, but sometimes it is focused on a technology area or occupation such as network administrator. While companies that employ IT workers occasionally do their own certification, it is generally left to the vendor (for example, Cisco providing Cisco certification), a third-party company offering specific vendor technology, or a professional or industry group offering certification in a technology area. Programs of study leading to a certificate are sometimes offered by two-year colleges but seldom by traditional four-year colleges or universities. Certification in various Microsoft products is by far the largest area of certification. As of summer 2002, there were more than one million Microsoft Certified Professionals and 450,000 Microsoft Certified Systems Engineers. Some of the other vendor companies whose products are subject to certification include IBM, Sun Microsystems, Hewlett Packard, and Apple. One professional group that has a popular technology certification program is the Computing Technology Industry Association (CompTIA) which has awarded more than 100,000 certificates in it's A+ certification program for computer service technicians where they are tested on basic computer hardware and software.

There are sometimes complaints about certification training especially from employers who pay the cost for their employees (Moncarz 2002; Prometric 2001). Common complaints are that:

- certification does not substitute for practical experience,
- costs have become exorbitant,
- it is more important for the employees to learn about the products they actually sell than about the technical details of the tools or infrastructure embodied in a Microsoft or Cisco product,
- the certification programs do not guarantee the certified employee has good problem-solving skills involving the technology,
- certification courses take employees away from too much work time, and
- certification can make employees more attractive to other employers and confident of their own abilities and thus encourage employee turnover.

Individuals tend to enroll in certificate training programs to learn a specific technology, get career advancement in their current workplace, find a job, or increase their salary. Certification seems to be most successful for career advancement in the areas of technical support and network administration (ITAA 2004). Salary with the same employer and job typically increased only 5 to 7% after completing the certification; however, median compensation for a certified employee averaged 25% higher than for a non-certified employee (The Association of Support Professionals 2001).

7.5 European Education

Traditionally, the European education systems (except for perhaps the United Kingdom) are quite different from those in the United States. Changes under the Bologna Declaration which is an attempt to unify the educational system across Europe has a target that is similar to American higher education, but there will nevertheless continue to be important differences between the US and European educational systems. After discussing the changes that are taking place across Europe as part of the response to the Bologna Declaration, this section presents a brief account of IT education in one European country, Germany, as it exists today, and draws some comparisons with degree programs in the United Kingdom.

It is not our intention to claim that we give a complete account of German IT education, that IT education in other European countries is carried out just like it is in Germany, or that these different countries are experiencing the same enrollment trends. For example, computer science enrollments are continuing to grow in Spain by an estimated 4% annually, presumably because the educational system, which historically did not have sufficient capacity, is continuing to expand, while in most of Western Europe, traditional computer science enrollments have dropped steeply over the past several years, though there have been modest gains in enrollment in newer IT disciplines such as telecommunications and bioinformatics. Nevertheless, we believe that the reader can gain an appreciation for some of the differences between European and American IT education as they relate to offshoring from this brief account. The German model is an important one for Europe, for the German-speaking countries which have similar IT educational programs, represent approximately a quarter of the European population.

The Bologna Declaration

The Bologna Declaration is aimed at coordinating university education across countries, especially the graduation process, by adopting the consecutive structure of the bachelor’s degree (3 to 4 years) and the master’s degree (additional 1.5 to 2 years), followed by doctoral studies (2 years or more) and lifelong-learning initiatives. Thus the plan is to adopt a system already well known worldwide. The Bologna Declaration was driven primarily by the European governments, but it was a bottom-up initiative, coming mainly from university management and education ministers responsible for research and education. It has been adopted by forty countries, mostly European, and has relatively strong support from university management in these countries. The process is to be completed by 2010. Today, nearly all of the universities in Europe are in the process of changing their educational systems to follow the regulations of the Bologna Declaration (some more rapidly than others). Here are the main goals.

(i) Introduction of a compatible graduation scheme across the European countries that supports the mobility of students and graduates (workforce), and attempts to conform to worldwide standards for the degree and graduation sequence (a consecutive scheme with a bachelor's degree followed optionally by a master's degree), also to support mobility. In the past, European countries had many different incompatible schemes. To further support mobility, a unique scheme to regulate student workload, known as the European Credit Transfer System (ECTS), has been introduced across Europe. Accreditation agencies have also been established to insure the quality standards of the programs at the participating universities.

