Networking and Information Technology Workforce Study: Final Report

Presented to:
NITRD- The Federal Networking and Information Technology Research and Development Program

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ACRONYMS

Symbol	Definition
ACM	Association for Computing Machinery
ACM-W	Association for Computing Machinery's Committee on Women in Computing
AP	Advanced Placement
AIS	Association for Information Systems
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
BPO	Business Process Outsourcing
BPT	Business, Professional, and Technical
CEPIS	Council of European Professional Informatics Societies
CISE	Directorate for Computer and Information Science and Engineering
CITREP	Critical Infocomm Technology Resource Program (Singapore)
CMU	Carnegie Mellon University
CompTIA	Computing Technology Industry Association
CPATH	CISE Pathways to Revitalized Undergraduate Computing Education
CPS	Current Population Survey
CRA	Computing Research Association
CS	Computer Science
CSTA	Computer Science Teachers Association
DoD	Department of Defense
EE	Electrical Engineering
EITO	European Information Technology Observatory
ICT	Information and Communications Technology
IDA	Infocomm Development Authority of Singapore
IEEE	Institute of Electrical and Electronics Engineers
ILO	International Labor Organisation
ISCED	International Standard Classification of Education
IT	Information Technology
ITE	IT-Enabled
ITEST	Innovative Technology Experiences for Students and Teachers
ITAA	Information Technology Association of America
JFEO	Japan Federation of Economic Organizations
KAIT	Korea Association of Information & Tele-communication
KISDI	Korea Information Society Development Institute
METI	Japanese Ministry of Economy, Trade, and Industry

MEXT	Japanese Ministry of Education, Science and Technology
MGI	McKinsey Global Institute
MIC	Japan Ministry of Internal Affairs and Communications
MoE	Ministry of Education
MOECC	Computer Center of the Ministry of Education
NAEP	National Assessment of Educational Progress
NAICS	North American Industry Classification System
NCES	National Center for Education Statistics
NCWIT	National Center for Women and Information Technology
NIT	Networking and Information Technology
NITRD	Networking and Information Technology Research and Development
NRC	National Research Council
NSA	National Security Agency
NSB	National Science Board
NSF	National Science Foundation
OECD	Organisation for Economic Co-operation and Development
OES	Occupational Employment Survey
PCAST	President's Council of Advisors on Science and Technology
PISA	Programme for International Student Assessment
S&E	Science and Engineering
SESTAT	Scientists and Engineers Statistical Data System
SIGCSE	Special Interest Group on Computer Science Education
STEM	Science, Technology, Engineering, and Mathematics
TIER	Taiwan Institute for Economic Research
TIMSS	Trends in International Mathematics and Science Study
URM	Underrepresented Minority

1. INTRODUCTION

1.1 Study Description

This report presents the results of a study of the global Networking and Information Technology (NIT) workforce undertaken for the Networking and Information Technology Research and Development (NITRD) Program. The objective of the study was to review existing data and literature and interview experts to analyze NIT workforce issues facing the United States and its likely global competitors over the next decade. This chapter provides some background regarding the study and defines key terms and concepts. The following chapters address specific NIT workforce issues.

1.2 Study Background

In 2007, the President's Council of Advisors on Science and Technology (PCAST) published a report reviewing the Federal Networking and Information Technology Research and Development (NITRD) Program.[1] The second chapter of this report examines NIT workforce issues and presents a number of findings related to:

- Demand: "Over the coming decade, US demand for networking and information technology professionals, with the exception of some readily outsourced or technologically outdated jobs, is likely to grow more rapidly than for most other employment categories. The new job openings are expected to offer higher than-average salaries and benefits."[2]

- Supply: "Although the overall supply of networking and information technology specialists is expected to grow in response to the growth in total demand, at current rates of enrollment and graduation, shortfalls in the numbers of highly qualified computer scientists and engineers graduated at the undergraduate and doctoral levels are likely. Women and other underrepresented groups will constitute a declining proportion of the new graduates."[3]

- Curriculum: "Networking and information technology curricula in general, and computer science curricula specifically, do not adequately meet employer and student needs."[4]

Based on these findings, the PCAST present a number of recommendations. This includes a call for a study of the NIT workforce:

> To provide a solid basis for subsequent action, the NITRD Subcommittee should charge the NITRD National Coordination Office to commission one or more fast-track studies on the current state of and future requirements for networking and information technology undergraduate and graduate education.

[1] PCAST (2007)
[2] PCAST (2007), p. 19
[3] PCAST (2007), p. 21
[4] PCAST (2007), p. 22

Drawing upon the knowledge of leaders from academia, professional societies, industry, and government, the project should address:

- **The expected supply of and demand for NIT professionals over the coming decade, with a focus on women and other underrepresented groups**
- The current state of and future requirements for curricula in NIT fields, with special attention to computer science and to the integration of computer science with fields that apply computer science
- Public and student perceptions of NIT fields and what might be done to improve those perceptions
- **Comparisons with other nations**[5]

The NCO for NITRD commissioned this study to address the first and last bullet points in this list.

1.3 Study Topics

In response to the PCAST recommendation above, the NCO for NITRD outlined a statement of work that included two tasks and a number of questions to be addressed under each task. The first task included questions about the NIT workforce in the United States. The second task included many of the same questions regarding comparisons with other nations. We organized these questions into the eight study topics below.

Table 1.1: Study Topics and Questions

1. Expected Demand for NIT Professionals
What is the expected demand for NIT professionals over the next decade? (by occupational field, citizenship status, and industry/sector)
What are the trends in US and global NIT workforce levels and future demand that are attributable to globalization and outsourcing?
2. Supply of NIT Students and Faculty
What are the trends in the numbers of students in NIT education programs at all levels of education? (US citizens in US programs; foreign nationals in US programs; foreign nationals in home country programs; US citizens in foreign programs)
What are trends in NIT teachers and faculty at all levels of education? (pre-college: elementary, middle, high school, undergraduate; graduate)
3. Pathways to NIT Careers
Where in the educational system or culture do students begin to learn about or take an interest in NIT?
Where do students lose interest in NIT?

[5] PCAST (2007), p. 23

What claims have been made about the prevailing reasons why students lose interest in NIT? What models exist that claim to address these reasons?
Are there data about the impact of teachers and family as role models in NIT education and career choices of students?
4. NIT Career Choice Trends and Pathways
What are the trends in NIT degree recipients that pursue traditional NIT careers, non-traditional NIT careers, and careers not focused on NIT?
What are the pathways for individuals moving from non-computing disciplines to transition into the computing professions?
5. Trends in US NIT Education and Workforce Needs Attributable to the Expansion of NIT in Other Science and Engineering Disciplines
What are the trends in NIT education and workforce needs attributable to the expansion of NIT in other science disciplines such as biology, chemistry, physics, mathematics, and medicine?
6. Initiatives to Encourage Interest and Engagement in NIT Careers
What is being done to help encourage interest and engagement in traditional and non-traditional NIT education and career paths? (all levels of government, private industry, professional societies, academic institutions)
What are the recommendations from technical conferences, professional societies, study groups, reports from the computer gaming industry, etc., for future efforts to encourage interest, promote retention, and reduce attrition in traditional and non-traditional NIT education and career paths?
7. Trends in Programs that Facilitate NIT Career Transitions
What are the trends (including funding) in programs that facilitate students' transitions at each step in their educational and professional lives? (scholarships, fellowships, internships, job shadowing, co-ops)
8. NIT Best Practices in Attracting and Retaining Students and Professionals
What are examples of NIT programs and best practices successful in attracting and retaining students and professionals?
What are examples of programs in other disciplines that have been successful in attracting and retaining students and professionals?

This report addresses each of these topics in three chapters focusing separately on the US workforce, underrepresented groups, and international comparisons.

1.4 Country Selection

We selected seven countries/regions in addition to the United States to be included in this study. The selected countries/regions are:

- European Union
- Japan
- South Korea
- Singapore
- Taiwan

- China
- India

These countries were identified in the 2007 PCAST report as current and emerging NIT competitors to the United States. The European Union, Japan, South Korea, and China were chosen because they are in the top twenty in the world in GDP,[6] R&D expenditures,[7] number of triadic patents,[8] and Science and Engineering (S&E) Indicators of Technological Competitiveness.[9] These countries/regions have both the economic strength and science and technology infrastructure to compete with the United States.[10] Taiwan and Singapore were selected because they export large numbers of NIT goods and are in the top twenty of S&E Indicators of Technological Competitiveness. Additionally, these countries are seeking to improve their innovation in the NIT industry. India was chosen because it is largely focused on the NIT service sector and it benefits significantly from the outsourcing of NIT services from the United States. While it is not currently a strong competitor in NIT innovation, India is seeking to capitalize on its experience and workforce to move up the NIT innovation chain. Because of its large population, relatively strong education system, English language capabilities, and emerging NIT industry, India clearly is a major factor in the global NIT workforce. While these seven countries were the focus of this study, examples from other countries are presented in this report when they are relevant.

1.5 Methodology

This study researched the topic areas and countries above using three different but intertwined approaches. First, we conducted an extensive literature review on each of the topic areas in each of the countries of interest. This literature search examined the academic literature, government and industry reports, and the international press among other sources. At the same time, we collected relevant data from various databases such as the Bureau of Labor Statistics (BLS), the International Labor Organization (ILO), and the National Science Foundation (NSF). Lastly, we conducted over twenty interviews with experts from academia, industry, and government on NIT workforce issues. The interviews were designed to explore the issues identified in the literature in more depth and included discussions of future trends often not contained in the literature. We interviewed at least one individual from each of the countries/regions examined in this study.

1.6 Defining NIT

Networking and information technology (NIT) can be defined in many ways. For this study, we use the broad definition provided in the 2007 PCAST report:

[6] International Monetary Fund World Economic Outlook Database 2008
[7] OECD Factbook 2008: Economic, Environmental, and Social Statistics
[8] OECD Factbook 2008: Economic, Environmental, and Social Statistics
[9] NSF Science and Engineering Indicators 2006
[10] OECD Factbook 2008: Economic, Environmental, and Social Statistics

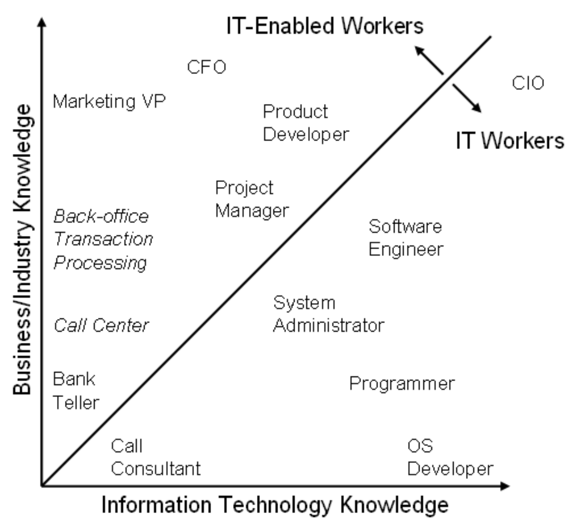
"Networking and Information Technology comprises the processing and communication of data and information and the hardware, software, and systems that perform those functions."[11]

The term NIT is not commonly used outside of the NITRD program. This is especially true outside of the United States. Therefore, in conducting this study, we had to be inclusive of a variety of terms that have similar meanings including information technology (IT) and information and communications technology (ICT/Infocomm). IT is the most commonly used term in the United States and is often assumed to include networking without an explicit mention. ICT is the most common term used outside of the United States. There is often some debate about whether communications fall under the term IT. However, given that the definition of NIT from the PCAST report specifically includes communication, we assume that NIT is equivalent to ICT and IT. These differences in definitions are important to keep in mind when comparing data from international and domestic sources. We try to be explicit in this report about the definitions used in each case.

1.7 Defining the NIT Workforce

The NIT workforce is also a term that can be defined in many ways. Many studies have tried to define a NIT worker but most are nearly a decade old and lack consistency.[12] One of the key distinctions regarding the NIT workforce is between IT workers and IT-enabled (ITE) workers. The term IT workforce is often used to refer to both IT and ITE workers. In this study, we focus only on IT workers. The best distinction between the IT and ITE workforce was made in a 1999 report by Freeman and Aspray,[13] as shown in Figure 1.1.

Figure 1.1: Distinguishing IT Workers from IT-Enabled Workers



Source: Based on Freeman and Aspray (1999)

[11] PCAST (2007)
[12] US Department of Commerce (1997), ITAA (1997), Freeman and Aspray (1999), NRC (2001)
[13] Freeman and Aspray (1999)

This framework distinguishes IT workers from ITE workers on two dimensions: business and industry knowledge and information technology knowledge. IT workers are defined by their greater core knowledge in information technology while ITE workers are defined by their greater core knowledge in business and industry. Under this definition, application developers and systems administrators are considered IT workers, while those that use IT platforms, such as marketing VPs and product developers, are considered ITE workers. This distinction is especially important internationally as many countries lump IT and ITE workers together, thereby including commonly offshored functions such as call centers and back-office operations in the IT workforce.

It is also important to define the skill level of the NIT workforce. A report on the IT workforce published by the National Research Council (NRC) in 2001 defined two types of NIT workers: category 1 and 2.[14] Category 1 IT workers were defined as those "involved in the development, creation, specification, design, and testing of an IT artifact, or the development of system-wide applications or services," who "relies heavily on conceptual ability and theoretical knowledge." Examples of category 1 workers include computer scientists, systems analysts, and programmers. These occupations typically require at least a bachelor's degree. Category 2 workers' "work primarily involves the application, adaptation, configuration, support, or implementation of IT products or services designed or developed by others." Examples of category 2 workers include help desk specialists, network administrators, and database administrators. These occupations typically require a high school diploma, certification, or an associate's degree. Many of the issues facing the category 1 and 2 NIT workforce are the same, but there are also important differences such as certification and the role of community colleges. The focus of this study is on the category 1 NIT workforce.

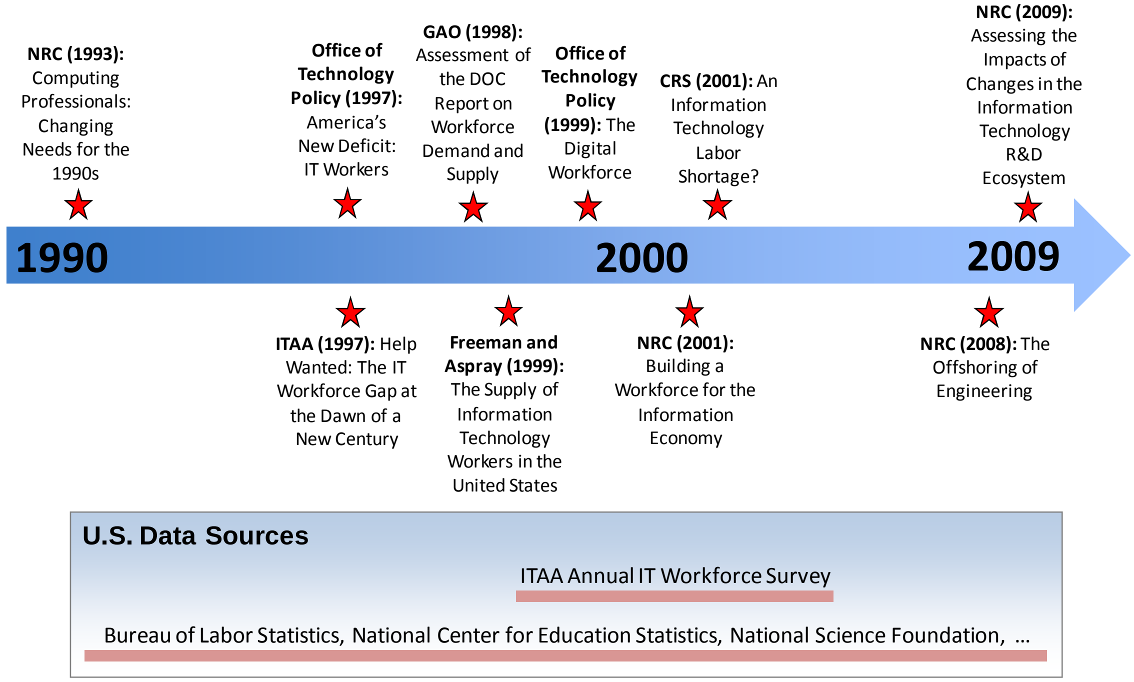
1.8 Literature Overview

The literature relating to the NIT workforce in the United States clusters around the year 2000. Between 1997 and 2001, numerous reports appeared about the IT workforce in the United States, but very little has been written since then.[15] The NRC published two recent reports that contain relevant information but do not directly address NIT workforce issues. Figure 1.2 shows a timeline of significant NIT workforce publications in the United States. This figure also includes a timeline of key workforce data available. Much of these data are continually compiled by the BLS, NSF, and the National Center for Education Statistics (NCES). The Information Technology Association of America (ITAA) conducted an industry survey of the NIT workforce survey for a few years but this ended in 2004.

[14] NRC (2001), p. 47

[15] The timing of the IT workforce studies coincides with the late 1990s IT industry boom when many were concerned with the adequacy of the supply of IT professionals.

Figure 1.2: Literature Timeline Overview



While this summary of the literature depicts only large reports addressing the NIT workforce, there have been numerous academic papers, news articles, and broader reports that address issues related to the NIT workforce. We have used these sources to provide as up-to-date a picture as possible of the current NIT workforce.

1.9 Relationship to Science and Engineering Workforce

Many of the issues facing the NIT workforce also face the broader S&E workforce. These include K-12 math and science education, underrepresented groups, and the career choices of undergraduates. There has been a significant amount of work done studying the S&E workforce, often producing conflicting results. Many of these reports have called for action to increase the supply and quality of S&E workers in the United States.[16] Others interpreted the data differently and concluded that such calls for action may be unfounded.[17]

Our examination of the NIT workforce shows that this same type of conflicting evidence is present. While the data we present are from reliable sources, they may be interpreted in many ways. Expert opinions also vary widely and tend to be highly correlated with the position of the expert (industry, academia, etc.). This study does not attempt to re-examine the broader S&E workforce issues. Where there are similarities to NIT workforce issues, we mention them to provide the reader with a sense of the relationships between these two closely intertwined issues.

[16] NSB (2003), Jackson (2003), Council on Competitiveness (2004), PCAST (2004), ITAA (2005), NRC (2007), Ezell and Atkinson (2008)
[17] Galama and Hosek (2008), Lowell and Salzman (2007)

2. NIT WORKFORCE IN THE UNITED STATES

The NIT workforce is a complex system that can be defined and categorized in many different ways. This chapter uses the definition provided in the previous chapter to describe NIT workforce trends in the United States. It covers the expected demand for NIT professionals, the supply of NIT students and faculty, the dynamics of the labor market, access to foreign talent, and efforts to increase participation in NIT careers.

2.1 Expected Demand for NIT Professionals

This section addresses the expected demand for NIT professionals over the next decade. We begin by describing the size and characteristics of the NIT workforce in the United States and then show how it may change over the next decade.

2.1.1 Size of the NIT Workforce

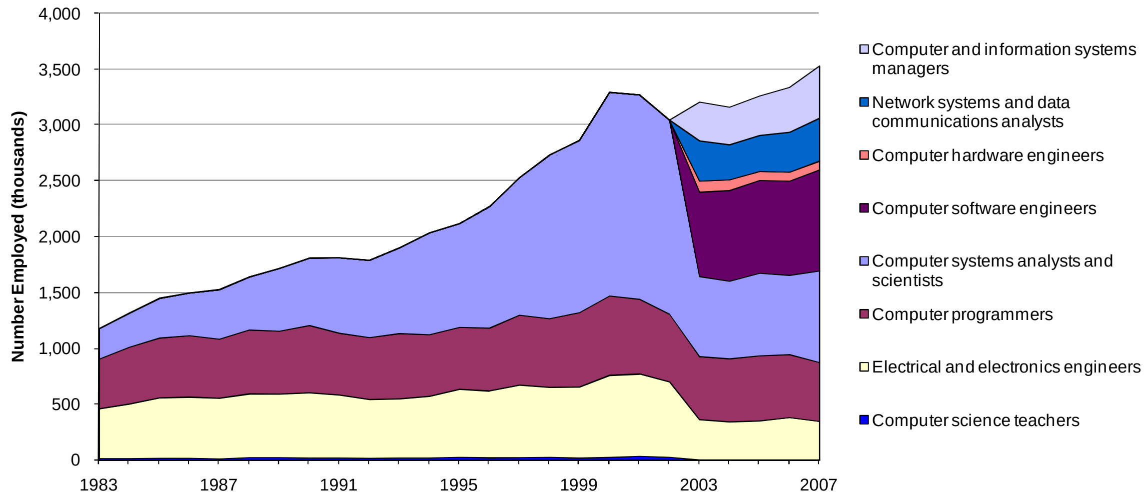
There are three sources of information for estimating the size of the NIT workforce. Two are compiled by the BLS and a third by the NSF. The first and most commonly used source is the Current Population Survey (CPS) that surveys households about their employment. The second is the Occupational Employment Survey (OES) that surveys establishments about their employees. The third source is the NSF's Scientists and Engineers Statistical Data System (SESTAT) that compiles data from a variety of surveys to estimate the size of the workforce in various occupations. The CPS is used most often because it is based on a single survey and includes individuals who are self-employed and not captured by surveying establishments. This section presents estimates from each source. Each of these sources classifies occupations according to job titles. This methodology is not the same as defining workers by the type of work they do as discussed in the 1999 Freeman and Aspray report but it is the only form in which employment data are publicly available in the United States.[18] It is important to note that BLS job classifications are typically based on occupations that existed five to ten years ago and thus do not adequately reflect the current occupations in fast moving fields such as NIT.[19]

2.1.1.1 Current Population Survey (CPS)

Based on data from the CPS, the size of the category 1 NIT workforce in the United States as of 2007 was about 3.5 million workers. Figure 2.1 shows the size of the category 1 NIT workforce from 1983 through 2007 broken down by occupation. Between 1983 and 2000, the category 1 NIT workforce grew at an average annual rate of six percent per year. The workforce shrank in size between 2001 and 2004 after which it rebounded and grew at an average annual rate of four percent between 2005 and 2007.