(ii) The introduction of a bachelor's degree that would provide students with a formal graduation after three years of study and be recognized by all institutions that follow the Bologna Declaration. This contrasts, for example, with the current German system in which a student receives the Diplom after no less than 4.5 years of study, but more typically after five or six years. There is an examination part way through the course of study in the German system which results in the Vordiplom for students who successfully complete it. However, institutions in other countries do not recognize the Vordiplom as a formal degree that qualifies the student for the next level of education.

(iii) The bachelor's degree, followed optionally by a master's degree, is seen as an entry point for international students especially from developing countries where it is common for bachelor courses but no master courses to be available. Before Bologna, these students were often forced to begin their studies anew, in the first semester of a diploma course. A growing number of European universities today use English as their language of instruction. This and perhaps other factors have led to a steady growth in the percentage of foreign students enrolling in these programs.

The Bologna Declaration stimulated other reforms in European education. These included, for many schools, reducing the length of time required to receive the first degree; a new system of continuous examinations (mid terms and finals) for every course instead of concentrated examinations after several years; and support for e-learning.[1]

The Bologna Declaration's greatest impact on computer science has been to start new interdisciplinary and specialized studies within European universities. The initiative has been directed in part at preparing an international workforce for the knowledge economy, and many universities are responding to the need for a growing number of computer science graduates with domain-specific knowledge.

As in the United States after the end of the dot-com boom, the number of students in traditional computer science programs decreased. It is typical in Europe that much software development is carried out in the context of embedded systems, for example, in the

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[1] The goal of e-learning is to use electronic devices (personal computers, CD-ROMs, digital televisions, PDAs, and mobile phones) to provide learning wherever the student is located. E-learning can provide not only Internet and email delivery of instruction but also more interactive learning through collaborative software, online discussion forums, and team learning systems.

automotive or aerospace industry sectors, but there is also software development in the biomedical, chemical, life science, and telecommunications areas as well as in the banking, finance, and insurance industries. Many job opportunities, therefore, require domain-specific knowledge in addition to computer science knowledge.

Because of this, many universities have started to include application-specific courses into computer science or offer combined degrees such as bioinformatics, medical technology, computational physics, computational chemistry, and computational science and engineering. These new programs have attracted some students away from traditional computer science where enrollment numbers have typically been down over the past few years.

However, there is some dispute over the Bologna Declaration. Critics argue that the traditional homogeneous model of university education leading to a diploma after nine semesters has considerable advantages over having separate curricula for the bachelor's and master's degrees. The TU-9 initiative, representing the nine leading and largest technical universities in Germany, takes an opposing position to the Bologna Declaration, doubting that it is possible to provide the students a professional qualification for an IT job within a three-year bachelor program. It is unclear whether there will be modifications in the Bologna Declaration over time.

What are the possible impacts of the Bologna Declaration on offshoring? It may be that Bologna will lead to more uniformity in the content as well as the formal structure of degree programs across Europe. If education in Eastern and Western Europe become more similar, the short-term effect is likely to be an increase in the amount of near-sourcing as a result of the wage differential. (There are, however, good reasons to believe that there will continue to be national differences in education after the Bologna Declaration has been completely implemented as the example of the United Kingdom and Germany that follows illustrates.) However, economic theory suggests that, over the long-term, wage rates would even out somewhat between Eastern and Western Europe, eventually making near-sourcing less attractive.