[18] Freeman and Aspray (1999)
[19] Expert interview

Figure 2.1: Size of the Category 1 NIT Labor Force Estimated from CPS in Thousands (1983-2007)



Source: Current Population Survey

To estimate the size of the NIT workforce, we selected the occupations from the CPS data that most closely matched the definition of a category 1 NIT worker discussed in the previous chapter. We had to define the category 1 NIT workforce differently for 1983-2002 and 2003-2007 because the Standard Occupation Classification (SOC) used by the federal government changed in 2003. The 2001 NRC report on the IT workforce defined the category 1 IT workforce to include the SOC occupations:

- computer systems analysts and scientists,
- computer programmers,
- electrical and electronics engineers, and
- computer science teachers.

We used these same occupations to define the category 1 NIT workforce from 1983 through 2002.[20] In 2003, the category previously titled computer systems analysts and scientists separated into five occupations: computer systems analysts and scientists, computer software engineers, computer hardware engineers, network systems and data communications analysts, and computer and information systems managers. Computer science teachers were no longer considered as a separate occupation after 2003. Table 2.1 shows the occupations we included in our estimate of the category 1 NIT workforce for 1999 through 2007 and the number of workers in each occupation.

[20] See the Department of Labor (DOL)'s O*NET website for detailed descriptions of the tasks, tools, knowledge, skills, abilities, work activities, work contexts, interests, work styles, and values for each occupation. (http://online.onetcenter.org)

Table 2.1: Size of the Category 1 NIT Workforce by Occupation Estimated from CPS in Thousands (1999-2007)

Occupation	1999	2000	2001	2002	2003	2004	2005	2006	2007
Computer systems analysts and scientists	1,549	1,829	1,835	1,742	722	700	745	715	825
Computer programmers	665	710	667	605	563	564	581	562	526
Electrical and electronics engineers	639	738	740	677	363	343	352	382	347
Computer science teachers	17	23	34	25					
Computer software engineers					758	813	832	846	907
Network systems and data communications analysts					359	312	322	356	383
Computer and information systems managers					347	337	351	401	467
Computer hardware engineers					99	96	81	80	79
Sum of category 1 NIT workers	**2,870**	**3,300**	**3,276**	**3,049**	**3,211**	**3,165**	**3,264**	**3,342**	**3,534**
Category 1 NIT workers growth rate	*5%*	*15%*	*-1%*	*-7%*	*5%*	*-1%*	*3%*	*2%*	*6%*

Source: Current Population Survey

The bottom row of Table 2.1 shows the annual growth rate in each year for the NIT workforce. There is substantial variation in growth rates, ranging from 15 percent growth in 2000 to declines in 2001, 2002, and 2004. The growth in 2003 is likely due a change in occupational definitions -- the inclusion of workers previously classified in other occupations -- rather than a real increase in the size of the NIT workforce. The changes in the size of the NIT labor force are consistent with the timing of the dot-com boom and bust.

Including a few category 2 occupations (computer support specialists, database administrators, and network and computer systems administrators) in the NIT workforce increases its size from 3.5 million to 4.2 million in 2007. The entire category 1 and 2 NIT workforce, which includes occupations such as health information technicians and electrical and electronics repairers, totaled about 5.8 million workers in 2007. The largest category 2 occupations are data entry keyers (449,000) and computer, automated teller, and office machine repairers (318,000). It is likely that the total category 1 and 2 NIT workforce is even larger than 5.8 million. NRC (2001) estimates that the category 2 NIT workforce was about the same size as the category 1 workforce in 2001.[21] Using this ratio, the total NIT workforce today would be comprised of about seven million workers. Developing a good estimate for the size of the category 2 NIT workforce is difficult as the distinction between IT and ITE workers is even less clear than it is for category 1 workers.

The fastest growing NIT occupation between 1983 and 2002 was computer systems analysts and scientists, growing at an average annual rate of ten percent per year. Between 2003 and 2007, the fastest growing occupation was computer and information systems managers, growing at a rate of eight percent per year. Two occupations have seen recent declines in the number of workers: computer programmers and computer hardware engineers. The number of computer programmers peaked in the year 2000 at 710,000 and has declined in each year since to 526,000 in 2007, a reduction of 26 percent from the peak. While this decrease is notable, some experts have noted that software engineers are very similar to computer programmers, and the number of computer

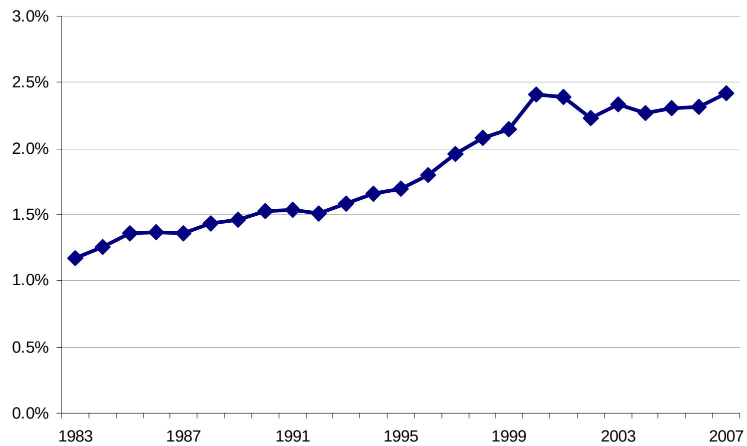
[21] NRC (2001), p. 61

software engineers has increased since it was included as an occupation in 2003 from 758,000 to 907,000 in 2007. Therefore, the decrease in computer programmers may simply be a shift from computer programmers to software engineers as the skill sets required by software developers move away from coding towards software design and project management.

Computer hardware engineer was first defined as an occupation in 2003 and their numbers have decreased almost 20 percent from 99,000 in that year to 79,000 in 2007. There does not appear to be any shift towards other occupations among computer hardware engineers as the number of electrical and electronic engineers, a closely related occupation, has also remained relatively flat since 2003.

The relative size of the NIT workforce is also increasing. Since 1983, the NIT workforce has doubled from about 1.2 to 2.5 percent of the labor force as shown in Figure 2.2.

Figure 2.2: NIT Workforce as a Fraction of the Total Workforce (1983-2007)



Source: Current Population Survey

This is an extension of longer-term trends in the growth of professional, technical, and kindred workers in the United States from about five percent of the workforce in 1910 to nearly 25 percent of the workforce by 2000. Engineers have also grown from 0.1 percent of the workforce in 1910 to nearly two percent of the workforce by 2000. Since 1960, computer specialists have grown from about 0.1 percent of the workforce to two percent of the workforce.[22] All of these trends show the US move towards a knowledge-based service economy.

2.1.1.2 Occupational Employment Survey (OES)

The OES does not use the same occupational classifications as the CPS. The OES defines more detailed occupations for computer systems analysts and scientists, electrical and electronics engineers, and computer software engineers. Table 2.2 shows how these occupation classifications correspond to those in the CPS.

[22] Wyatt and Hecker (2006)

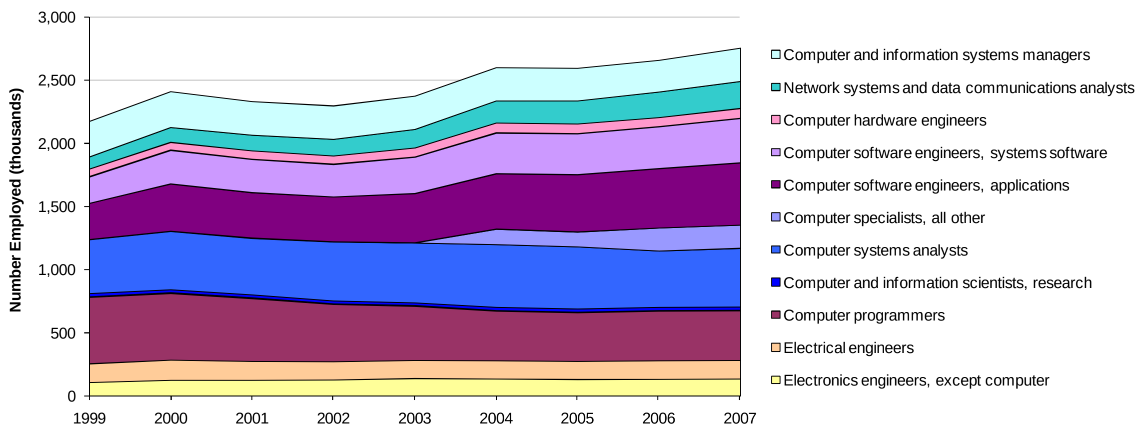
Table 2.2: CPS-OES Occupation Comparisons

Current Population Survey	Occupational Employment Survey
Computer systems analysts and scientists	Computer and information scientists, research
	Computer systems analysts
	Computer specialists, all other
Computer programmers	Computer programmers
Electrical and electronics engineers	Electrical engineers
	Electronics engineers, except computer
Computer software engineers	Computer software engineers, applications
	Computer software engineers, systems software
Computer hardware engineers	Computer hardware engineers
Network systems and data communications analysts	Network systems and data communications analysts
Computer and information systems managers	Computer and information systems managers

Source: Current Population Survey and Occupational Employment Survey

Using the OES data, we estimate that the size of the category 1 NIT workforce in 2007 was 2.8 million people as shown in Figure 2.3. This is likely lower than the estimate using the CPS data because OES data does not capture self-employed workers.

Figure 2.3: Size of the Category 1 NIT Workforce Estimated from the OES in Thousands (1999-2007)



Source: Occupational Employment Survey

Most of the trends in the OES data are consistent with trends in the CPS data. There are a declining number of computer programmers in both datasets (but a growing number of software engineers) while almost every other occupation is growing rapidly except for electrical, electronic, and computer hardware engineers, as shown in Table 2.3. Computer specialists were added as an occupation to the OES in 2004. Before 2004, these individuals were likely classified in other occupations both inside and outside of the NIT workforce.

Table 2.3: Size of the Category 1 NIT Workforce by Occupation Using OES (in Thousands)

Occupation	1999	2000	2001	2002	2003	2004	2005	2006	2007
Computer and information scientists, research	26	26	26	24	23	27	26	28	29
Computer systems analysts	428	463	448	468	475	497	492	446	464
Computer specialists, all other						121	117	180	183
Computer programmers	529	531	502	457	432	396	389	396	395
Electrical engineers	149	162	151	146	146	147	145	148	149
Electronics engineers, except computer	107	124	123	126	137	133	130	132	134
Computer software engineers, applications	288	375	362	357	392	440	456	473	496
Computer software engineers, systems software	209	265	262	255	286	321	321	329	349
Computer hardware engineers	60	64	68	67	73	80	79	74	79
Network systems and data communications analysts	98	119	126	133	148	177	185	204	216
Computer and information systems managers	281	283	267	265	266	264	259	251	265
Category 1 NIT workers	**2,175**	**2,412**	**2,334**	**2,299**	**2,378**	**2,603**	**2,599**	**2,661**	**2,759**
Growth in category 1 NIT workers		*11%*	*-3%*	*-2%*	*3%*	*9%*	*0%*	*2%*	*4%*

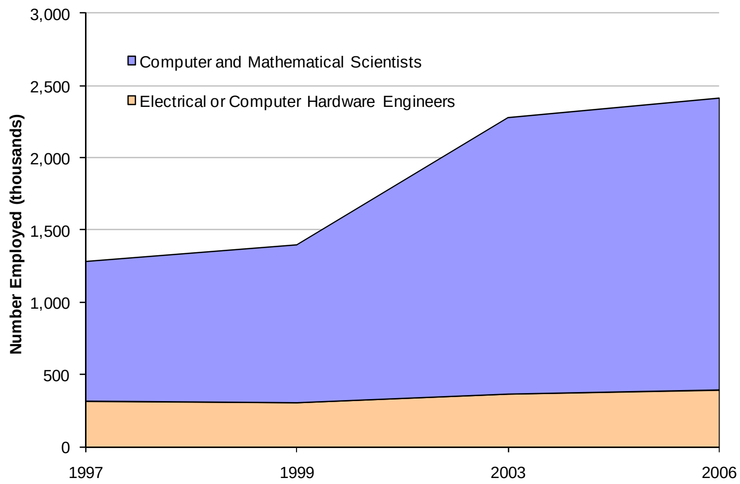
Source: Occupational Employment Survey

One of the interesting differences between the CPS and OES data is in the overall growth rate of the category 1 NIT workforce. The CPS data show the workforce contracting between 2001 and 2004. The OES data only show a decline in 2001 and 2002 and show a significant increase (nine percent) in the size of the NIT workforce in 2004. This discrepancy arises since the CPS also captures the self-employed NIT workforce where the OES data does not.

2.1.1.3 Scientists and Engineers Statistical Data System (SESTAT)

The NSF SESTAT data estimates employment in various occupations by integrating data from the Survey of Doctorate Recipients, the National Survey of College Graduates, and the National Survey of Recent College Graduates. This dataset estimates the number of workers with a bachelor's degree and higher, exactly the group we are examining in this study. In the SESTAT data, there are two NIT-related occupations: computer and mathematical scientists, and electrical or computer hardware engineers. This definition is inclusive of some (mathematicians, etc.) who are not NIT workers under any reasonable definition. Using SESTAT, we estimate that there were 2.4 million workers in these occupations in the United States in 2006. This is lower than both the CPS (3.5 million) and OES (2.8 million) estimates of the category 1 NIT workforce. Figure 2.4 shows the SESTAT-estimated size of the NIT workforce between 1997 and 2006.

Figure 2.4: Size of the Category 1 NIT Workforce Estimated from SESTAT in Thousands (1997-2006)



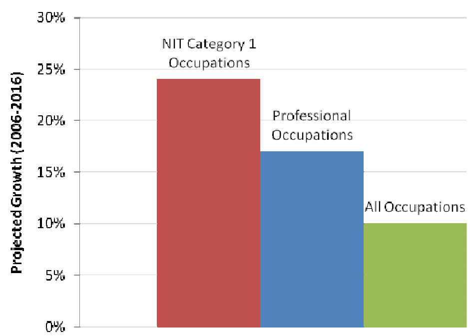
Source: SESTAT

The SESTAT data shows a similar trend to that observed in the CPS and OES data, with the size of the NIT workforce growing rapidly between 1997 and 2006 and with the majority of that growth driven by an increase in the number of computer and mathematical scientists and less so by electrical and computer hardware engineers. The SESTAT data do not capture the dynamics of the dot-com bust in 2001-2002 because data was only collected in 1999 and 2003 and not in the years in between.

2.1.2 Expected Growth of the NIT Workforce

Every two years, the BLS projects the growth in all occupations over the next decade. In 2007, the most recent projections were published covering the period 2006-2016.[23] The size of the category 1 NIT workforce is expected to grow significantly faster than other occupations, as shown in Figure 2.5.

Figure 2.5: Projected Growth of NIT Occupations Relative to Others (2006-2016)



Source: Bureau of Labor Statistics

[23] Dohm and Shniper (2007)

Predictions on the number of workers in category 1 NIT occupations show an increase in size by 24 percent by 2016. This is significantly higher than the 17 percent increase projected for professional occupations and the ten percent increase projected for all occupations. This will lead to 1,278,000 new job openings in NIT occupations. Mann describes a theoretical framework to support these projected increases by arguing that software services will drive the next wave of productivity growth in the United States.[24] Table 2.4 shows the breakdown of projected growth by occupation.

Table 2.4: BLS NIT Occupational Growth Projections (2006-2016)

Occupational Category	BLS 2006 (thousands)	BLS 2016 (thousands)	% Growth	Total Job Openings (thousands)
Computer systems analysts and scientists	665	838	23%	349
Computer and information scientists, research	25	31	21%	12
Computer systems analysts	504	650	29%	280
Computer specialists	136	157	15%	57
Computer programmers	435	417	-4%	91
Electrical and electronics engineers	291	306	6%	82
Computer software engineers	857	1,181	38%	449
Computer hardware engineers	79	82	5%	28
Network systems and data communications analysts	262	402	**53%**	193
Computer and information systems managers	264	307	16%	86
Category 1 NIT Occupations	**2,853**	**3,533**	**24%**	**1,278**
Professional Occupations	**29,819**	**34,790**	**17%**	**11,067**
All Occupations	**150,620**	**166,220**	**10%**	**50,732**

Source: Bureau of Labor Statistics

The occupation categories used to make the BLS projections are similar to those used in the OES but they provide additional categories that aggregate the two types of software engineers and combine electrical and electronics engineers. The difference between the baseline numbers in 2006 compared to both the CPS and OES estimates are due to the way the BLS constructs its National Employment Matrix by combining CPS and OES data.

BLS predicts that the fastest growing category 1 NIT occupation over the next decade will be network systems and data communications analysts, which is projected to grow 53 percent between 2006 and 2016, leading to 193,000 new job openings. In absolute size, the largest increase in the number of job openings is projected to be 449,000 for software engineers. Computer programmer is the only NIT occupation for which there is an expected decline. The BLS projects a four percent decline in the number of computer programmers between 2006 and 2016. This continues a trend identified in the CPS data as the number of computer programmers has declined in almost every year since 2000. Some of this decline can be attributed to offshoring, as computer programming is often a well-defined task that can be packaged and performed abroad. In addition, there appears to be a shift in the skill mix of the software development workforce in the United States

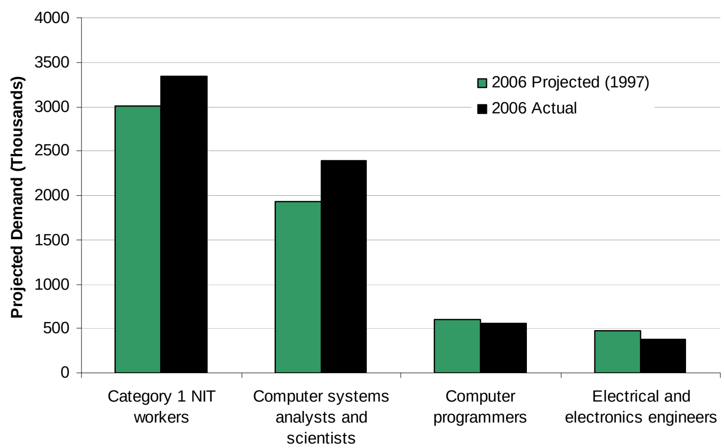
[24] Mann (2003)

from coding performed by computer programmers to design and project management performed by software engineers.

The BLS projections are based on a rigorous modeling approach utilizing demographic projections, macroeconomic models, and input-output models.[25] To assess the credibility of these projections, it is important to examine their validity. We find that the BLS projections are sensitive the state of the labor market at the time they are made. When the NIT workforce was growing slowly, the BLS projected slow growth over the next decade. When the NIT workforce was growing rapidly, the BLS projected more rapid growth. We see this trend in comparisons of the BLS projections for the NIT workforce.

In 1997, the BLS projected the number of NIT workers through 2006. Figure 2.6 shows the projected versus actual number of workers for this time span. We see that the actual size of the NIT workforce was higher in 2006 than it was projected to be in 1997, mainly due to a larger-than-expected increase in the number of computer systems analysts and engineers. However, overall, the projections were fairly close to the actual values.

Figure 2.6: BLS NIT Projections Validation (1997-2006)

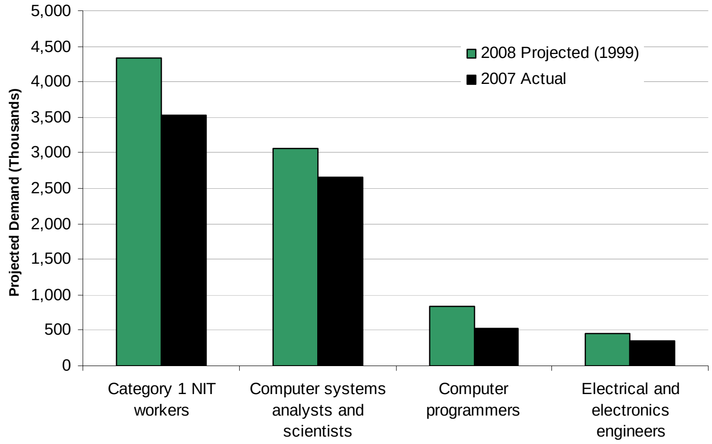


Source: Bureau of Labor Statistics

We can also compare the 1999 projections for 2008 with the actual values in 2007. We expect that the 2007 values should be slightly lower but close to the projections for 2008. We can see from Figure 2.7 that the projections for 2008 were significantly higher than we might expect due to a one-year difference. There would have to be a significant increase in the number of computer systems analysts and scientists (15 percent), computer programmers (59 percent), and electrical and electronics engineers (30 percent) between 2007 and 2008 to reach the projections. The only one of these that appears plausible is the 15 percent increase in the number of computer systems analysts and scientists as this occupation grew by 15 percent from 2006 to 2007.

[25] Franklin (2007)

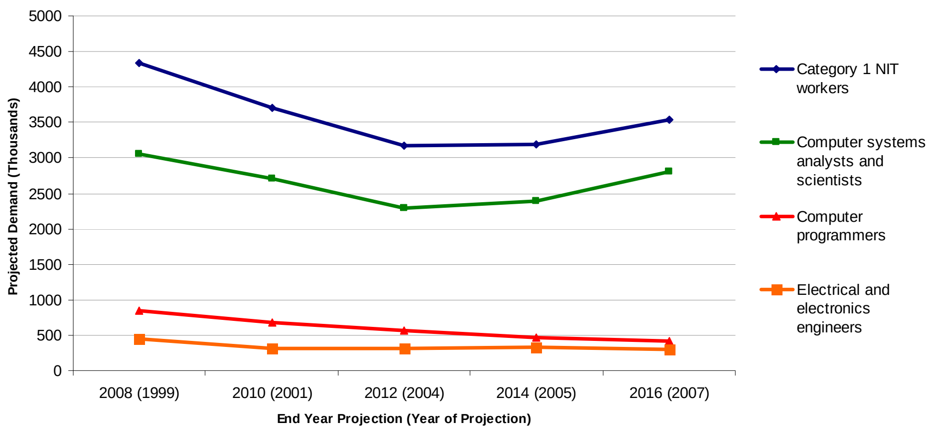
Figure 2.7: BLS NIT Projections Validation (1999-2008)



Source: Bureau of Labor Statistics

For a workforce that has been growing significantly over time, we might expect projections to increase every two years. However, Figure 2.8 shows a decline in projections made between 1999 and 2004. Projections only began to increase after the NIT labor market began to rebound in 2005 and 2007.

Figure 2.8: Changes in BLS NIT Projections over Time



Source: Bureau of Labor Statistics

Overall, BLS projections have been good at predicting the actual size of the NIT labor force. However, projections often vary with business cycles, being more optimistic during times of growth and more pessimistic during times of workforce contraction. Given the recent economic downturn, we might expect growth over the next decade to be lower than that projected by the BLS in 2007.

2.1.2.1 Comparisons with Other Occupations

NIT occupations are projected to be among the fastest growing occupations over the next decade. Among the five fastest growing occupations between 2006 and 2016 are two category 1 NIT occupations, as shown in Table 2.5. They are also the only two in the top five that require a bachelor's degree. The number of network systems and data communications analysts is projected to grow faster (53 percent) than any other occupation between 2006 and 2016. Computer software engineers (applications) rank fourth with an expected increase of 45 percent. Both of the NIT occupations in the top five fastest-growing occupations have median wages significantly higher than the other occupations on this list.

Table 2.5: BLS Projected Fastest Growing Occupations (2006-2016)

Occupational Category	BLS 2006 (thousands)	BLS 2016 (thousands)	% Growth	Median weekly earnings	Most significant source of postsecondary education or training
Network systems and data communications analysts	**262**	**402**	**53%**	**1,039**	**Bachelor's degree**
Personal and home care aides	767	1,156	51%	380	Short-term on-the-job training
Home health aides	787	1,171	49%	423	Short-term on-the-job training
Computer software engineers, applications	**507**	**733**	**45%**	**1,455**	**Bachelor's degree**
Veterinary technologists and technicians	71	100	41%	844	Associate degree

Source: Dohm and Shniper (2007)

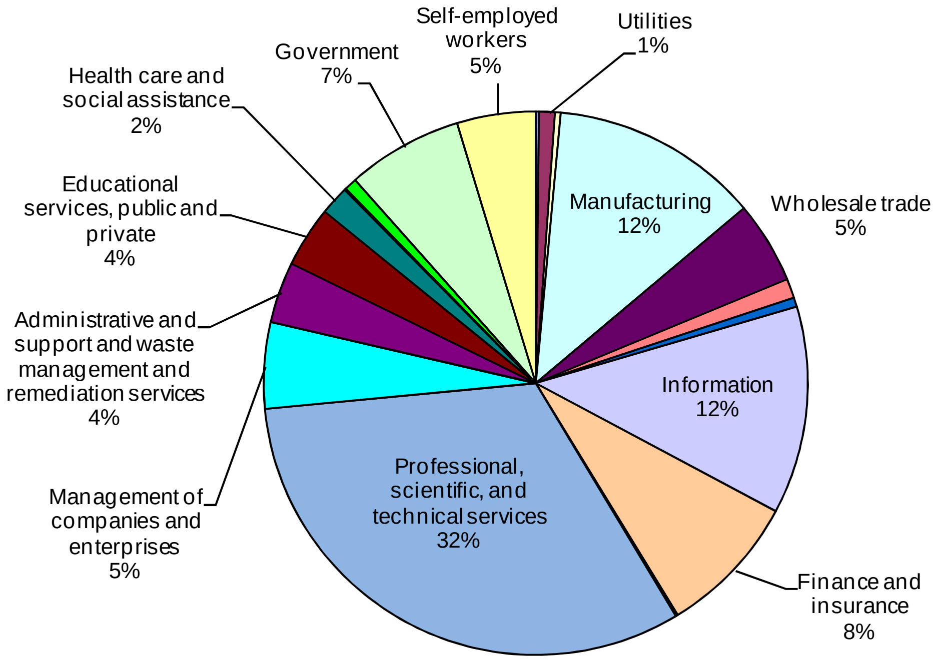
Additionally, NIT jobs comprise the majority of projected growth in the S&E workforce. Using the 2004-2014 BLS projections, the Computing Research Association (CRA) calculated that 71 percent of new S&E jobs and 59 percent of new and replacement S&E jobs would be computer specialists.[26]

2.1.3 NIT Workforce by Sector

The NIT workforce is distributed across many sectors of the US economy. There are NIT workers in NIT firms such as Microsoft and Google as well as NIT workers in non-NIT firms such as General Motors and Bank of America. We used the OES data to estimate the distribution of category 1 NIT workers across industries using two-digit North American Industry Classification System (NAICS) codes. In 2006, one-third of NIT workers were in the industry classified as professional, scientific, and technical services, as shown in Figure 2.9. Relatively large fractions of NIT workers were also in the manufacturing (12 percent), information (12 percent), and finance and insurance (8 percent) industries. Seven percent of NIT workers were in the government (local, state, and federal).

[26] Roberts (2007)

Figure 2.9: Fraction of NIT Workers by Industry (2006)



Source: Bureau of Labor Statistics

As would be expected, the industry groups within professional, scientific, and technical services that had the largest number of NIT workers were computer systems design and related services (69 percent of professional, scientific, and technical NIT workers), and architectural, engineering, and related services (11 percent of professional, scientific, and technical NIT workers). In addition, nine percent of professional, scientific, and technical NIT workers were involved in research and development in the physical, engineering, and life sciences. Also not surprising, within manufacturing, the majority of NIT workers (65 percent of NIT manufacturing workers) were in the computer and electronic product manufacturing industry. NIT workers were split evenly among industries within information, ranging from software publishers to Internet service providers to data processing. The majority of the NIT workers within the finance and insurance industry worked in the insurance industry.

We also calculated NIT worker intensity in each industry by dividing the number of NIT workers in an industry by the total number of workers in that industry. The professional, scientific, and technical services industry (12 percent) and the information industry (11 percent) had the highest fraction of NIT workers, as shown in Table 2.6. Management of companies and enterprises (eight percent) and utilities (five percent) were the only other industries with more than three percent of the industry workforce in NIT occupations.

Table 2.6: Industry NIT Worker Intensity (2006)

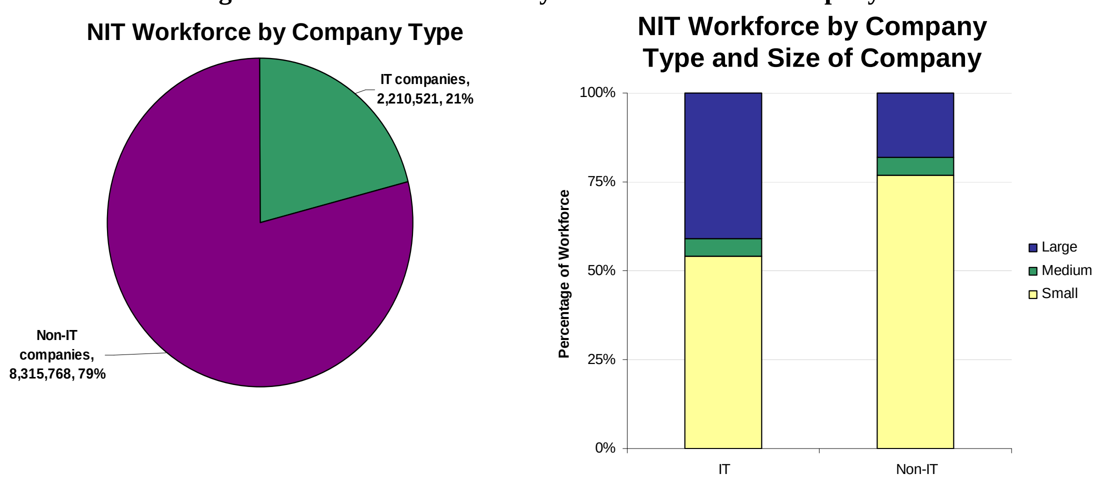
Industry (NAICS Code)	Fraction of Workers in NIT Occupations
Professional, scientific, and technical services (54)	12 %
Information (51)	11 %
Management of companies and enterprises (55)	8 %
Utilities (22)	5 %

Source: Bureau of Labor Statistics

The BLS does not project the industry composition of the NIT workforce to change significantly between 2006 and 2016. They project that the fraction of NIT workers in the professional, scientific, and technical services industry will increase from 32 to 36 percent while the fraction of NIT workers in manufacturing will decrease from 12 to 10 percent. This is consistent with the labor force projection data showing a shift from hardware occupations to software occupations. The BLS also projects small increases in the fraction of NIT workers in the information industry (12 to 13 percent), and slight decreases in educational services (four to three percent) and government (seven to six percent).

In addition to the BLS data, the ITAA conducted an annual survey through 2004 that estimated the breakdown of the NIT workforce by sector and size of company. The ITAA looked at the distribution of all NIT jobs, not just category 1 jobs, across NIT and non-NIT firms and by size of firm. In 2004, the ITAA found that only 21 percent of IT workers in the United States worked in IT companies, with the other 79 percent working in non-IT companies, as shown in Figure 2.10. This figure also shows the percentage of IT workers employed in large, medium, and small enterprises for both the IT and non-IT sectors. It shows that the majority of IT workers tended to work in small firms. Workers in non-IT firms were more likely than workers in IT firms to be in small firms.

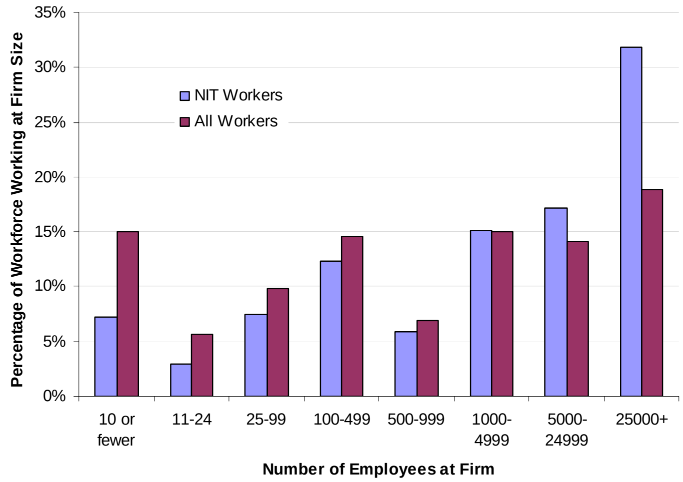
Figure 2.10: NIT Workforce by Sector and Size of Company



Source: ITAA (2004a)

The NSF SESTAT survey data provide a more recent breakdown of category 1 NIT workers by size of company. Figure 2.11 shows the distribution of NIT workers and all workers by firm size in 2006.

Figure 2.11: Fraction of Workforce by Employer Size NIT vs. All Workers (2006)



Source: SESTAT

Compared to the workforce as a whole, IT workers are more likely to work in large companies. About 32 percent of IT workers work in companies with more than 25,000 employees compared to 19 percent of all workers as a whole. The SESTAT data include only category 1 NIT workers; excluded are systems administrators and computer support staff who are likely to be found in smaller firms.

2.1.4 Government NIT Workforce

The coming retirement of the baby-boom generation of federal employees is a significant issue for the government workforce[27] and is especially important for NIT occupations. Many federal jobs require US citizenship[28] and a declining number of graduates from traditional NIT degree programs are US citizens.[29] The government NIT workforce has not been studied in-depth nor are there many reliable statistics about the projected needs for NIT workers due to the coming retirement boom. However, the Office of Personnel Management (OPM) manages a database called FedScope that provides a breakdown of the federal workforce by occupation.[30] In 2008, there were about 100,000 federal employees in NIT occupations: computer science, electronics engineering, computer engineering, electrical engineering, and information technology. The majority of workers (about 68,000) were in information technology. It is likely that these data include both category 1 and category 2 NIT workers. The size of the federal NIT workforce has not changed significantly since 2004, growing at a rate of about one percent per year as shown in Figure 2.12.

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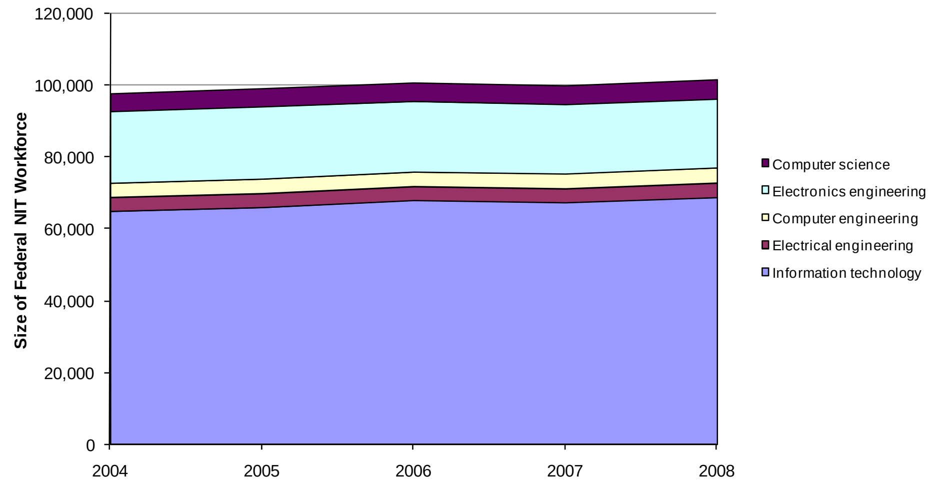
[27] GAO (2007)
[28] http://www.usajobs.opm.gov/EI9.asp
[29] See Section 2.2
[30] http://www.fedscope.opm.gov

Figure 2.12: Size of the Federal NIT Workforce



Source: US Office of Personnel Management FedScope Database (2009)

The BLS also provides another source of data on the size of the federal NIT workforce. Using the BLS occupation-industry data, we estimated the size of the category 1 NIT workforce in the federal government to be about 83,000 in 2006. This is consistent with the larger OPM estimate that included both category 1 and 2 NIT workers. The BLS projects the number of category 1 NIT workers in the federal government to shrink by 6,000 workers to about 77,000 workers by 2016. Using BLS data, we also estimate that the number of total government NIT workers (federal, state, and local) was about 195,000 in 2006. The BLS projects this workforce to shrink to about 189,000 by 2016. We also used SESTAT to estimate the size of the total government (federal, state, and local) category 1 NIT workforce to be about 223,000 workers in 2006. All of these estimates show that the size of the federal, state, and local government category 1 NIT workforce is likely near 200,000 workers, or about six percent of the overall NIT workforce, while the size of the federal category 1 NIT workforce is about 80,000 workers, or two percent of the overall NIT workforce.

One of the major factors affecting the government NIT workforce is the outsourcing of NIT work to contractors. Both the OPM and BLS data show little to no growth in the government NIT workforce. In 2003, Light estimated that at least 50 percent of the total government workforce in 2002 was comprised of contractors.[31] It is likely that this fraction is even higher in NIT occupations. While no good estimates exist for the NIT contractor workforce, a conservative estimate based on Light's estimate for all occupations would mean the size of the federal-supported NIT workforce is closer to 200,000 workers. The use of contractors may also be masking growth in the federal NIT workforce as government agencies may find it easier to expand by using contractors rather than hiring federal employees for NIT occupations.

[31] Light (2003)

While there is little information available on the demand for NIT workers who are US citizens, jobs related to national security almost certainly require US citizenship. We found that more than half of federal NIT workers worked for the Department of Defense (DoD) in 2008. DoD employees comprised only 35 percent of the total federal workforce but 54 percent of the federal NIT workforce. It is likely that the majority of these positions require US citizenship. In addition, many NIT jobs for defense contractors also require US citizenship. Assuming a contracting NIT workforce of 100,000 workers and the same ratio of defense to civilian workers as in the federal government, the total number of DoD supported NIT workers requiring US citizenship would have been about 100,000. However, many positions outside of DoD also require US citizenship, which could make the total number of NIT jobs requiring US citizenship significantly higher. The National Defense Industry Association has identified the lack of qualified science, technology, engineering, and mathematics (STEM) workers who are US citizens as an important issue and organized a conference around it in 2004. On the subject of supply and demand, they concluded, "macro level data are good for the current state of national workforce. However, specificity for National Security needs is lacking for both demand and supply of US citizens. There is a need for consistent feedback between unmet workforce demands and sources of supply for both industry and government. In addition, labor demand analysis lacks integration and sufficient correlation with projected government budgets, technology needs, and global competition."[32]

2.1.5 Other NIT Workforce Characteristics

The NSF SESTAT database provides a number of other characteristics of the category 1 NIT workforce that are not included in either the CPS or OES. While all surveys contain data on salary, gender, and race,[33] SESTAT contains data on age, degree composition, job satisfaction, work-related training, and foreign origin. These SESTAT data only break down occupations in broad categories, with the closest NIT occupation categories being "computer and mathematical scientists" and "electrical and computer hardware engineers."

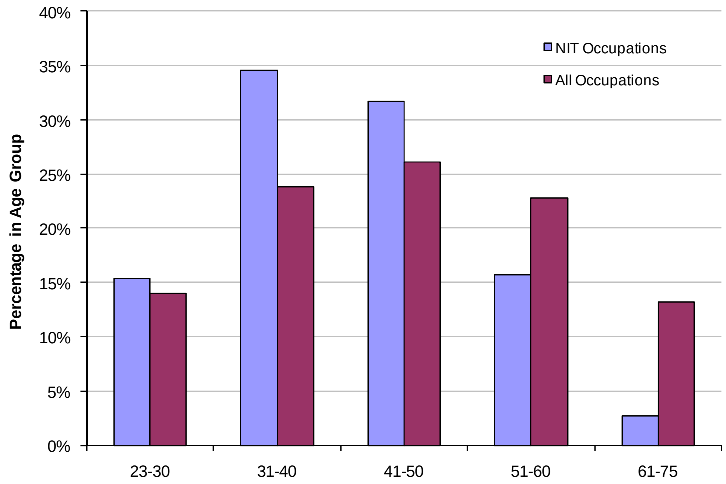
2.1.5.1 Age

NIT workers tend to be younger than workers in other occupations. The average age of workers in SESTAT NIT occupations in 2006 was about 41 years compared to 45.5 years for all individuals in all occupations. About 49 percent of NIT workers were less than 40 years old in 2006 while only 36 percent of all workers were less than 40. Figure 2.13 shows the age distribution of workers in NIT occupations versus those in all occupations in 2006.

[32] http://www.ndia.org/Resources/OnlineProceedings/Pages/534E_National_Security_Workforce.aspx

[33] See Section 3 for more on gender and race.

Figure 2.13: Age Distribution of NIT Occupations vs. All Occupations (2006)



Source: SESTAT

In contrast, the average age of the federal NIT workforce in 2008 (46.3 years) was slightly greater than the average age of the overall federal workforce (45.7 years).[34] The average age of the federal NIT workforce was much greater than the average age of the NIT workforce as a whole.