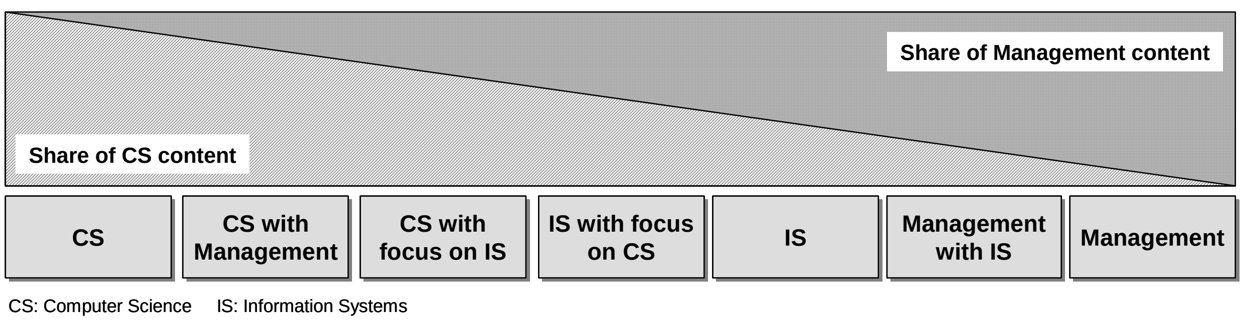
German IT Education

At the moment, even in the presence of the Bologna Declaration, there is considerable variation in IT study programs across Europe, and it is difficult to compare them. In the United Kingdom, for example, courses in information systems were offered as conversion courses for graduates whose first degree was in a discipline other than computing; this is now referred to as *vertical integration.* The aim of these programs was to provide a competence in computing disciplines and in the business applications of information technology. In general, they did not provide a deep knowledge of either the computing discipline or the engineering aspects of information systems. With the acceptance of benchmark standards for masters degrees, this situation has changed but the concept of vertical integration of certain kinds is still accepted and seen as desirable (and is much discussed). In contrast, the German programs, both before and after the Bologna Declaration, tend to have an integrated structure that anticipates that the master's students will have studied the same subject (often at the same university) in their bachelor's program. Having this integrated structure enables the German system to go into greater technical depth, but it makes it more difficult for students from another undergraduate major, or even the same major from a different university, to enter into the master's program.

To take one other example where the UK and German degrees are different, consider business informatics (in German, Wirtschaftsinformatik). The German degree has a strong focus on mathematics, logic, operations research, and statistics, and focuses mainly on information system architecture. Graduates are expected to be able to actively and systematically design business information systems. The German course of study includes detailed modules on such business topics as accounting, logistics, marketing, production management, and human resources. In contrast, the UK course of study in business informatics focuses more on the alignment of business strategies and information technology. The UK programs tend to include more electives, giving the students more opportunity at the master's level to specialize their education (Helfert and Duncan 2005).

Information systems programs in German-speaking countries have a longer tradition than information systems programs at US universities. Graduates of these programs in Germany are typically well prepared for development work on commercial software packages. This characteristic is often regarded as one of the advantages of the German education when compared to those in developing or low-wage countries. In recent years, more and more computer science programs have been enriched by elements of information systems, and more and more management programs have been combined with parts of computer science and information systems. At a number of German universities, for example, the job descriptions for academic positions in computer science departments have been modified in this direction in recent years. By choosing the electives, students can flexibly position themselves along a spectrum of different preparations, ranging from pure computer science without any components of management education to management without computer science elements (see Figure 4). So they may adapt to the actual requirements of the job market in the last part of their studies (real-time specialization).

Figure 7-4: Combination of computer science and management contents in university education.



There has been a shift in enrolment from computer science to information systems in Germany. Between 1998 and 2003, the computer science enrollments declined by 20%, while those for information systems climbed by the same percentage. Nonetheless, today three times as many German students study computer science as study information systems. Many European countries, including France, Italy, and Spain seem to be following this same enrollment trend away from computer science and towards information systems especially in the business computing programs (informatique de gestion) in France.

Table 6 shows how educational programs relate to skill requirements of software production as they are practiced at the German software company SAP. (We omit the selling of the systems from this discussion.) Many graduates of German universities take jobs with SAP or its customers, and because of its sheer size, growth, and leadership, many economists and educational policy leaders in Germany pay close attention to SAP's employment practices including its policies about near-shoring and offshoring.