2.1.5.2 Degree Composition

In 2006, the majority of workers in the category 1 NIT workforce (68 percent) had bachelor's degrees. This is higher than the fraction of bachelor's degree recipients in the overall workforce (59 percent). The major difference between the degree composition of the NIT workforce and the overall workforce is the lack of professional degrees in the NIT workforce, as shown in Figure 2.14. This is explained by the lack of professional degree programs as a pathway for NIT workers. There have been recent proposals to change this pathway and create more professional degree programs for S&E workers.[35]

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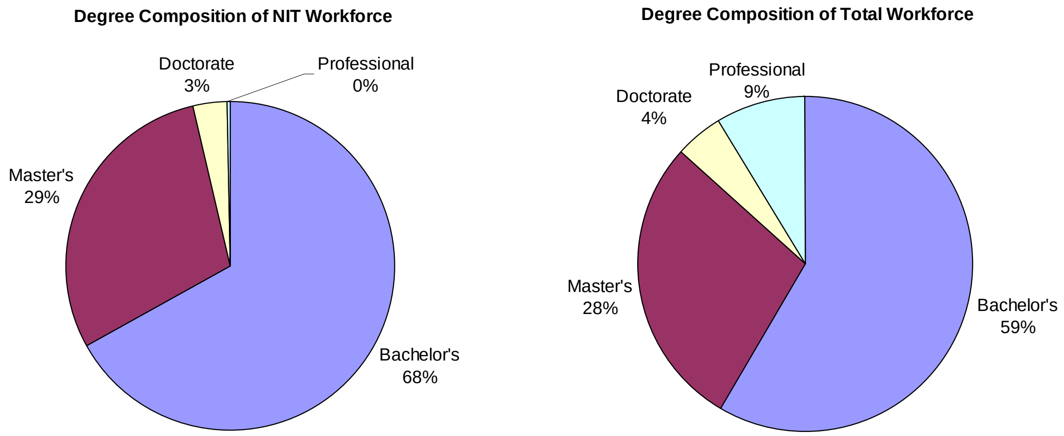
[34] Calculated from FedScope database

[35] Colwell (2009)

Figure 2.14: Degree Composition of NIT vs. Overall Workforce (2006)

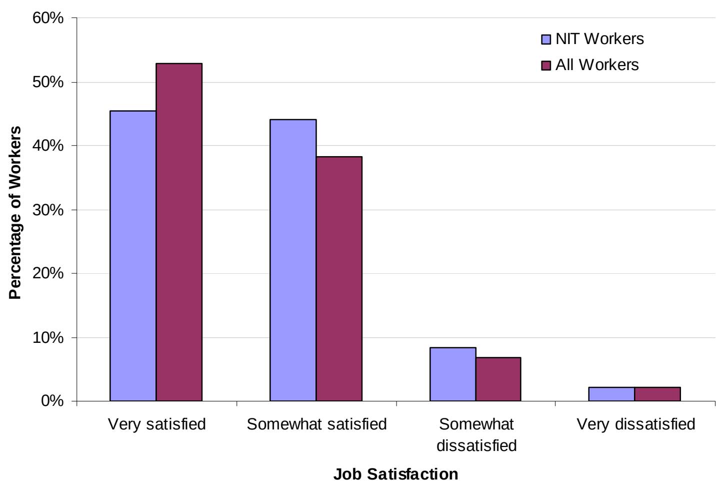


Source: SESTAT

2.1.5.3 Job Satisfaction

Compared to the overall workforce in 2006, fewer NIT workers reported being very satisfied with their jobs while more reported being somewhat satisfied and somewhat dissatisfied, as shown in Figure 2.15. The fraction of workers reporting that they were very dissatisfied with their jobs was the same in the NIT workforce as it was for all occupations. Overall, NIT workers appeared to be about as happy with their jobs as all workers.

Figure 2.15: Job Satisfaction of NIT Workers vs. All Workers (2006)

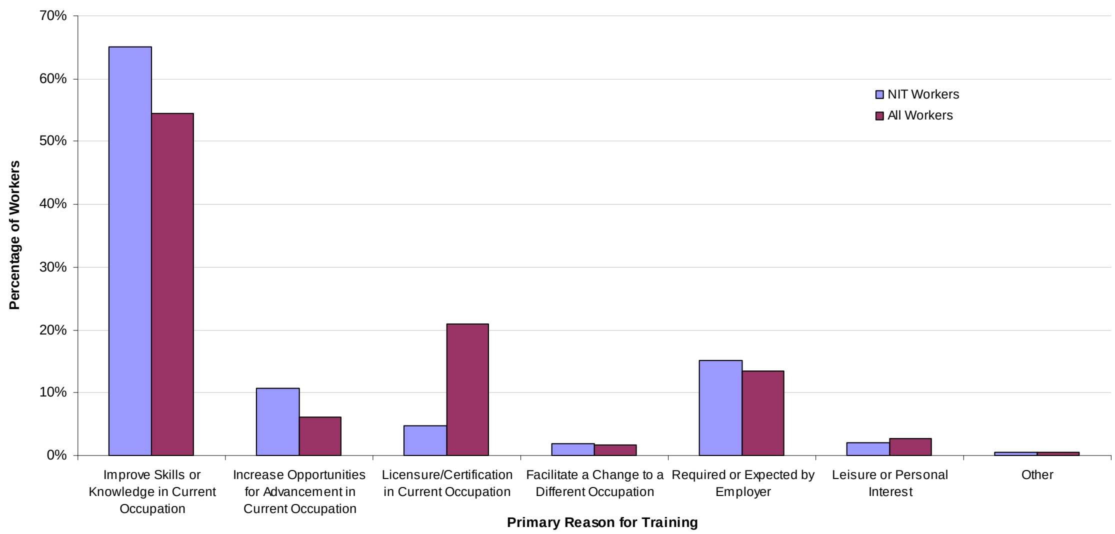


Source: SESTAT

2.1.5.4 Work-Related Training

Perceptions of NIT occupations often include the need for continuous training to learn new skills as technology evolves. In 2006, NIT workers reported participating in work-related training at about the same rate (58 percent) as all workers (59 percent), according to SESTAT survey data. NIT workers more frequently cited improving their skills or knowledge in their current occupation as the principal reason for participating in the training compared to all workers, as shown in Figure 2.16. This is consistent with anecdotal evidence from experts interviewed for this report that NIT workers are required to learn new skills at a faster rate than workers in other occupations, as well as with empirical evidence that the number of skills required by NIT workers has been increasing.[36] NIT workers also cited increasing opportunities for advancement and employer expectations as reasons for receiving training more frequently than other workers. Licensure/certification was cited much less frequently by NIT workers as the primary reason for training compared to all other workers.

Figure 2.16: Reason for Participating in Work-Related Training: NIT vs. All Workers (2006)



Source: SESTAT

2.1.5.5 Workers Born Outside of the United States

NIT occupations have a high fraction of workers born outside of the United States compared to other occupations. Table 2.7 shows that the two most closely related NIT occupations (electrical or computer hardware engineers and computer and mathematical scientists) were among the top five occupations with the highest fraction of foreign-born workers in 2006. The average fraction of foreign-born workers across all occupations was about 17 percent while the fraction for the two NIT occupations was about 30 percent.

Table 2.7: Top 5 Occupations with Highest Fraction of Foreign Born Workers (2006)

Occupation	Fraction Foreign Born
Physicists and astronomers	36 %
Postsecondary Teachers - Engineering	32 %
Electrical or computer hardware engineers	**31 %**
Biological and Medical Scientists	30 %
Computer and mathematical scientists	**28 %**
All Occupations	17 %

Source: SESTAT

[36] Gallivan et al. (2002)

The two NIT occupations also had among the highest fraction of naturalized citizens comprising the US citizen component of the workforce: 19 percent of US citizens who were electrical or computer hardware engineers and 14 percent of US citizens who were computer and mathematical scientists were naturalized citizens. The average fraction of naturalized citizens for all occupations was 10 percent.

2.1.6 Demand Due to Expansion of NIT in Other S&E Disciplines

Networking and information technology has played an increasing role in virtually all fields of science and engineering over the last several decades. The NITRD program and its predecessor interagency programs have played a major part in this expansion through their longstanding emphasis on the applications of high performance computing and networking to science and engineering.[37] Today there are few, if any fields of science and engineering that have not been significantly affected by networking and information technologies. In some areas, new interdisciplinary subfields focused on IT-intensive approaches to science, such as bioinformatics and computational physics, have emerged. This section analyzes the workforce implications of these trends.

2.1.6.1 NIT Applications in Science and Engineering

There are a wide variety of NIT applications in science and engineering, including digital data collection and management, modeling and simulation, visualization, and digital communication and collaboration. These applications affect many fields of science including biology, chemistry, physics, mathematics, and medicine.

With respect to data collections and management, NIT has enabled rapid increases in data collection and improved technology for storing, sharing, and accessing data collections.[38] New families of computer-controlled instruments have greatly expanded the quantity of data available to scientists. In medicine, tools such as gene sequencers have improved researchers ability to understand and target disease. Remote sensing technologies, personal digital assistants, and laptops have also greatly aided field data collection for social scientists, geologists, and ecologists. Data collections may include text, numbers, images, video, or movies, audio, or software. They range from collections for an individual research project to collections shared by hundreds or thousands of investigators. Such data collections are increasing rapidly in number and size. Because data collections can be made widely available to scientists anywhere, they can be a catalyst for progress and democratization of science and education.[39] Internet connected datasets, such as the Protein Data Bank, enable a loosely structured form of cooperation or collaboration.[40] Such collections are transforming the fields of biology, chemistry, and medicine.

NIT also provides new tools for data analysis including a wide variety of statistics, models, algorithms, equations, visualizations, and simulations. Advances in modeling and

[37] FCCSET (1993); NSTC (2001)
[38] NRC (1989, 2001); NSB (2005); ETAN (1999)
[39] NSB (2005)
[40] ETAN (1999)

simulation enable the study of complex problems.[41] Some suggest that computer simulation provides a qualitatively new and different methodology for the physical sciences, and that this methodology lies between traditional theoretical physical science and its empirical methods of experimentation and observation.[42] NIT is also used for visualization, which is used to present complex data in a visual form, frequently in three dimensions and often over time. Visualization allows the presentation of data or simulation results in a form that lets the user see patterns and develop an understanding of the data. One example of efforts to utilize visualization technologies to educate students about the fundamentals of chemistry is the ChemViz tools created by the University of Illinois.[43]

NIT also enables scientists and engineers to communicate and collaborate in new ways. The Internet is used to connect data collection devices, data storage, and computational resources to provide a wide variety of services, such as electronic journals, videoconferencing, community databases, and community models. NIT enables greater scientific collaboration, particularly collaborations involving many people and several sites. IT is seen as leading to virtual communities of researchers[44] and extended research teams.[45] The term "cyberinfrastructure" is now commonly used to refer to a whole set of resources and tools available to scientists and engineers that serve to relax barriers of time and distance (which can be geographic, organizational, or disciplinary) to bring expertise, information, tools, instruments, and facilities together for the discovery, dissemination, and application of knowledge.[46]

These NIT applications are affecting virtually every field of science and engineering. In some fields, new subfields have emerged around the applications of IT in the field. Examples include bioinformatics and computational biology, linguistics, physics, chemistry, medicine, and mathematics. In these areas, the subfields have evolved to have journals and conferences, and in most cases degree programs. For example, the field of mathematics has seen the creation of the Journal of Computational Mathematics[47] and degree programs such as the Program in Applied and Computational Mathematics at Princeton University,[48] the Center for Computational Mathematics at the University of Colorado at Denver,[49] and the Center for Computational Mathematics at the University of California at San Diego.[50] A few examples of the many computational programs in other fields include:

[41] FCCSET (1993); NSTC (2001)
[42] Rohrlich (1990)
[43] http://education.ncsa.illinois.edu/products/chemviz/index.html
[44] NRC (2001)
[45] ETAN (1999)
[46] Atkins (2003)
[47] http://www.global-sci.org/jcm
[48] http://www.pacm.princeton.edu/index.shtml
[49] http://www-math.cudenver.edu/ccm
[50] http://ccom.ucsd.edu

- Biology/Bioinformatics: the National Cancer Institute Center for Bioinformatics,[51] the University of Pennsylvania Center for Bioinformatics,[52] and the University of Maryland Center for Bioinformatics and Computational Biology.[53]

- Linguistics: the Center for Computational Linguistics at Charles University in the Czech Republic[54] and the Centre of Computational Linguistics at Vytautas Magnus University in Lithuania.[55]

- Physics: the Center for Computational Physics at the University of Tsukuba in Japan[56] and the Center for Computational Physics at the Universidade de Coimbra in Portugal.[57]

- Chemistry: the Center for Computational Chemistry at the University of Georgia,[58] the Computational Chemistry Center at the Universität Erlangen-Nürnberg,[59] and the West Center for Computational Chemistry and Drug Design at the University of the Sciences in Philadelphia.[60]

- Medicine: the Center for Computational Medicine and Bioinformatics at the University of Michigan,[61] the Institute for Computational Medicine at Johns Hopkins University,[62] the IEEE Computer Society for Computational Medicine,[63] and the Computational Medicine Center at the University of Cincinnati.[64]

2.1.6.2 Workforce Implications

While there is little doubt that the role of NIT is expanding in nearly all fields of science, there are much less data or analysis of the effects of these trends on either the science and engineering workforce or the NIT workforce. Workforce statistics are not classified in a way that allows analysis of these trends and there have been few studies that specifically address workforce issues at the interface between NIT and science. There are, however, some studies that discuss education and workforce issues in the context of addressing the role of IT or cyberinfrastructure in science and engineering. These discussions reflect the views of experts in the fields but appear to be based on little data. In addition, there have been studies of some workforce issues in new NIT-science subfields. This section summarizes some of this information.

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[51] http://ncicb.nci.nih.gov
[52] http://www.pcbi.upenn.edu
[53] http://www.cbcb.umd.edu
[54] http://ufal.mff.cuni.cz/ckl
[55] http://donelaitis.vdu.lt/index_en.php
[56] http://www.ccs.tsukuba.ac.jp/CCS
[57] http://cfc.fis.uc.pt
[58] http://www.ccc.uga.edu
[59] http://www.chemie.uni-erlangen.de/ccc
[60] http://www.usp.edu/westcenter
[61] http://www.ccmb.med.umich.edu
[62] http://www.icm.jhu.edu
[63] http://www2.computer.org/portal/web/cm/home
[64] http://www.computationalmedicine.org

There are several studies that address, at some level, workforce needs to take advantage of the opportunities presented by NIT for science and engineering. In 2007, The NSF Cyberinfrastructure Council identified both needs for changing education and training of scientists and engineers as well as the development of new NIT professionals.[65] The study suggests that changes in graduate curricula will be needed to take advantage of the new methods to observe, acquire, manipulate, and represent data. It emphasizes the need for increased interdisciplinary science and engineering training, reflecting the complex nature of modern science and engineering problems. It also notes the importance of continued professional development opportunities to allow teachers and faculty to learn to use new techniques enabled by cyberinfrastructure, both in research and education.

With respect to NIT professionals needed to support cyberinfrastructure, the study notes the need for "digital data management" or data curation professionals. Such careers may involve the development of new degree programs that combine library science with scientific disciplines. Similarly, the study notes a need for new specialized careers that pair the graphic arts with a science or engineering discipline to develop and apply visualization and other presentation technologies to the interpretation of data.

The study also notes that new NIT-science and engineering hybrid disciplines will continue to develop, and that the NSF will be an enabler in developing the workforce for these newly formed disciplines by supporting curricula, stimulating partnerships, and supporting the dissemination of "best practices" in cyberinfrastructure workforce development.

There have been two studies focused on computational skills needed in the sciences. The first, an NSF-supported study on computational physics, noted the need for training computational physicists and for integrating computation into the standard physics curriculum.[66] It notes that computational scientists are needed in industries ranging from aerospace to Wall Street, and that computational scientists require backgrounds in applied mathematics, computer architectures, and software engineering, as well as in their own disciplines. A number of universities have established interdisciplinary programs in computational science and engineering. However, the study notes that such programs are labor intensive to design, and that the creation of course software often requires staff support and infrastructure. It recommends seed funding for such courses. The study also says that graduate and postdoctoral fellowship programs in computational physics would be helpful. Finally, the study notes that greater integration of computation into the core curriculum could have a dramatic positive impact on undergraduate education in physics.

The second study, undertaken in 2003 by the Subcommittee on 21st Century Biology of the NSF's Directorate for Biological Sciences Advisory Committee, addressed the skills needed to use cyberinfrastructure in the biosciences.[67] The report notes the need for a new cadre of scientists prepared for work at the frontier between computing and biology, able to recognize important biological problems, understand what computational tools are

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[65] National Science Foundation Cyberinfrastructure Council (2007)
[66] Steering Committee on Computational Physics (2001)
[67] BIOAC (2003)

required, and capable of being a communicator between traditionally trained biologists and traditionally trained computational scientists. They recommend more short courses, continued support for interdisciplinary training, and support of novel training approaches, particularly for more senior scientists who need retraining and for new undergraduate curricula.

In a study focused on creating and maintaining large datasets across all disciplines, a 2005 National Science Board (NSB) study on long-lived data collections identified needs for education, training, and workforce development.[68] They note that there needs to be innovative data scientists available to create cutting-edge collections technology, as well as many people with the knowledge and skills to use the collection infrastructure. The Board noted that training is needed to permit researchers who are domain experts to be able to access collections in sophisticated ways. This kind of training needs to be multidisciplinary in character and targeted to researchers with diverse backgrounds. In addition, the Board noted that there is a need to make data collections intelligible to the general public and that this is an additional challenge to the data scientists who devise the interfaces.

One computational science area where there has been some scholarly analysis of the workforce is bioinformatics. Black and Stephan studied the bioinformatics labor market during the period 2000-2004.[69] They surveyed all 74 known academic programs offering degrees in bioinformatics, analyzed position announcements for all bioinformatics-related ads placed in *Science* during the three-year period ending in 2003, analyzed position announcements on two Internet sites, and studied the perception of seven firms of the state of the bioinformatics labor market. Results of the study were compared to those from a 1999 survey of academic programs and a 1998 study of position announcements. Black and Stephan found that there was a dramatic increase in the number of academic training programs as well as the number of individuals enrolled in programs. Nevertheless, the number of newly trained individuals in bioinformatics was fairly small relative to the number of position announcements, suggesting that most hires came from other fields, rather than from the bioinformatics degree programs. They also found that the number of advertised positions decreased from 1999 to 2003. The wage premium associated with bioinformatics positions in 1999 had disappeared by 2004. This suggests that, at least in the area of bioinformatics, the labor market was responsive to needs, with some time lag. A high demand for bioinformatics specialists led to higher wages that attracted people from other fields and to the creation of new degree programs. The increased demand for bioinformatics specialists did not increase without bounds, however, and in fact soon leveled off, and this, combined with the new training programs, appeared to allow supply and demand for bioinformatics specialists to approach equilibrium. We found no similar studies in other areas of computational sciences.

One effort to provide a capable workforce for all fields of science using computing is the Initiative in Innovative Computing at Harvard University. This program aims to provide "two-way collaborative flow of ideas and inventions between basic science and computer

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[68] NSB (2005)
[69] Black and Stephan (2004)

science, academia and industry, professional staff and faculty, teachers and students. The IIC trains the next generation of creative and computationally capable scientists, and communicates with the public at large about the value of computing in science and the science it enables."[70]

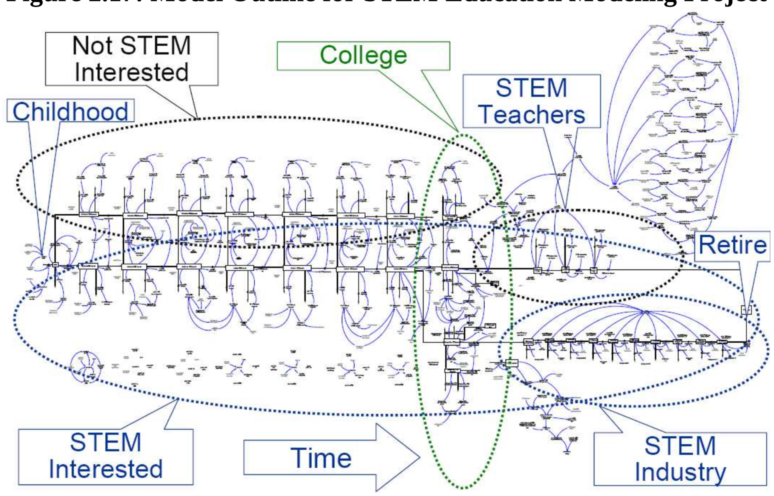
2.2 Supply of NIT Students and Faculty

Defining the supply of NIT workers is inherently a subjective task. Traditional definitions of supply have included computer science (CS) and electrical engineering (EE) degree recipients. However, as explained in the report by Freeman and Aspray: "One of the least known and most important facts is that the vast majority of IT workers do not obtain formal degrees in IT-related disciplines."[71] Additionally, the supply pipeline reaches further back than higher education where students gain experience with information technologies both in and out of the classroom. This section begins by describing pathways to NIT careers and then describes the supply of potential NIT workers.

2.2.1 Pathways to NIT Careers

Depicting all of the pathways to NIT careers is a complex task as there are many different avenues and feedback loops. A collaborative effort between the Business Higher Education Forum and Raytheon is attempting to model these pathways for STEM careers using a systems dynamics approach.[72] Figure 2.17 shows a high-level outline of their model in the early stages of its development.

Figure 2.17: Model Outline for STEM Education Modeling Project



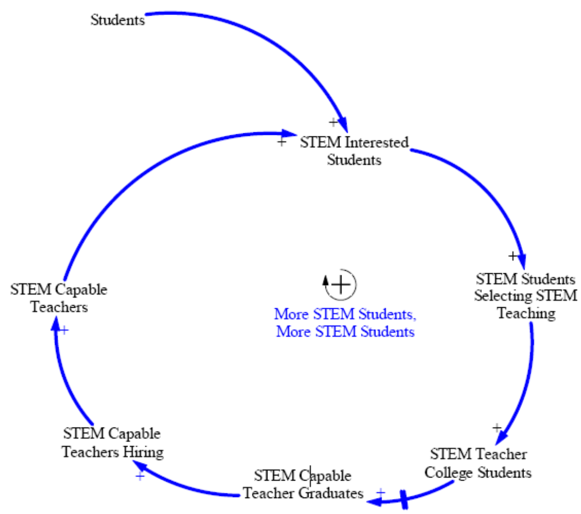
Source: Roe (2008)

The model was created using the system dynamics modeling software Vensim and is a combination of stocks, flows, and feedback loops that combine to simulate the dynamic workforce. Figure 2.18 shows an example of one feedback loop depicting how the number of STEM interested students is affected by the number of STEM capable teachers

70 http://iic.harvard.edu
71 Freeman and Aspray (1999), p. 72
72 http://www.stemnetwork.org

while at the same time the number of STEM capable teachers is affected by the number of STEM capable students.

Figure 2.18: STEM Model Feedback Loop

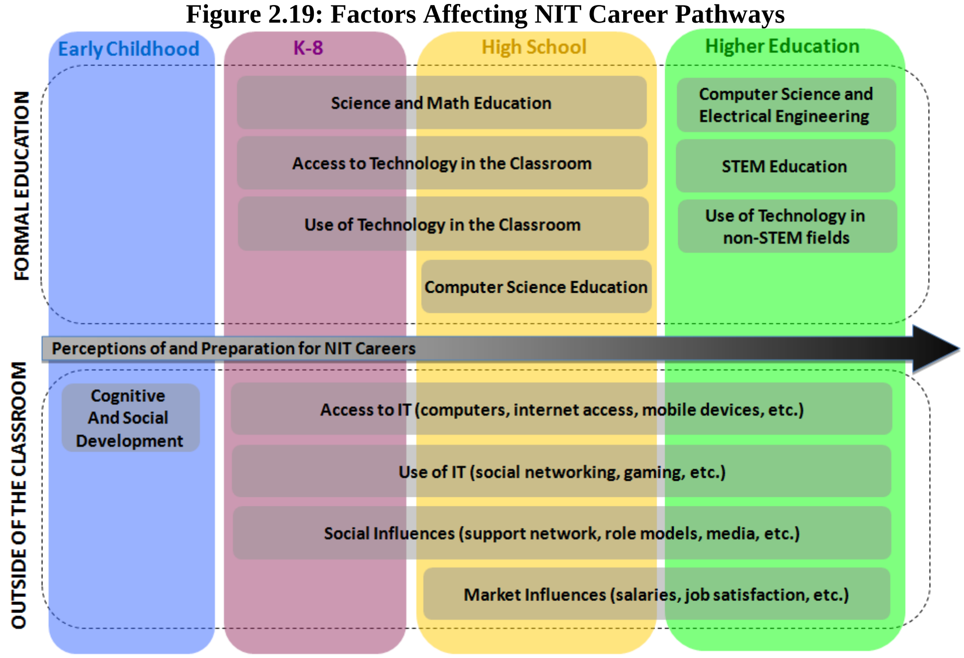


Source: Roe (2008)

No such model currently exists for the NIT workforce but many of the fundamentals would be the same. Most of the STEM career literature conceives of the system as a pipeline.[73] Individuals move through the pipeline from early childhood through retirement and a variety of factors influence their career decisions. Based on a thorough review of the literature and interviews with experts, Figure 2.19 shows some of the key factors affecting NIT career pathways.

[73] Hilton and Lee (1988), Eccles (1989)

Figure 2.19: Factors Affecting NIT Career Pathways



Preparation and perceptions affect the career choices that individuals make. These are influenced by experiences both within the formal educational system and outside of the classroom. Over time, these experiences shape and solidify an individual's preparation for and perceptions of various careers. This is consistent with Eccles et al.'s Expectancy Value model, which hypothesizes that individuals' educational and vocational choices are influenced by their interests, values, and expectations of success.[74] The majority of the literature on NIT career pathways has focused mainly on higher education. The following subsections highlight some of the factors that influence NIT career preparation and perceptions at various points in the pipeline. It is worth noting that there are some drawbacks to the pipeline conception, as it does not explicitly address the conglomeration of social and psychological factors affecting career decisions.[75] The following sections are based on the view that perceptions and preparations build upon each other and interact to determine career choices.

2.2.1.1 Early Childhood

The experiences that affect NIT career choices begin in early childhood. While there is a significant literature on the importance of early childhood cognitive and social development as a key determining factor of later skill development,[76] there is little focus specifically on preparation for NIT careers at this level of education. The literature shows that skill formation during this period is a key determinant of future labor market outcomes.[77] This has very important implications for the development of "soft skills" that are often cited as being in high demand by NIT employers.

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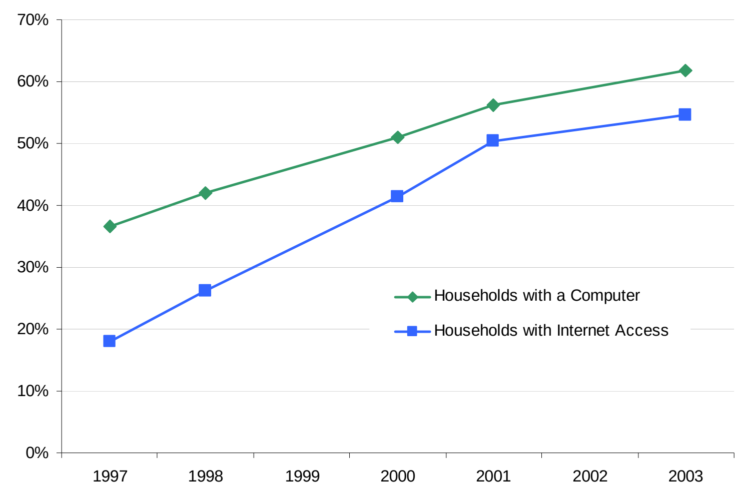
[74] Zarrett and Malanchuk (2005)
[75] Zarrett and Malanchuk (2005)
[76] Heckman (2006), Cunha et al. (2006)
[77] Heckman et al. (2006)

2.2.1.2 K-8

At the K-8 level, NIT preparation and perceptions are determined by a variety of factors. At this level, science and math education is considered essential preparation for NIT careers. More specifically, learning the scientific method of inquiry and discrete math are considered important foundations for NIT careers. Access to technology in the classroom is also considered an important factor. While there are very few K-8 courses that focus specifically on NIT skills, many schools use computers for a variety of classroom activities and some begin to teach the fundamentals of computer use such as word processing and spreadsheets in middle school.[78]

Students at the K-8 level are also profoundly influenced by their experiences outside of the classroom. Access and use of information technologies are key factors that influence NIT career perceptions and preparation. Access to information technology is often measured by access to a computer and the Internet. According to the 2004 report by the US Department of Commerce, *A Nation Online: Entering the Broadband Age*,[79] the prevalence of computers and Internet access for US households was steadily increasing between 1997 and 2003 (the most recent available data from the Census Bureau), as shown in Figure 2.20.

Figure 2.20: Percent of US Households with Computers and Internet Connections (1997-2003)



Source: US Department of Commerce (2004)

Access to information technologies is only relevant if students use these technologies. Common uses of these technologies include gaming and social networking. While these technologies do not require a student to understand how a device works, they provide students with an appreciation of the uses of NIT, which is often seen as an important factor in career decisions.

At all levels of education, social influences are also thought to be key contributing factors to career choices. The influence of peers, role models, and the media play a significant

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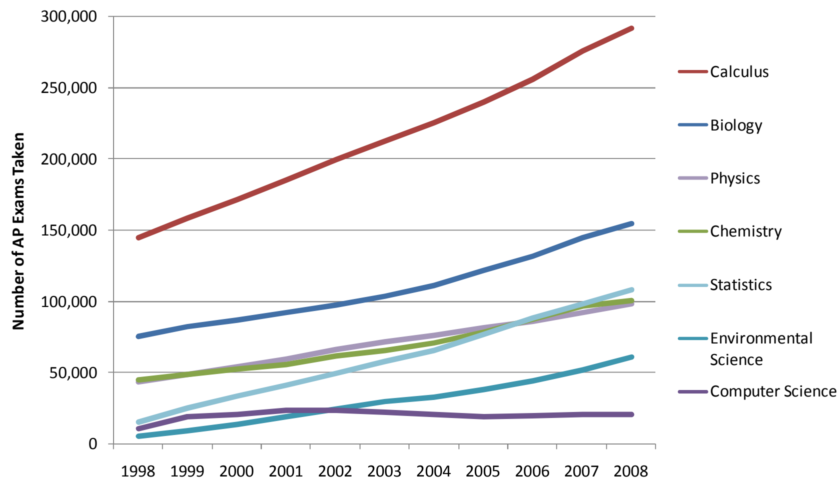
[78] http://www.sidwell.edu/middle_school/technology.asp
[79] NTIA (2004)

role in affecting the career perceptions of individuals throughout the educational pipeline. These influences begin primarily during the K-8 years and continue through an individual's retirement from the workforce.

2.2.1.3 High School

High school is often the first period in the formal educational system where students take computer science courses. According to a 2007 survey by the Computer Science Teachers Association (CSTA), 73 percent of high schools in the United States offer some form of computer science course, while only 33 percent of schools require students to take such a course.[80] An indicator of interest in CS at the high school level, the number of students taking the Advanced Placement (AP) test in CS, has been declining while the number of students taking all other AP tests has increased, as shown in Figure 2.21.

Figure 2.21: Advanced Placement Tests Taken in CS Relative to Other Subjects (1997-2007)



Source: College Board AP Data 2008[81]

While some of this decline could be attributed to a lack of interest, some experts have attributed the decline in AP CS test taking to the redesign of the exam to focus on the object-oriented language Java, which has increased its complexity. Some interviewees raised concern about the qualifications of high school computer science teachers to teach Java to students.

Due to the lack of prevalence of CS in high school, science and math continue to be a key focus of preparation for NIT careers at the high school level in addition to access and use of information technologies inside and outside of the classroom. High school students may also begin to think about careers in terms of salary and job satisfaction.

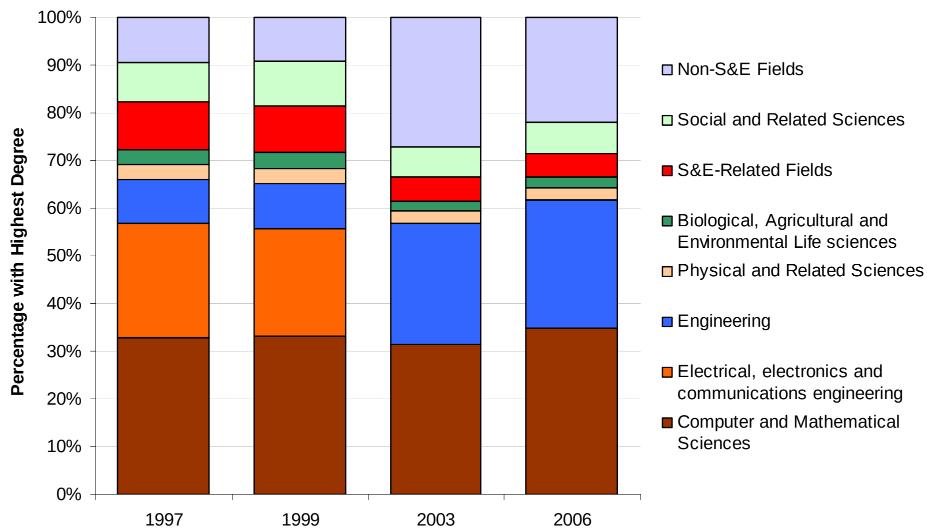
2.2.1.4 Higher Education

The selection of academic major by undergraduate students is one of the first clear indicators of their career choice. It is not a binding choice but gives some indication of

[80] CSTA (2007)
[81] http://professionals.collegeboard.com/data-reports-research/ap/data

their career objectives. This is especially true in fields that are more "career oriented" such as CS and EE.[82] While CS and EE are not the only academic avenues to NIT careers,[83] selection of these majors remains one of the first indicators of NIT career choice. This is especially true when NIT careers are considered more narrowly as Category 1 IT occupations. However, the majority of NIT workers do not obtain degrees in the typical NIT fields. Figure 2.22 shows the fraction of category 1 NIT workers whose highest degrees were in various fields in 1997, 1999, 2003, and 2006. These data are derived from the NSF SESTAT database in which the most relevant NIT occupations are computer and mathematical scientists and electrical and computer hardware engineers.

Figure 2.22: Degree Field of Category 1 NIT Workers (1997-2006)



Source: SESTAT

We can see from these data that in 1997 and 1999 about 57 percent of NIT workers received their highest degree in traditional NIT degree fields (computer and mathematical sciences and electrical, electronics, and communications engineering). Another 33 percent received their degrees in STEM fields, leaving only about 10 percent receiving degrees outside of STEM fields. The definitions of the SESTAT data changed in 2003, at which point electrical, electronics, and communications engineers were included in the engineering degree category. If we assume that electrical, electronics, and communications engineers comprised the same proportion of the engineering workforce in 2003 and 2006 as they did on average in 1997 and 1999 (71 percent), then the number of NIT degree holders in NIT careers fell to 50 percent in 2003 and increased back to 54 percent in 2006. The number of NIT workers receiving STEM degrees fell significantly from 90 to 73 percent in 2003 and increased slightly to 78 percent in 2006. The trend we see here may be a result of the dot-com boom in the early 2000s, which brought many non-NIT degree holders into the NIT workforce. By 2006, many of these workers left the

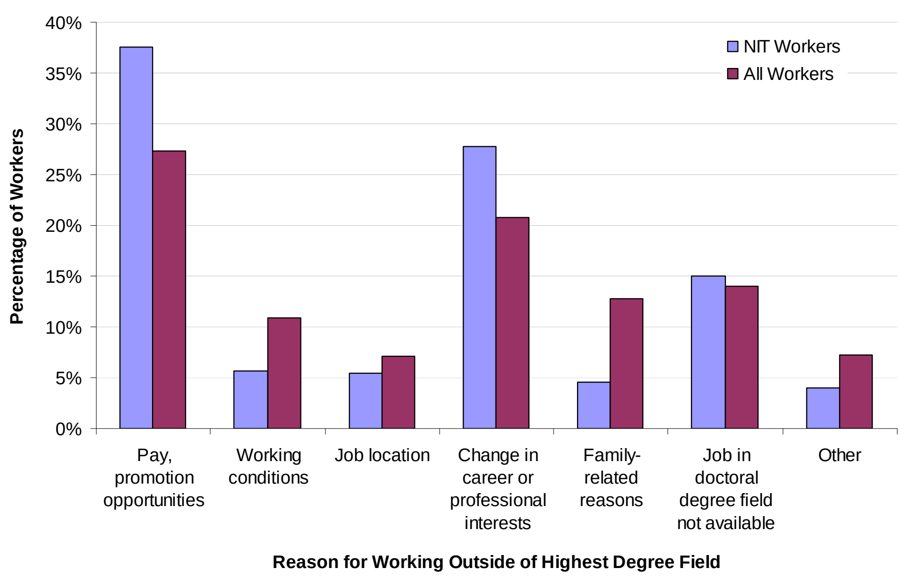
[82] NCES (2008a)
[83] Freeman and Aspray (1999)

NIT workforce but the fraction of NIT and STEM degree holders remained lower than it had been in the 1990s.

The NSF surveys workers about the relation of their highest degree to their occupation. In 2006, NIT occupations had among the lowest percentage of workers who said their occupation was closely related to their highest degree. Fifty percent of NIT workers said that their occupation was closely related to their highest degree compared to an average of 68 percent for all occupations. Fewer computer and mathematical scientists (48 percent) reported their occupation being closely related to their highest degree than electrical and computer engineers (68 percent). NIT occupations also had the highest fraction of workers reporting their occupation was not related to their highest degree at 18 percent compared to an average of nine percent across all occupations. The data affirms that NIT workers tend to come from a variety of degree backgrounds that may not be related to NIT.

For those who reported working outside of their highest degree field, the most cited reason for working in NIT occupations was pay and promotion opportunities, as shown in Figure 2.23. The fraction of workers reporting this as the primary reason for working outside of their highest degree was much higher for NIT occupations (38 percent) than for all occupations (27 percent). A larger fraction of NIT workers (28 percent) than all workers (21 percent) also cited changes in career or professional interests as a primary reason for working outside of their degree field. NIT workers less frequently cited working conditions, job location, and family-related reasons.

Figure 2.23: Fraction of Workers Citing Primary Reason for Working Outside of Degree Area: NIT vs. All Workers (2006)



Source: SESTAT

Overall, while a significant amount of emphasis is placed on the NIT degree pipeline, a significant portion of NIT workers do not have NIT degrees. Most recently, in 2006, 46 percent of the NIT workforce did not have an NIT degree and 22 percent of the workforce did not have a STEM degree. Higher pay and changes in professional interest appear to be two of the major factors that lead non-NIT degree holders to choose NIT careers.

We can also track NIT pathways from another perspective by asking where those with degrees in traditional NIT areas like computer science end up working. A study by the NCES, *Ten Years After College: Comparing the Employment Experiences of 1992-93 Bachelor's Degree Recipients With Academic and Career Oriented Majors*, is one of the most recent and comprehensive studies that track the occupational trajectory of bachelor's degree recipients. The study uses data from the Baccalaureate and Beyond Longitudinal Study to identify the career trajectories of 1992-93 bachelor's recipients, two, five, and ten years after their graduation.

The study separates degrees by category – academic versus career-oriented degrees. One of the findings is that recipients of degrees in career-oriented fields tend to remain in careers associated with their undergraduate education, while graduates with academic degrees displayed much more variation in their careers. CS is classified as a career-oriented degree implying that students who choose to pursue CS at the undergraduate level are more likely to be making a career choice with their undergraduate major and more likely to remain in NIT career paths. CS graduates, however, are found in an array of fields other than computer science, as seen in Table 2.8.

Table 2.8: Percentage Distribution of 1992-93 Bachelor's Degree Recipients' Occupations in 2003 by Degree Field and Occupation

Undergraduate Degrees	Business workers and managers	Educators	Service workers	Admin/ clerical/ legal support workers	Medical Professionals	Human/ protective services/ legal professionals	Researchers, scientists, technology workers	Engineers/ architects	Editors/ writers/ performers	Computer scientists	Other
Total	28	19	10	3	10	8	5	5	4	5	3
Academic Degrees	**23**	**19**	**10**	**5**	**10**	**12**	**8**	**2**	**5**	**3**	**3**
Social and behavioral sciences	30	15	12	4	5	19	5	1	4	3	3
Arts and humanities	20	24	13	7	3	9	5	1	12	3	3
Biological sciences	11	12	7	1	43	2	15	3	2	2	2
Mathematics/physical sciences	19	22	3	2	11	5	24	4	1	7	3
Other academic	23	29	6	5	5	12	7	0	2	5	4
Career-oriented Degrees	**31**	**18**	**10**	**3**	**9**	**6**	**3**	**7**	**4**	**6**	**3**
Business and management	56	6	15	3	2	3	2	1	1	6	5
Education	9	65	6	2	3	5	1	0	4	2	2
Health	10	6	4	1	69	4	3	1	0	1	1
Engineering	23	2	4	0	1	1	4	48	1	13	4
Computer science	**18**	**4**	**4**	**3**	**1**	**1**	**3**	**18**	**0**	**48**	**2**
Other career-oriented	25	11	14	5	4	18	4	4	12	2	3

Source: NCES (2008a)

Forty-eight percent of CS degree recipients remained in CS occupations ten years after receiving their degrees. The fraction that stayed in CS was lower at one year after graduation (47 percent) and peaked five years after graduation (56 percent). The two occupational categories with the second largest representation of computer scientists in 2003 were business/managerial careers (18 percent) and engineering-related occupations (18 percent). Engineering occupations include electrical engineers and computer hardware engineers, which are considered part of the category 1 NIT workforce. The proportion of CS degree holders working in business and managerial occupations reflects the prevalence of technology-based managerial opportunities and the likely migration over time of workers moving along the spectrum from strict IT work to ITE work. NCES (2008a) also shows that STEM degree recipients are increasingly likely to become computer scientists, with 10 percent choosing NIT occupations after one year and 13 percent choosing NIT occupations after five and ten years.