Both computer science departments and management schools within universities frequently cooperate with large software houses that produce business application systems. The tight cooperation of software companies such as SAP and universities has a manifest influence on computer education in Germany. It enables the universities to organize a curriculum in which computer science, information systems, and management specialists can collaborate with practitioners. Through this kind of collaborative education, Germany seems to have an advantage over low-wage countries such as India and China, and maybe even over the United States.

Table 7-6: Education Needed for IT Work at SAP

Departmental-level Activity	Educational Training
BASIS (basis technology): build transaction mechanisms, data bases, data warehouses, cache memory optimization, knowledge warehouses, generic expert systems, human-computer-interaction, etc.	Typically a computer science degree
Software development - organized along economic sectors or industries (e.g. automotive, construction, pharmaceutics/chemicals, banking, public administration ...) or functions/processes (human resources, logistics, accounting, Strategic Enterprise Management ...).	Typically an information systems degree
Development of special algorithms such as Advanced Planning Systems, genetic algorithms, neural networks, optimization of production, production planning or transportation.	Typically a math, operations research, or management science degree
Development of architectures such as NetWeaver or Business Process Platform.	Typically requires teams of people with computer science, information systems, and business administration degrees
SAP Consulting: customizing and regulating the manifold of interdependent parameters (e.g. selection of priority rules, forecasting procedures, service delivery levels, safety stocks, Available-to-Promise-mechanisms in Supply Chain Management, etc	Typically requires information systems and business administration degrees

The European education systems provide the opportunity to learn a second and often third foreign language. The majority of management, computer science, and information systems students tend to participate in internships in English-, French-, or Spanish-speaking countries, and, increasingly, they take internships in China. In this way, students are prepared to take part in projects of firms located in countries with cultures and languages different from the one they grew up in.

Educational Implications of European Near-Sourcing

The Western European countries such as Germany, Austria, and France send a lower proportion of their offshoring to India than the United States does because of the presence of near-shore alternatives in Eastern Europe. (See Chapters 1 and 3 on near-sourcing.). As a result of the geographic proximity, and because of language and cultural affiliations, cooperation on larger projects between software producers in Austria, Germany, and Switzerland and software companies in Eastern Europe (or between France or Spain and countries in North Africa, e.g., Tunisia) are entirely possible. Convenient train service between Western and Eastern Europe minimizes travel time to between one and six hours, depending on the particular cities in question. The actual migration of workers from Eastern to Western Europe where many of these Eastern European computer scientists have received their education also reduces the need to send work across national borders. Nevertheless, a number of large and medium-sized German software producers choose to send components of their projects to Eastern Europe. Thus specialists and managers in the industrialized countries cooperate with those in Eastern Europe or North Africa instead of with India or China. Figure 5 depicts a typical model of labor division as it exists today. This partition of labor evolved in a kind of trial-and-error process through the efforts of Germany's leading producer of individualized software, sd&m (software design & management). Since this model can be applied to many different projects, the German IT Association (BITKOM) recommends it as a kind of reference model (BITKOM 2005; Taubner 2003).

Figure 7.5: Division of labor between industrialized and offshore / near-shore countries.

What? / Where?	Industrialized Country			Offshore/Near-shore Country		
Specification	X	X	X	X		
Construction	X	X		X	X	
Coding	X			X	X	X
Implementation and Integration	X	X	X	X		
Service and Maintenance	X			X	X	X

X = Share of work

Figure 5 represents the current situation. It would probably be difficult today to find a sufficient number of firms in Eastern Europe that have sophisticated application systems that could be used for the practical education of students during their internships. This implies that the Eastern European educational systems are, at the moment, best prepared to train students for jobs in lower-value work such as coding and maintenance, while the Western European countries are better prepared than the Eastern European countries to train their students for jobs involving higher-level tasks such as specification and implementation. This division in occupational preparation (and IT career opportunities for their citizens) is likely to change over time because of the ambitions of the low-wage countries to climb up the value chain.

One of the reasons for the near-sourcing relationship between Eastern and Western Europe is the presence of Eastern European (and North African) workers who speak Western European languages. If there were greater emphasis on learning English-language skills, Eastern Europeans would be able to compete more effectively for offshoring work from the United States, the United Kingdom, Australia, and other countries that conduct their business in English; and the English-speaking countries represent the majority of offshore software work that is outsourced. Similarly, better English-language skills in the Western European workforce would give them access to the large population of offshoring firms in India, Malaysia, the Phillipines, Mexico, and some other places.