2.2.1.5 Non-traditional Academic Pathways

Traditionally, Ph.D.-granting institutions are the primary producers of bachelor's degrees in the sciences and engineering, but this is not the case for CS. In 2001, at the height of CS degree production, the top producer of bachelor's degrees in CS in the United States was Strayer University, a for-profit institution with campuses all across the east and southeast with an array of online and evening options that cater to non-traditional college students. Five of the other top ten producers were DeVry Institute of Technology campuses, as shown in Table 2.9. DeVry is a similar for-profit institution that operates in several states.

Table 2.9: Top Producers of Computer Science Bachelor's Degrees (2001)

Rank	Academic Institution	Degrees Awarded
1	Strayer University	840
2	DeVry Institute of Technology (Addison, IL)	477
3	CUNY Bernard Baruch College	465
4	University of Maryland Baltimore County	463
5	DeVry Institute of Technology (Phoenix, AZ)	440
6	DeVry Institute of Technology (City of Industry, CA)	349
7	Rutgers, the State University of New Jersey	336
8	DeVry Institute of Technology (Kansas City, MO)	316
9	DeVry Institute of Technology (Long Beach, CA)	301
10	James Madison University	393

Source: Malcom et al. (2005)

By demonstrating the sources of CS degree production, Malcom et al. (2005) calls into question the traditional path to an NIT career. Anecdotal evidence suggests that graduates of degree programs such as Strayer and DeVry largely work in fields directly related to their course of study. That is one of the marketing strategies of the institutions, and one of the main reasons students enroll – to find a specific type of job. Non-traditional entrants to NIT careers, such as those highlighted by Freeman and Aspray (1999) and Aspray (2007), are typically older, more diverse, likely to have had previous careers, and often select CS programs with certainty based on reasoned calculation and experience. CS students at these institutions are making the investment in these programs with the specific intention of entering NIT careers. This implies that non-traditional students are choosing NIT careers with more certainty than their traditional counterparts.

This trend has significant implications for the allocation of resources targeted at academic pathways to increasing the NIT workforce and initiatives to persuade students to choose NIT careers. Perhaps computer science is sufficiently different from other science and engineering disciplines that addressing NIT workforce needs requires a new template. As shown in Table 2.10, all of the top ten producers of engineering bachelor's degrees in 2001 were from "traditional" non-profit colleges and universities.

Table 2.10 Top Producers of Engineering Bachelor's Degrees (2001)

Rank	Academic Institution	Degrees Awarded
1	Pennsylvania State University, Main Campus	1,221
2	Georgia Institute of Technology	1,169
3	University of Illinois-Urbana Champaign	1,088
4	Purdue University, Main Campus	1,079
5	University of Michigan-Ann Arbor	1,036
6	North Carolina State University at Raleigh	982
7	Virginia Polytechnic Institute and State University	961
8	Texas A&M University Main Campus	895
9	University of California-Berkeley	750
10	University of Florida	749

Source: NCES

The significant production of CS degrees at for-profit, vocationally focused institutions suggests that CS has a heavily vocational component. The vocational dimensions of CS distinguish it from the more traditional science and engineering fields with which it is commonly associated. This implies that strategies to influence the career choices of young people through educational policies may need to be bifurcated – those focused on career choice and educational pathways of traditional students at traditional non-profit institutions versus those focused on non-traditional students at for-profit institutions.

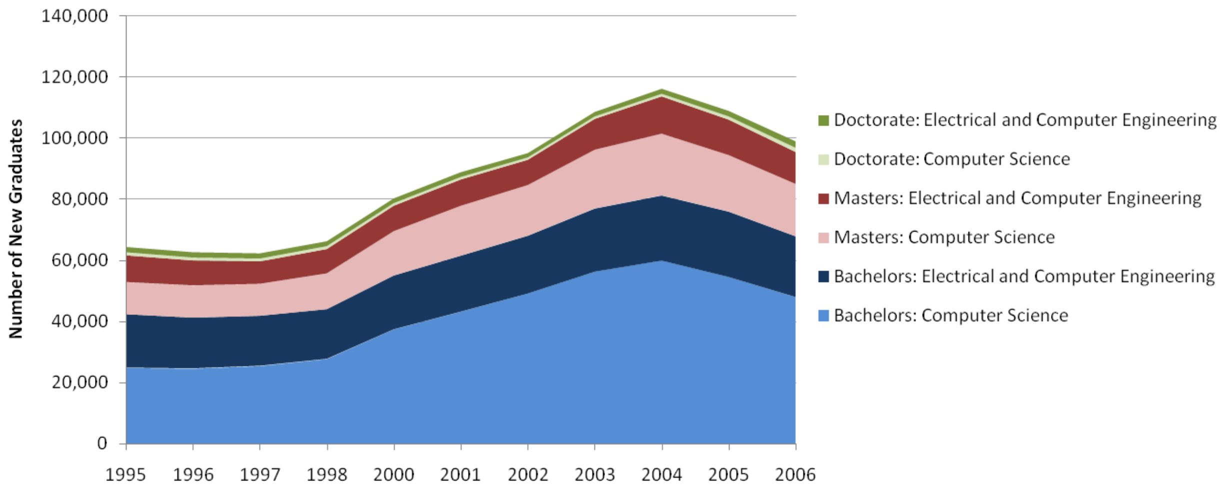
As noted above, older students with prior careers in other disciplines are more likely to attend for-profit degree programs in computer science. This is an important transition point for individuals from non-computing disciplines to transition into computing professions. While more traditional non-profit institutions can also serve this purpose, it appears that the flexibility, curriculum, and culture of for-profit institutions is more appealing to those looking to move into NIT careers. Targeting these individuals requires targeting these transitions. The literature does not discuss other pathways for individuals to transition from non-computing to computing careers.

2.2.2 Supply of NIT Workers from Traditional NIT Disciplines

Although many NIT workers do not have traditional NIT degrees, one must limit the definition of supply in some way. Therefore, like nearly all studies of the NIT workforce conducted in the past, we limit our discussion of the supply to students and faculty in computer science and electrical engineering. Although these groups do not comprise the complete supply, they are a significant portion of the supply and may serve as an indicator of the overall trends. The end of this section provides a brief overview of the supply of STEM workers who comprise the majority of the NIT workforce.

Using NCES data, we estimate the number of NIT graduates in 2006 at the bachelor's level and above to be about 99,000. The number of new NIT graduates has been declining since 2004 when it peaked at 116,000. Figure 2.24 shows the supply of NIT graduates broken out by field and degree level from 1995 through 2006.

Figure 2.24: Supply of Traditional NIT Graduates (1995-2006)



Source: NCES

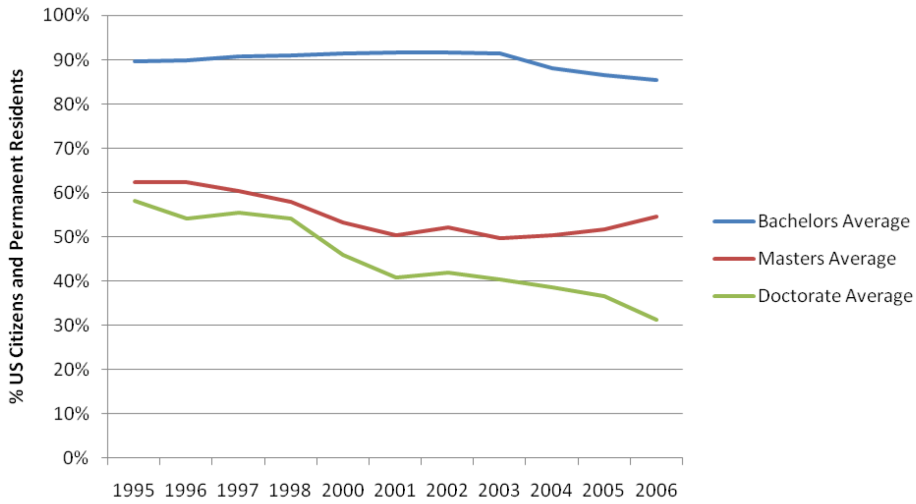
The CPS data estimate that there were 78,000 new category 1 NIT jobs created between 2005 and 2006. This is 21 percent fewer jobs than the number of new NIT graduates in 2006. However, a significantly larger number of graduates would also be needed to replace workers leaving the NIT workforce. For this reason, direct comparisons of supply and demand based on these data are difficult. However, it is clear that the number of US students choosing traditional academic pathways to NIT careers has been declining. This is occurring despite constant public appeals by science agencies and university and K-12 educators about the existing and increasing demand for IT workers and the increasingly important need for computing competency.[84] These choices are also taking place in the face of evidence presented in previous sections that unemployment in NIT occupations is low and the projected demand for workers in NIT occupations is growing faster than in other fields.

2.2.2.1 Citizenship

Many studies on the science and engineering workforce have raised concerns about the number of S&E graduates who are not US citizens.[85] This is also a concern for the NIT workforce. Most experts point to the fact that US graduate training programs are the best in the world but they need more US students to attend. Figure 2.25 shows the fraction of NIT graduates at the bachelor's, master's, and doctoral level who are US citizens or permanent residents.

[84] Guzdial and Soloway (2003), Patterson (2005), Dean (2007)
[85] NRC (2007)

Figure 2.25: Fraction of NIT Graduates who are US Citizens and Permanent Residents (1995-2006)

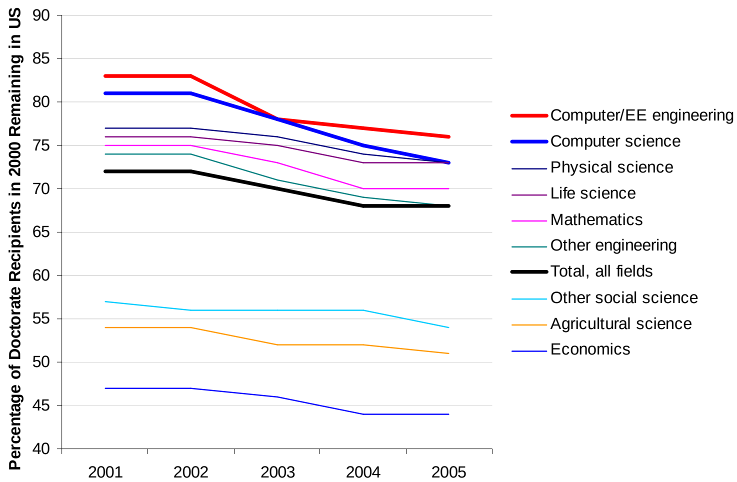


Source: NCES

We observe that the number of NIT graduates who are US citizens and permanent residents has been declining since 1995 at nearly every level. The fraction is the lowest for doctorate recipients, among whom the fraction of US citizens has dropped from nearly 60 percent in 1995 to almost 30 percent in 2006. The share of master's degree recipients who are US citizens and permanent residents declined from about 60 percent in 1995 to about 55 percent in 2006. The fraction of master's recipients who are US citizens and permanent residents declined through 2003 to near 50 percent and then increased over the period 2004-2006. The percentage of NIT bachelor's degrees awarded to US citizens and permanent residents has been around 90 percent from 1995 through 2006. However, this fraction declined recently from 92 percent in 2002 to 85 percent in 2006. The fraction of degrees granted to US citizens and permanent residents is important because many government and defense IT jobs require US citizenship and there is a concern about the supply of qualified individuals for these jobs as the baby-boom generation retires.

While a significant fraction of NIT doctoral degrees are granted to non-US citizens and permanent residents, a large fraction of these degree recipients remain in the United States. About three-quarters of foreign nationals receiving NIT doctoral degrees in 2000 remained in the United States in 2005. This is the highest stay rate among all fields of study, as shown in Figure 2.26.

Figure 2.26: Percentage of Foreign NIT Doctoral Students Remaining in the US After Graduation



Source: Finn (2007)

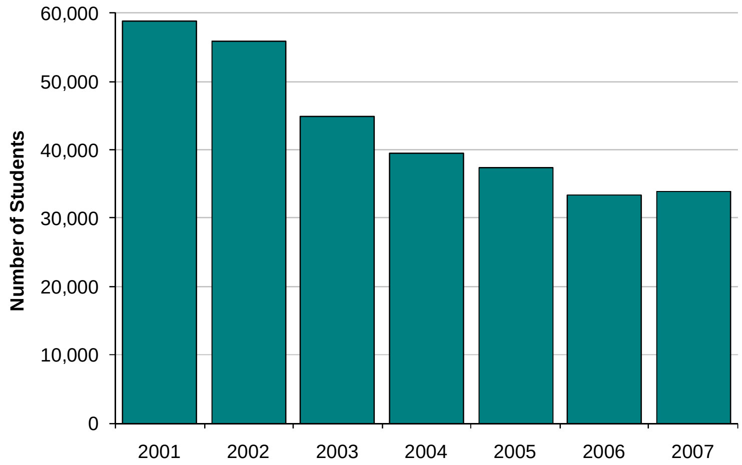
While the data show that stay rates of foreign graduates have been relatively high, Wadhwa argues that this trend may be reversing as perceived economic opportunity in home countries (especially India and China) have made it more attractive for foreign students trained in the United States to return home.[86] While this trend was identified from non-random survey samples, combined with anecdotal evidence, it identifies only trends captured in official government statistics with a time lag.

2.2.3 Supply of Computer Scientists

It is helpful to look at the degree programs that award traditional NIT degrees separately to get a sense of the issues facing these fields. The supply of computer scientists is well studied by organizations such as the Computing Research Association (CRA) and the Association for Computing Machinery (ACM). Almost all data on data on the supply of computer scientists show a declining interest in the field. Figure 2.27 shows declining interest in computer science at the high school level based on majors students reported on the SAT exam.

[86] Wadhwa et al. (2009)

Figure 2.27: Number of Students Indicating Computing and Information Sciences as Intended Major on SAT (2001-2007)



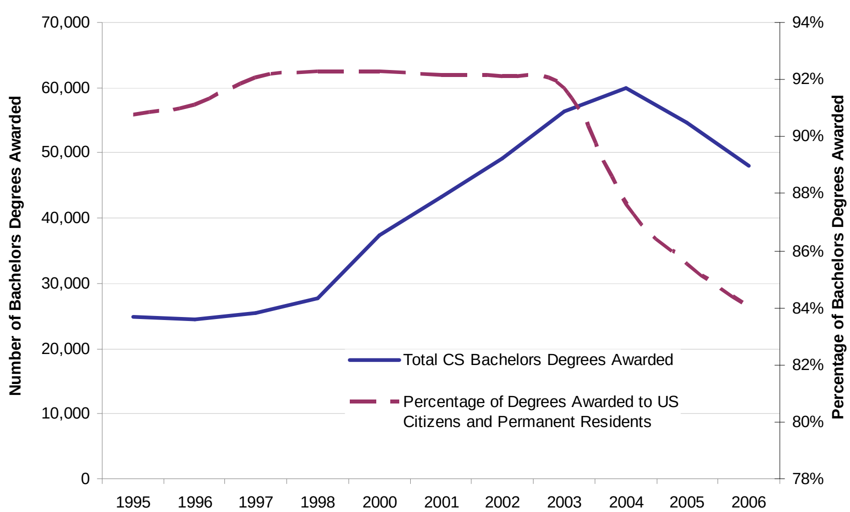
Source: IT Business Advocacy Roundtable (2008)

The following sections look at the supply of CS graduates at various levels of higher education.

2.2.3.1 Bachelor's Degrees

The number of bachelor's degrees awarded in CS peaked in 2004 and declined in every year thereafter. NCES data estimate that nearly 60,000 CS bachelor's degrees were awarded in 2004 and that the number declined to under 50,000 by 2006. However, the number of degrees awarded is still significantly higher than the average annual number of degrees awarded in the years before the peak (36,000 over the years 1995 through 2003). The fraction of CS degrees awarded to US citizens and permanent residents declined from 92 percent in 2002 to 84 percent in 2006, as shown in Figure 2.28.

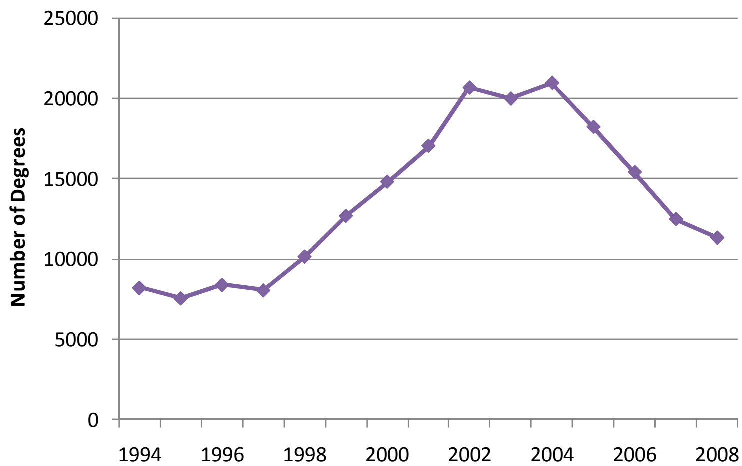
Figure 2.28: Computer Science Bachelor's Degrees Awarded by US Institutions (1995-2006)



Source: NCES

More recent data on the number of CS bachelor's degrees awarded are available from the CRA's annual Taulbee survey of institutions in the United States and Canada that grant computer science Ph.D.s. These data show the same peak in degrees awarded in 2004 followed by an almost 50 percent decline by 2008, as can be seen in Figure 2.29.

Figure 2.29: Computer Science BS Degrees Awarded in US and Canada by PhD Granting Institutions (1994-2008)

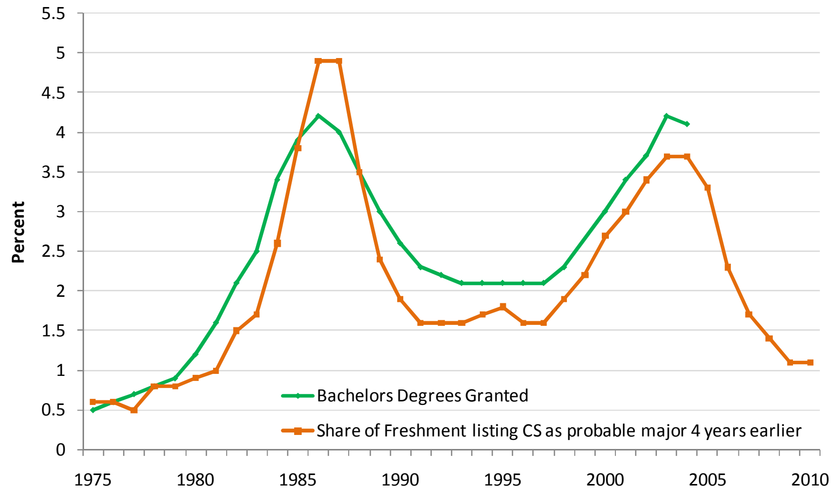


Source: Compilation of Yearly Taulbee Survey Results[87]

It is relatively easy to predict changes in the number of CS bachelor's graduates over the next four years by looking at data on the intentions of incoming freshmen to major in CS. Figure 2.30 compares the fraction of CS degrees granted with the fraction of students listing CS as a probable major four years earlier. Current data on the intentions of freshmen to major in CS foreshadows a further decline in the number of CS degrees granted through 2009.

[87] http://www.cra.org/statistics

Figure 2.30: Percentage of Incoming College Freshmen Listing Computer Science as their Probable Major Four Years Previously Compared to Degree Production



Source: Vegso (2007)

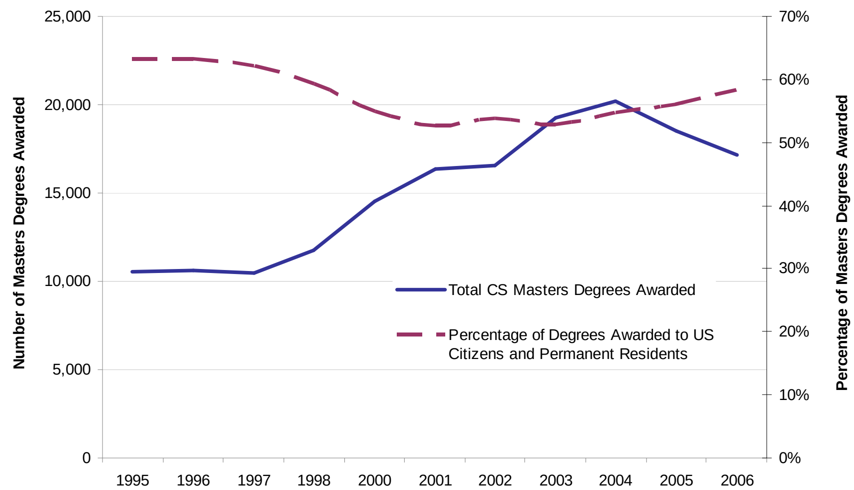
However, the CRA reports that in 2007-2008, enrollments per CS department increased for the first time in six years.[88] The number of CS majors and pre-majors grew 6.2 percent from the previous year while the number of majors grew 8.1 percent.[89] Additionally, at Stanford University, the number of students taking introductory computer science courses increased by 20 percent in the 2008-2009 school year.[90] These trends indicate that the drop in CS degree production observed since 2004 may be turning around. Some hypothesize that this change is part of a broader trend following the economic downturn, where students' career interests are shifting away from finance and consulting and towards public service and science.[91]

2.2.3.2 Master's Degrees

The number of master's degrees awarded in CS nearly doubled between 1996 and 2004. Like bachelor's degrees, the number of CS master's degrees awarded declined thereafter, from about 20,000 in 2004 to about 17,000 in 2006. The percentage of CS masters degrees awarded to US citizens and permanent residents declined from about 65 percent in 1995 to a low of about 55 percent in 2003. That fraction recently increased to nearly 60 percent in 2006. Figure 2.31 shows the number of master's degrees awarded and the percentages awarded to US citizens and permanent residents from 1995 through 2006.