Small and medium-sized firms have difficulties with near-shoring and even greater difficulties with offshoring. A new kind of service provider is addressing these difficulties.

These providers work as a kind of intermediary between the firms and the vendors in lower-wage countries. In order to do their jobs effectively, they need workers who have not only IT skills but also a set of business skills, including:

- software engineering
- project management
- contract negotiation
- contract development
- finding, evaluating and controlling service providers (sourcing)
- assessment of local business conditions, e.g. taxation, costs, education, non-tariff trade barriers, security, fluctuations, labor legislation, data protection, power of unions
- assessment of cultural conditions, e.g., attitude towards quality

7.6 The Educational Response to Offshoring

As we described at the beginning of this chapter, the question of how best to educate students to become professionals in a field that is evolving as rapidly as computing and information technology is a challenging one. Offshoring aside, the rate of change in the computing and information technology profession may be as great or greater than in any other area that universities prepare students to enter. Determining how to respond to this change is a difficult problem for educational institutions particularly because they must balance the need to be responsive to the evolution of the field with the needs to provide a firm foundation and not to overreact to trends. Factoring in the additional evolution and change in the profession as practiced in any given country due to the dynamics of the global economy, that is, the segments of software and IT work that a particular country emphasizes and wishes to emphasize in the future, only increases the challenge for educational planning and delivery. Both the basic content of the IT field and the portions emphasized in the profession in each country can change quickly.

This chapter has discussed the current state of higher education in computing and IT, and how it is responding to a global software/IT economy in which offshoring is a major factor. It has done so from the viewpoints of India, China, the United States, and Western Europe. It has considered both how computing and IT education is responding to the fundamental changes in the field, and how offshoring is further impacting this education from the perspectives of countries that play different roles in the global software/IT economy.

Although the educational needs and issues may look different from different national or individual perspectives, six overarching principles emerge from the discussions of this chapter.

(1) There is a need to consider the levels of IT work that are predominant in the national or multinational economy being served by the educational institution and which are likely to be predominant in the future. The software and IT industry can be characterized by a series of skill levels, ranging from the more routine to the more complex, strategic, and innovative. For example, Andriole (2005) defines a five-tier system of IT work in business applications, consisting of support, infrastructure, enterprise business technology architecture, strategic business applications, and business strategy. This classification is based in part on a series of interviews with technology managers and leaders conducted between 2001 and 2004. He draws a distinction between operational technology which can more readily be treated as a commodity and is prone to offshoring, and strategic technology

which is a competitive differentiator and less likely to be offshored. The first two tiers are in the commodity category, the final two in the strategic category, the middle tier is a combination of the two. His analysis applies best in the business context, and in a world where low-wage countries are more prone to take on low-skill rather than high-skill work. But his analysis shows that, in the context he considers, certain kinds of jobs are more likely to be sent to low-wage countries and other kinds of jobs are likely to remain in a high-wage country. The educational consequences of this point of view are discussed under principle (5).

Another point, emphasized by Drezner (2004) and others, is that work that has been made routine and commoditized is also work that is most likely to be subject to automation. It has not happened to a large degree yet, but routine programming might be handled in the future with automated software tools. It does not matter whether a job is lost to a person in another country or to a machine as far as the worker is concerned. Certain kinds of jobs are less likely to be automated as discussed in detail in Chapter 1. Although the wage rate affects the equation, it can make economic sense to automate in low-wage as well as high-wage countries.

For software and IT work, in general, an analogous concept to that defined by Andriole for business IT exists. That is, software and IT work can be thought of as consisting of a spectrum from the more routine (e.g., system and computer maintenance and support, basic programming) through the more advanced (e.g., application programming that requires knowledge of IT and specific applications whether business, science, engineering, media or otherwise, or sophisticated systems programming and IT architecture development) to the advanced strategic level (development of approaches that utilize IT to advance the organization strategically and provide it with a competitive advantage).