[88] Zweben (2009)
[89] Zweben (2009)
[90] Lohr (2009)
[91] Lohr (2009)

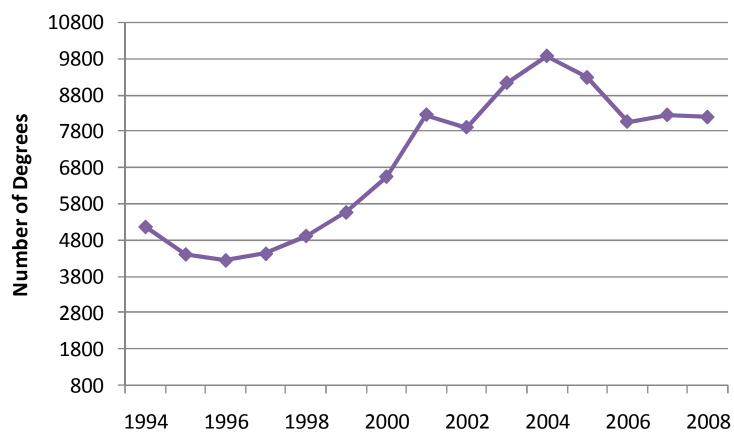
Figure 2.31: Computer Science Master's Degrees Awarded by US Institutions (1995-2006)



Source: NCES

More recent results for CS degrees awarded in the United States and Canada from the Taulbee survey show that the number of master's degrees awarded has remained relatively flat since 2006, as shown in Figure 2.32.

Figure 2.32: Computer Science Master's Degrees Awarded in US and Canada by PhD Granting Institutions (1994-2008)

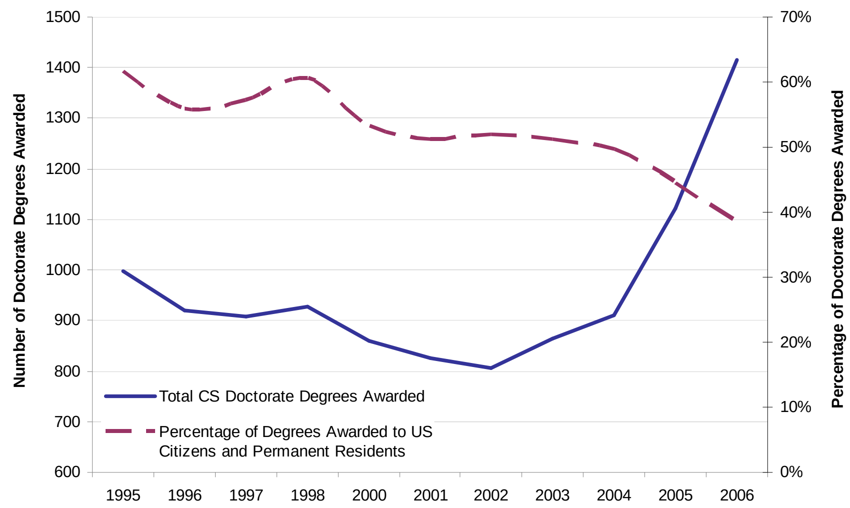


Source: Compilation of Yearly Taulbee Survey Results

2.2.3.3 Doctoral Degrees

The number of doctoral degrees awarded in computer science increased significantly between 2004 and 2006. While about 900 CS doctorates were awarded each year between 1995 and 2004, 1,400 CS doctorates were awarded in 2006. However, there has been a decline in the number of US citizens and permanent residents receiving these degrees, from 50 percent in 2004 to 40 percent in 2006, as shown in Figure 2.33.

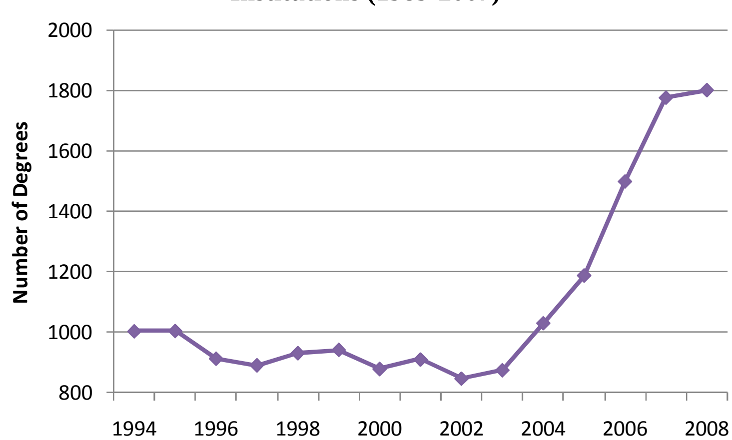
Figure 2.33: Computer Science Doctoral Degrees Awarded by US Institutions (1995-2006)



Source: NCES

The significant increase in the number of CS doctorates awarded has continued since 2006. Figure 2.34 shows the number of CS doctorates awarded in the United States and Canada through 2008, based on the Taulbee survey. These data show a doubling in the number of CS doctorates between 2002 and 2008.

Figure 2.34: Computer Science Doctoral Degrees Awarded by US and Canadian Doctoral Institutions (1989-2007)



Source: Compilation of Yearly Taulbee Survey Results

Many have attributed the significant increase in the number of CS doctorates awarded to an increase in the number of students choosing CS doctoral programs after the dot-com bust in 2001. There is currently a concern about the availability of jobs for this influx of doctoral students. However, after this wave of students graduates, the number of CS doctoral graduates is expected to fall.[92]

[92] Expert interviews

2.2.3.4 Faculty

It is difficult to break out faculty data by academic field because the NCES Fall Staff Survey does not include such a variable. However, the Taulbee survey compiles statistics on CS faculty, as shown in Table 2.11.

Table 2.11: Number of Computer Science Faculty at PhD Granting Institutions in the US and Canada

	Actual	Projected	
Type of Faculty	**2007-2008**	**2008-2009**	**2009-2010**
Tenure-Track	4,390	4,575	4,774
Researcher	633	642	660
Postdoc	400	436	483
Teaching Faculty	353	421	467
Other/Not Listed	131	138	139
Total	**5,907**	**6,212**	**6,523**

Source: Zweben (2008)

According to these data, there were about 5,907 CS faculty at Ph.D.-granting institutions in the United States and Canada in 2007-2008. This number is expected to grow five percent per year through 2010. The majority of this growth is expected to be in the number of postdocs and teaching faculty, with the number of tenure-track and researcher positions still increasing but at a slower rate. There is no data available on the number of CS faculty at non-Ph.D.-granting institutions.

Estimating the number of computer science teachers at the K-12 level is even more difficult than estimating the number of college faculty. The NSF SESTAT database reports 53,000 computer and mathematical scientists in 2006 who report their primary work activity as teaching. This includes both K-12 teachers and professors in higher education in both science and math. No further breakdown is available. In 1999, Deek and Kimmel reported that computer science courses are often taught by math or science teachers. [93] The 2007 CSTA survey discussed earlier sent survey forms to 13,000 individuals in the United States who defined themselves as computer science teachers. To provide context, the Census Bureau reported in 2004 that there were 770,000 secondary school teachers in the United States. It is likely that many teachers who report themselves as CS teachers also teach math or science. As one expert explained, “being a high school computer science teacher is not a career.”

2.2.4 Supply of Electrical Engineers

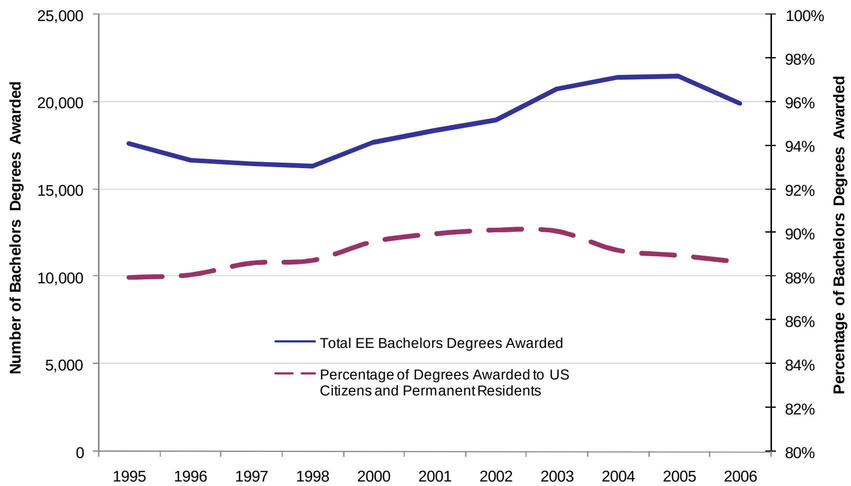
While there is no survey of electrical engineering (EE) programs as there is for CS programs, we can identify trends in EE degrees awarded from the NCES data. This section looks at trends in the number of EE degrees awarded at various levels of higher education.

[93] Deek and Kimmel (1999)

2.2.4.1 Bachelor's Degrees

The number of bachelor's degrees awarded in electrical engineering increased from 1998 through 2005 and dropped somewhat in 2006. The fraction of EE bachelor's degrees awarded to US citizens and permanent residents increased slightly from 1995 through 2003 and declined slightly from 2004 through 2006, although it remained close to 90 percent over this entire time period, as shown in Figure 2.35.

Figure 2.35: Electrical Engineering Bachelor's Degrees Awarded by US Institutions (1995-2006)

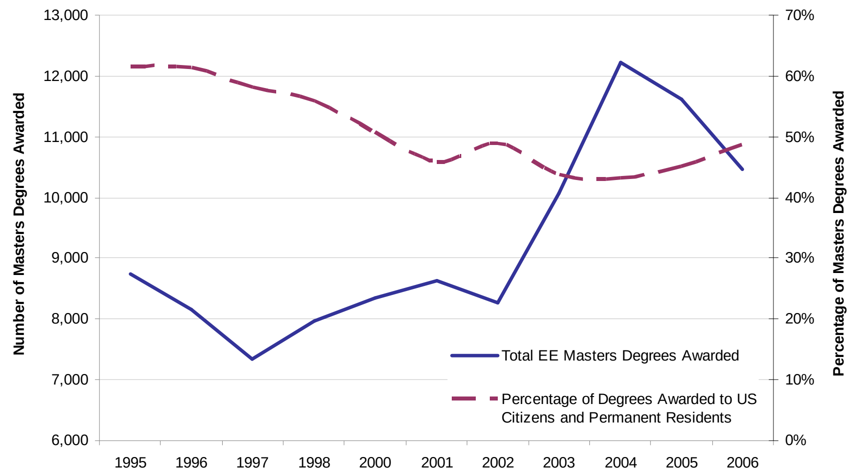


Source: NCES

2.2.4.2 Master's Degrees

The number of master's degrees awarded in EE has followed a similar trend to bachelor's degrees, increasing between 1998 and 2004 and then decreasing from 2004 through 2006, although the decrease has been more significant for master's degrees. Over this time period, the fraction of US citizens and permanent residents receiving EE master's degrees decreased from about 60 percent in 1995 to near 50 percent in 2006. Figure 2.36 shows these trends.

Figure 2.36: Electrical Engineering Master's Degrees Awarded by US Institutions (1995-2006)

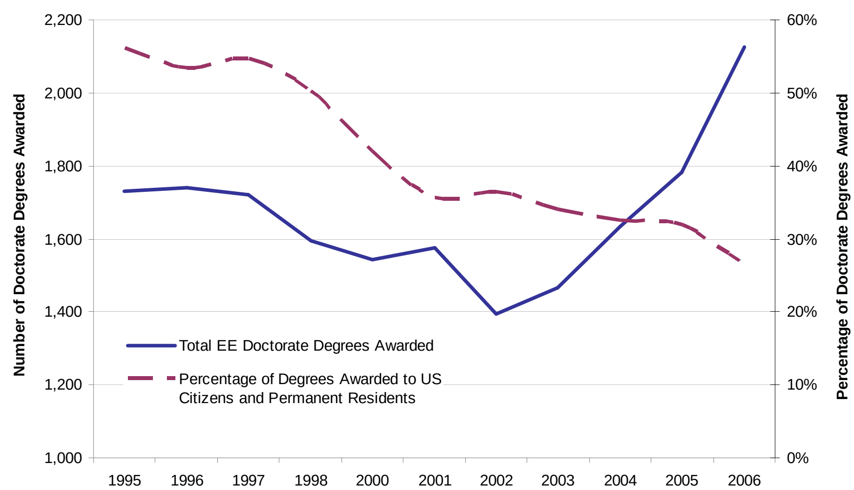


Source: NCES

2.2.4.3 Doctoral Degrees

As with CS doctoral degrees, there has been a significant increase in the number of EE doctoral degrees granted over the past few years. The number of doctorates granted increased from about 1,500 in 2002 to over 2,000 in 2006. This is consistent with the explanation that NIT workers who could not find jobs after the dot-com bust went to graduate school. However, it appears that the majority of those who decided to attend graduate school during that time were not US citizens or permanent residents. Figure 2.37 shows trends in recipients of EE doctoral degrees from 1995 to 2006. The fraction of US citizens and permanent residents receiving EE doctoral degrees decreased significantly from about 55 percent in 1995 to below 30 percent in 2006.

Figure 2.37: Electrical Engineering Doctoral Degrees Awarded by US Institutions (1995-2006)



Source: NCES

2.2.4.4 Faculty

There is little available information on the number of electrical engineering faculty in the United States. There is no equivalent of the CRA's Taulbee survey for EE. The NSF SESTAT database estimates that, in 2006, there were 4,600 electrical and computer hardware engineers who identified their primary work activity as teaching. This is the only estimate available for the number of EE teachers in the United States. Since there are few, if any, electrical engineering courses at the K-12 level, we can assume that these teachers are all in higher education.

2.2.5 Supply of STEM Educated Workers

As discussed earlier in this section, STEM education is considered a key foundation for NIT careers. In addition, we have seen that many NIT workers obtained their highest degree in STEM fields other than computer science or electrical engineering. This section presents a high-level overview of the supply of STEM workers at both the K-12 level and in higher education.

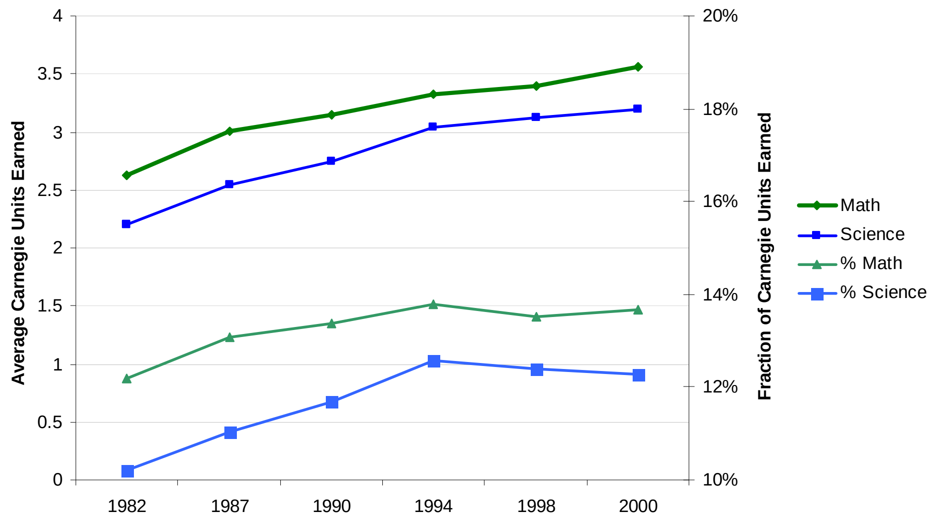
2.2.5.1 K-12 STEM Education

NIT courses are not part of the core curriculum in US K-12 education and it is generally thought that the pipeline of qualified NIT graduates emerging from the K-12 system are those that are proficient in math and science.[94] While the literature on the topic of K-12 science and math education is extensive and not directly related to NIT, it is important to look at key trends as K-12 science and math education is generally thought to be the pipeline of students who are prepared for NIT careers.

Education in science and math at the high school level has been increasing since 1982 both in absolute and relative terms. Figure 2.38 shows the average number of Carnegie units (a measure of student-teacher interaction in a subject area) for science and math in absolute terms and as a fraction of total units earned. We can see that exposure to math and science increased in both absolute terms and as a fraction of all exposure from 1982 through 2000.

[94] Klein (2006)

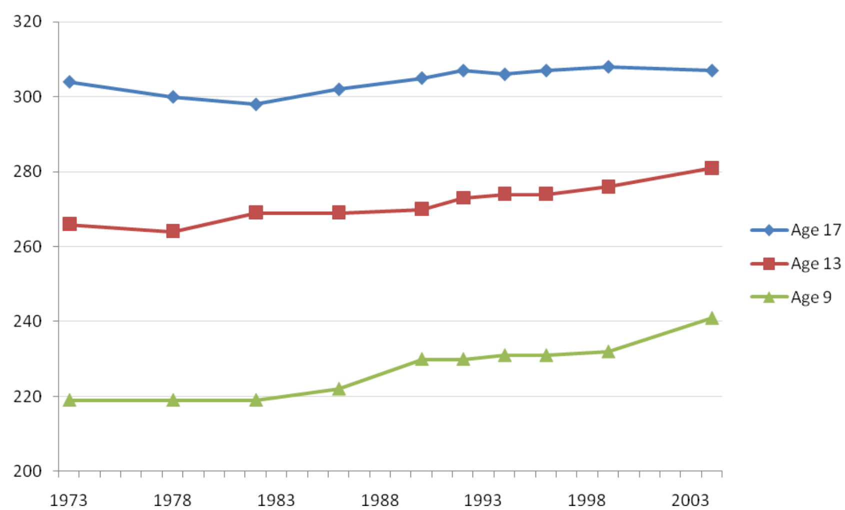
Figure 2.38: Average Number and Fraction of Carnegie Units Earned by Public High School Graduates in Math and Science



Source: NCES (2004a)

Average performance in math and science has also remained relatively constant over the past few decades. Math scores on the National Assessment of Educational Progress (NAEP) have either remained constant or increased over the past three decades, as shown in Figure 2.39. NAEP science scores have also not changed significantly between 1996, when they were first collected, and 2000.[95] The fraction of students meeting basic and proficient math levels has been increasing at the 4th and 8th grade level since 1990.[96]

Figure 2.39: NAEP Math Scores (1973-2004)



Source: NAEP Long-Term Trends in Mathematics[97]

[95] Lowell and Salzman (2007)
[96] CRS (2008)
[97] http://nces.ed.gov/nationsreportcard/ltt/results2004/natmathinfo.asp

While math and science scores may not have declined over time, many cite the declining performance of US students in math and science relative to other countries as a significant concern.[98] The results of the Trends in International Mathematics and Science Study (TIMSS) are often cited among concerns about US student math and science performance. Table 2.12 shows that US fourth grade students rank eleventh among students in thirty-six countries and US eighth grade students rank ninth among students in forty-eight countries in math scores. The shaded countries have test scores that are statistically (p=0.05) significantly higher than US scores.