As computer science and IT curricula are developed, particularly at the national and global level, it is important to consider these levels of software and IT work and identify which levels the curriculum is intended to prepare students for. In procuring countries, it may be desirable to focus the curriculum more heavily on the lower levels. This may vary, however, as the roles played by IT professionals in these countries evolve, and the provider companies aim to perform higher-level work. In countries that are sending their commodity IT work offshore, it will be desirable for the curriculum to prepare students for the middle and upper levels of IT work where the ability to merge computer science and IT with applications and strategy are important. This is likely to lead to an increased emphasis on application knowledge and conceptual understanding and a reduced emphasis on routine programming skills. It should be stressed that, in all cases, however, the predominance of a certain level of IT work in a certain country or region is just a generalization; all levels will exist in all countries, and students will be needed to move into all of these levels. It is the distribution that will vary.

(2) There is a need for computing/IT education to evolve whether due to globalization or not. The skills and talents needed by software and IT professionals have evolved over the past decades independent of the issue of offshoring. In general, IT professionals are more likely to work in an application-specific context than previously, and conversely, less likely to work in computer-specific areas such as compiler or operating system development. They are more likely to work on large software applications in teams that include applications specialists, and, depending on the organization, may also collaborate with sales and marketing staff. They are also more likely to work in an environment where they are expected to be masters of certain software platforms and interoperability standards and know how to reuse code. Thus in general, it will be increasingly important that a computer science or IT education involve training and conceptual material that enables the student to work on large-scale software applications; understand important business, scientific, or other application areas; and be familiar with the tools and platforms that are increasingly

the standards in the international marketplace. It also is increasingly important that the education emphasize teamwork and communication skills especially as they are practiced in a geographically distributed fashion. In order to develop and implement good planning concerning how to update IT education, it would be good to collect data about the relation between various educational choices and career outcomes. Given the importance of the model curricula prepared by the professional societies and the rapid changes in IT, it is worth considering a process that updates the model curricula more than once a decade and that has more industry input to balance the academic input into the curriculum revision process.

(3) There is a need for education to begin to prepare students for a global economy and its possible impacts on their careers. It is increasingly likely that an IT professional will be working in a global context. This may include being part of a multinational team or collaborating with customers or suppliers from other parts of the world. Thus, it will be increasingly important that an education in computer science and IT help prepare students for this global workplace. Education that acquaints students with different languages and cultures, whether through courses, study abroad, or other means, will be increasingly beneficial. One possibility is international internships for students so that a student from a developed country could spend a summer or a year working in an IT environment in a developing country or vice versa. Finally, to the extent that English is the universal language, the ability of countries to educate their IT professionals to be fluent in English will be a major factor in determining their success in the outsourcing economy and in multinational endeavors

If one had a crystal ball and could determine the changes that offshoring and, more generally, globalization will make to the software industry, it would of course be much simpler for everybody involved to figure out what action to take. One of our reviewers suggested the following scenario: "One perspective that goes beyond 'move up the value chain' is really to think 50-100 years ahead and imagine a world in which barriers to knowledge work are low but cost-of-labor disparities have largely equalized. What would drive value then? I would suggest it consists of specialization, clustering, the ability to leverage the global system through cooperation, and the ability to connect capabilities with results. Education and policy can affect these." (anonymous review, edited)

*(4) Educational systems that help prepare students to be creative and innovative will create advantages for those students and their countries***.** As the lower tiers of software and IT work become more commoditized, creativity and innovation will become even more important, particularly in countries that experience the loss of support and programming work. The creation of new products and new businesses will continue to lead to the greatest commercial and scientific successes, and even more, will serve as the differentiator between organizations and between countries. Historically, some educational systems are seen as fostering creativity in students more successfully than others. One crucial differentiator in fostering a creative mentality in students is the research component of the educational system and the participation of students at all educational levels in research activities. Another differentiator is the degree of rote learning versus more open problem solving. Countries that currently have an advanced research enterprise in their university systems may increasingly see this as their greatest competitive advantage in educating computer science and IT students for the higher tiers of the IT workforce. Countries that do not include a research component in their university systems will need to consider whether strategically the investment in developing this component and culture is needed to attain their goals for the IT economies in their countries. Teaching research and innovation should not be left to the research universities alone. In the United States, small liberal arts colleges with limited research efforts prepare a disproportionately high number of the

country's scientists and engineers. There is a place for innovation and research in the undergraduate curriculum.

(5) Educational systems that not only pay attention to current business and industry needs but also provide a core foundational knowledge will create advantages for those students and their countries. To cite two national examples, the Indian educational system has been particularly good at teaching the latest technology that is needed in business and industry today. In contrast, the United States has been particularly good at teaching foundational knowledge that is likely to serve a student through most of his or her career. Foundation skills help students remain current and not become obsolete as the technology changes rapidly around them. Although the particulars of a new technology in the workplace may be different from what a student was taught in school, a basic understanding of computing principles and ways of addressing problems will remain current even as the particular technologies change.

There needs to be a balance between fundamentals and currently relevant technologies in the student's education. In order to prepare students to be productive workers when they enter the job market, it is important not only that the educational system teach fundamentals but also pay attention to the reality of life-long learning and to the current needs of business and industry, and that it select carefully the particular technologies it exposes students to in order to address these needs. Andriole (2005) argues, for example, that all IT students need to learn more about business, particularly about business strategy, business applications, and enterprise architecture for higher-end jobs, or about infrastructure and support for lower-level jobs. This could perhaps be done by spending a term at a business through a university cooperative program, for instance.

Placing the right balance and right materials in the curriculum is tricky and may vary from institution to institution, but it can be achieved through respectful interchange between people in the academic and industrial/business worlds. No IT education can possibly fulfill all of the student's educational needs for an IT career, however, and IT workers should expect to have to engage in life-long learning in order to keep up with the rapid pace of technological change and the rapid changes in the way that organizations employ information technology. This is particularly true in the US higher education system where baccalaureate students are required to study a breadth of courses and not spend all their time studying IT. To give further emphasis to a point made earlier in this section, what constitutes fundamental knowledge also changes over time and can change in response to such exogenous factors as offshoring.

(6) A good educational system requires the right technology, a good curriculum, and good teachers. Fortunately, personal computers are relatively inexpensive, software for them has been commoditized, and fast broadband communication is readily available at low cost in most places in the world. Thus, the technology for training an IT workforce is within reach of much of the world. The model curricula that have been designed by the professional societies have been and should be used as important reference points in many places around the world. There is probably value in developing a process by which these curricula can have greater business and industrial input and react more rapidly to changes in the way that IT gets used in the world. Although adopted around the world, the model curricula have been designed primarily for degree programs in the United States. If the professional societies really aspire to be world bodies and develop world curricula, they should pay attention to the needs of other countries and their degree programs as well. These might include a wide variety of IT jobs, including purely technical jobs but also including jobs enabled by the use of IT such as business or knowledge process outsourcing.

The teacher problem may be the most difficult one to address. For example, in India, critics complain that the general quality of the IT faculty is poor, salaries are low, and there are no funds to enable research by the faculty members or their students. In the United States, there are serious problems with the preparation of high school teachers who introduce students to IT, and several times in the past (in the late 1970s and again during the dot-com boom), American universities had difficulty recruiting and retaining quality faculty because of the lure of industrial IT positions and the inadequate number of students obtaining doctorates which are required to become faculty members. If the curriculum is to change to contain more business knowledge or knowledge of other application domains, it will be that much harder to find faculty members with the right combination of technical and domain-specific skills, or to manage an academic enterprise that has people with different disciplinary backgrounds. Certainly academic teams and cooperation between faculty members is part of the answer but not the whole answer. Inducements to improve the quality of the faculty would be helpful in India, the United States, and other countries. Inducements include not only good salaries and working conditions, but also funding for research and access to good doctoral programs for training the next generation of faculty members. The United States has attracted a large number of faculty members in its computing departments from developing countries, such as India and China. As IT globalizes, there will be more and more competition for this talent. Thus, the United States and other developed nations will be in a position where they must compete harder to attract talented faculty.

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