Table 2.12: TIMSS Mathematics Test Score Comparison (2007): Average=500

Grade Four		Grade Eight	
Country	**Score**	**Country**	**Score**
Hong Kong	607	Chinese Taipei	598
Singapore	599	Republic of Korea	597
Chinese Taipei	576	Singapore	593
Japan	568	Hong Kong	572
Kazakhstan	549	Japan	570
Russian Federation	544	Hungary	517
England	541	England	513
Latvia	537	Russian Federation	512
Netherlands	535	**United States**	**508**
Lithuania	530	Lithuania	506
United States	**529**	Czech Republic	504

Source: TIMSS (2007)

Another commonly used international comparison for K-12 math and science students is the Programme for International Student Assessment (PISA). On the most recent (2006) PISA assessment, US 15-year olds ranked below 24 other countries in math and 23 other countries in science among the 30 OECD countries.[99] The US ranking in math remains low (25th) even when looking at the average scores of top performers. While statistics like these are often used to argue for the inadequacy of the US math and science education in the United States, the PISA data reflect not only on the educational system but also on broader societal trends. As noted by PISA researchers: “It cannot automatically be inferred that the schools or particular parts of the education system in the first country are more effective than those in the second. However, one can legitimately conclude that the cumulative impact of learning experiences in the first country, starting in early childhood and up to the age of 15 and embracing experiences both in school and at home, have resulted in higher outcomes.”[100]

Overall, the United States is not highly ranked among OECD countries in K-12 math and science test scores. Given the US position in the global economy, it is not unreasonable to expect the United States to rank higher in math and science given that those skills are expected to be necessary to retain a competitive edge in the future.[101] Although many use these data to argue that the United States is falling behind in math and science, Lowell

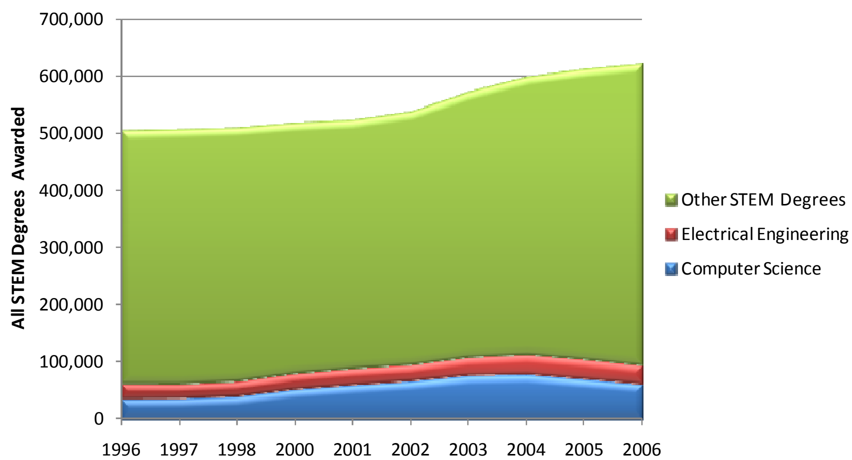
[98] McKinsey and Company (2009)
[99] McKinsey and Company (2009)
[100] Lowell and Salzman (2007), p. 15
[101] Murray (2008)

and Salzman argued: "Rather than concluding that the United States is behind in the world, it would be more accurate to conclude that the test results show the United States is not the highest performing nation in any single science or math test, but it is one of a very few nations that consistently rank above the international average in tests of academic performance … and the United States is one of the few that show consistent improvement over time across grades and subjects."[102] While comparing average test data paints a bleak picture of US competitiveness in math and science, these data come with many qualifications to carefully consider.

2.2.5.2 Supply of STEM Workers in Higher Education

While about half of NIT workers have degrees in traditional NIT disciplines, more than three-quarters have STEM degrees.[103] The number of STEM degrees awarded each year is many times the number of NIT degrees. There were about 624,000 STEM degrees awarded in 2006 at the bachelor's level and higher, as shown in Figure 2.40; 18 percent of STEM degrees awarded in 2006 were in NIT fields of study.

Figure 2.40: Total STEM Degrees Awarded (1996-2006)



Source: NCES

The number of STEM degrees increased at an average annual rate of two percent between 1996 and 2006. The annual number of degrees awarded grew more rapidly in 2003 and 2004, at seven and five percent, respectively, than it did over the rest of this time period. In the period in which we identified a decrease in the number of NIT degrees (2004-2006), the number of STEM degrees continued to grow at a rate of two percent per year.

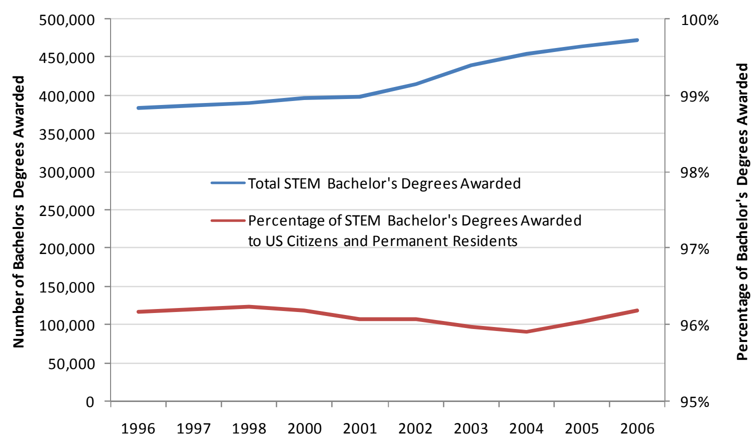
[102] Lowell and Salzman (2007), p. 14

[103] The National Science Foundation defines STEM fields to include: Aerospace Engineering, Agricultural Sciences, Anthropology, Area and Ethnic Studies, Astronomy, Atmospheric Sciences, Biological Sciences, Chemical Engineering, Chemistry, Civil Engineering, Computer Science, Earth Sciences, Economics, Electrical Engineering, Engineering Technologies, Health Technologies, History of Science, Industrial Engineering, Interdisciplinary or Other Sciences, Linguistics, Materials Engineering, Mathematics and Statistics, Mechanical Engineering, Oceanography, Other Engineering, Other Physical Sciences, Other Science and Engineering Technologies, Other Social Sciences, Physics, Political Science and Public Administration, Psychology, Science Technologies, and Sociology.

Therefore, although there has been a decrease in the number of NIT graduates for NIT careers, the number of STEM graduates continues to grow.

At the bachelor's degree level, the number of STEM degree recipients has steadily increased since 1996 at an average rate of two percent, as shown in Figure 2.41. The rate of growth in STEM bachelor's degrees awarded in 2003 and 2004 was six and three percent, respectively, the greatest period of growth over this time period. In 2006, there were 473,000 STEM bachelor's degrees awarded, of which 13 percent were NIT degrees. The fraction of STEM bachelor's degree recipients who were US citizens and permanent residents remained relatively constant from 1996 to 2006 at about 96 percent.

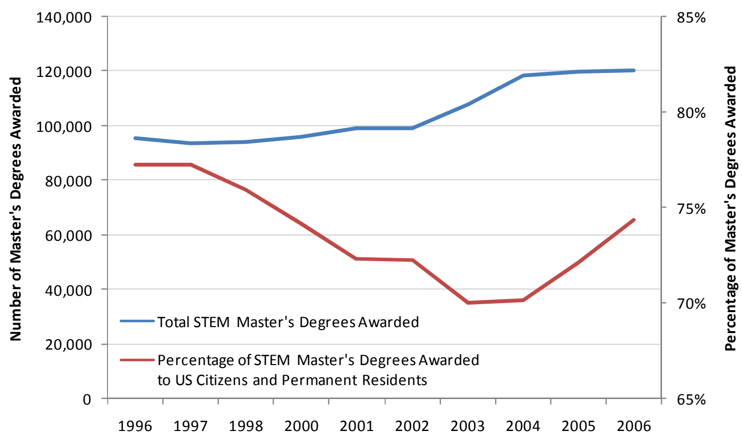
Figure 2.41: STEM Bachelor's Degrees Awarded and Foreign Degree Recipients (1996-2006)



Source: NCES

At the master's degree level, the number of STEM degree recipients grew rapidly in 2003 and 2004 at nine and ten percent, respectively, and then leveled off with nearly no growth in 2005 and 2006, as shown in Figure 2.42. In 2006, there were 120,000 STEM master's degrees awarded, of which 23 percent were NIT degrees. The fraction of STEM master's degree recipients who were US citizens and permanent residents decreased from 77 percent in 1997 to a low of 70 percent in 2003 and then rebounded to about 75 percent by 2006.

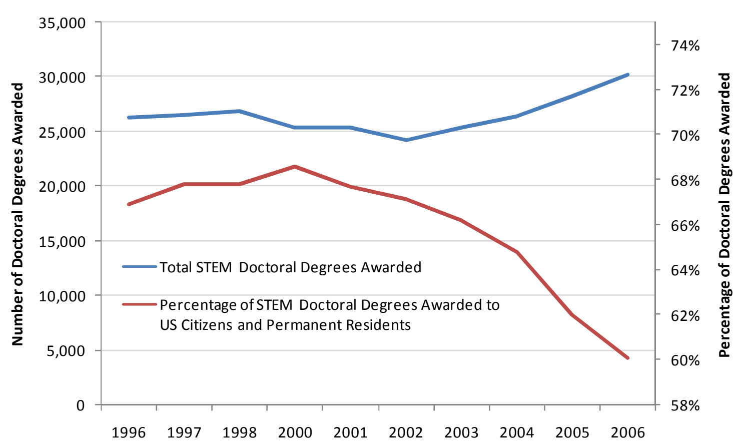
Figure 2.42: STEM Master's Degrees Awarded (1996-2006)



Source: NCES

At the doctoral level, the number of STEM degrees awarded decreased slightly between 1996 and 2002 and then began increasing at an annual rate of about seven percent in 2005 and 2006. In 2006, the number of STEM doctoral degrees awarded was about 30,000, of which 13 percent were NIT degrees. The fraction of STEM doctoral recipients who were US citizens and permanent residents increased slightly from 1996 through 2000 and then decreased from about 69 percent in 2000 to about 60 percent in 2006.

Figure 2.43: STEM Doctoral Degrees Awarded (1996-2006)



Source: NCES

Some of the trends in NIT degrees are visible in STEM degree trends; most salient is the drop in the percentage of US citizens and permanent residents receiving doctoral degrees. The key difference is that while the number of NIT degrees awarded decreased from 2004 through 2006, the number of STEM degrees awarded continued to grow. The 2008 version of *Science and Engineering Indicators* published by the NSB contains much more detail on the STEM pipeline and workforce.[104]

[104] NSB (2008)

2.3 NIT Labor Market Dynamics

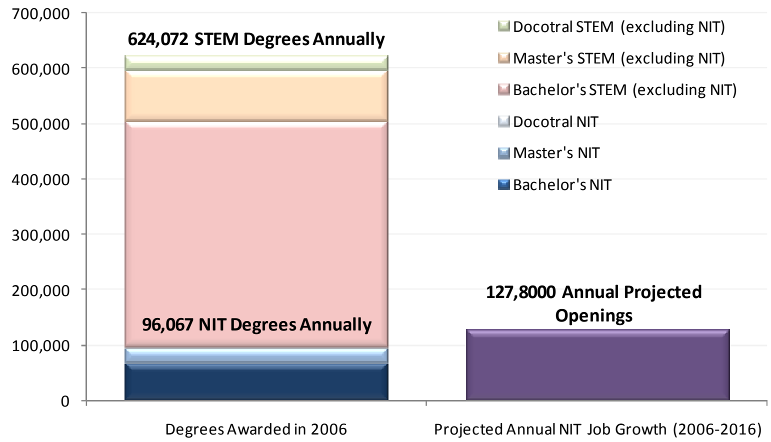
We have seen data on both the supply and demand for NIT professionals. Many of the previous studies on the NIT workforce attempted to assess whether there was a shortage of NIT workers or tightness in the NIT labor market.[105] These are very difficult assessments to make as they depend on the definitions of shortage and tightness. Some economists argue that there cannot be a shortage of NIT workers because the market will always balance supply and demand by increasing wages and drawing more people into the field. One problem with this argument is that the educational pipeline is long and there may be a supply delay in response to increasing demand (especially for category 1 NIT workers). Other types of shortages can be characterized by the Social Demand Model, which defines a shortage by whether there are as many NIT workers as is socially optimal.[106] However, defining what is socially optimal is subjective. Nonetheless, it is almost always the case that there are spot shortages in some region or occupation as it often takes time for supply to adjust in response to demand. Examining indicators of the NIT labor market provides some evidence on the state of the NIT labor market.

2.3.1 Matching Supply and Demand

As recently as 2008, some have argued that there is a shortage of IT workers.[107] We do not find any convincing evidence in either direction as to whether there will or will not be a shortage of NIT workers over the next decade. We have seen that the demand for NIT workers is expected to increase substantially over the next decade. At the same time, we observe declines in the number of graduates with traditional NIT degrees. However, this decline has been occurring for some time and there is no direct indication of recent shortages in the NIT workforce. In addition, only half of NIT workers have NIT degrees. The majority of NIT workers have STEM degrees and we have seen that the number of STEM degrees awarded has been increasing. Figure 2.44 shows the annual number of projected NIT job openings relative to the number of NIT and STEM degrees awarded in 2006.

[105] Most recently: Luftman and Hira (2008)
[106] Barnow et al. (1998), p. 8
[107] Chabrow (2008)

Figure 2.44: Annual Degrees and Job Openings in NIT and STEM Fields



Source: BLS and NCES

Looking at the raw data, we see that if all NIT degree recipients entered NIT careers, there would be a shortfall of 28,777 NIT workers if these degree recipients were the only source of workers. However, not all NIT workers enter NIT careers. NCES (2008a) estimates that the fraction of CS degree recipients in CS careers one year after graduation (in 1994) was 46 percent.[108] Assuming this is the rate of NIT career entry for NIT degree recipients in the future, there would be about 82,229 new openings each year that must be filled by non-NIT degree recipients. We used NSF SESTAT data to calculate that seven percent of non-NIT STEM degree recipients were in NIT occupations in 2006. Assuming this is the rate of NIT career entry for non-NIT STEM degree recipients, there would be about 45,947 openings each year (36 percent of all openings) that must be filled by non-STEM degree recipients. This is much higher than the historical rate of non-STEM degree holders in NIT careers, which was about 28 percent at its highest in 2003. However, these calculations are making some key assumptions. First, not all openings are filled with new graduates as people move into NIT occupations from other fields over time. NCES (2008a) shows that the fraction of non-STEM degree holders moving into NIT careers increases in nearly every degree field as individuals progress in their careers. Second, the NIT career entry rates we assumed for non-NIT STEM degree holders were for the overall workforce and not for graduates. It is possible that new non-NIT STEM graduates enter NIT careers at a rate higher than seven percent. The feedback loops in the NIT labor market also make it difficult to project supply and demand into the future. The entry and exit rates are likely to change with supply and demand, as the labor market is a dynamic system that tends towards equilibrium but often never reaches it. In addition, the BLS warns against trying to estimate shortages using their demand projections because their models assume labor market equilibrium.[109]

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[108] We used NSF SESTAT data to estimate that the fraction of NIT degree recipients in NIT careers in 2006 across all ages was 42 percent.
[109] BLS (2007)

2.3.2 NIT Labor Market Indicators

There are a number of other indicators we can examine to learn about the state of the NIT workforce. Previous studies of the NIT workforce often looked at two indicators of the attractiveness of NIT occupations: earnings and unemployment. We find that NIT earnings have been high relative to other occupations and that unemployment has been generally low except during the early 2000s following the dot-com collapse. NIT labor market indicators reflecting the current economic downturn are not available.

2.3.2.1 Earnings Levels

In 2007, the average median weekly earnings for a category 1 NIT worker were $1,321. Median earnings for NIT occupations ranged from a low of $1,039 per week for networking systems and data communications analysts to as high as $1,553 for computer and information systems managers, as shown in Table 2.13.

Table 2.13: NIT Occupation Earnings Comparison

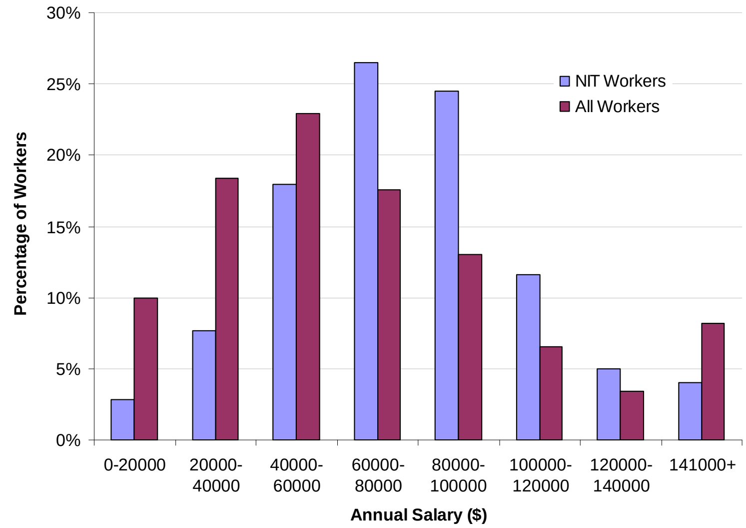
Occupation	2007
Computer systems analysts and scientists	1,173
Computer programmers	1,232
Electrical and electronics engineers	1,454
Computer software engineers	1,455
Computer hardware engineers	1,325
Network systems and data communications analysts	1,039
Computer and information systems managers	1,553
Average for category 1 NIT workers	**1,321**
Average for professional occupations	**951**
Average for all workers	**695**

Source: Current Population Survey

Compared to the average median weekly earnings for professional occupations, the earnings for category 1 NIT workers were 39 percent higher in 2007. Earnings for category 1 NIT workers were 90 percent higher than the average median earnings for all workers.

A more apt earnings comparison can be made between category 1 NIT workers and all workers with a bachelor's degree or higher. The SESTAT database contains earnings data for these groups. Figure 2.45 shows the distribution of workers across earnings ranges in 2006 for NIT occupations compared to all occupations. When compared with all workers holding bachelor's degrees or higher degrees, there were higher fractions of NIT workers earning annual salaries in the $60,000-$120,000 range and lower fractions at the very low and high ends of the salary distribution.

Figure 2.45: Annual Earnings Comparison: NIT vs. All Workers (2006)



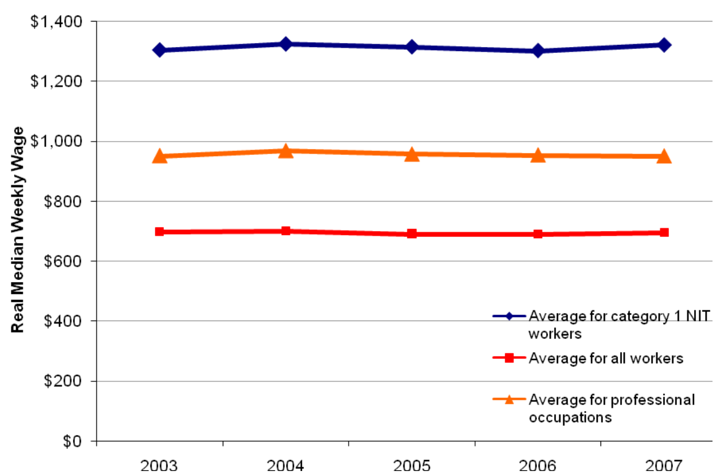
Source: SESTAT

The average annual salary for a NIT worker in the 2006 SESTAT dataset was 17 percent higher ($79,000) than the average for all workers ($67,000).

2.3.2.2 Changes in Median Earnings

Since 2003, the real median weekly earnings for NIT workers remained relatively flat as they have for both professional occupations and all workers, as shown in Figure 2.46.

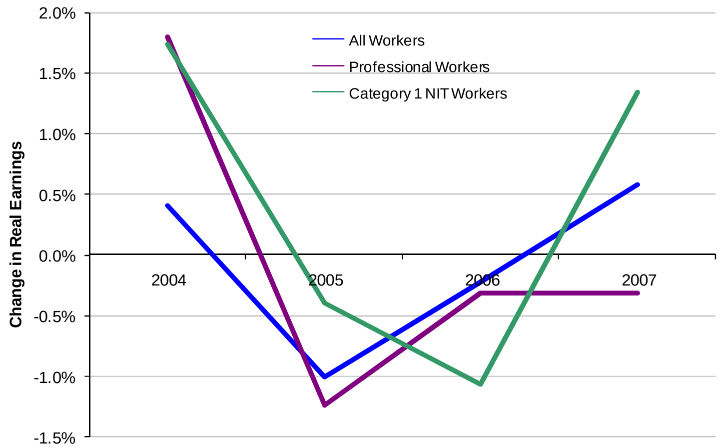
Figure 2.46: NIT Occupations Real Earnings Trends (2003-2007)



Source: Current Population Survey and Consumer Price Index (2007 dollars)

Many previous studies of the NIT workforce used real earnings growth as a measure of the supply-demand balance in the NIT workforce. Economists often use increases in real wages as indications of a shortage. Figure 2.47 shows the percentage change in real earnings for category 1 NIT workers, professional workers, and all workers between 2004 and 2007.

Figure 2.47: Changes in NIT Occupation Real Earnings (2004-2007)



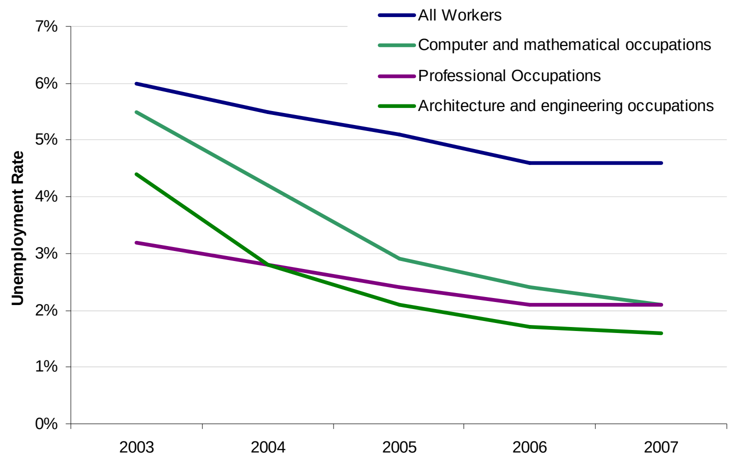
Source: Current Population Survey and Consumer Price Index

In 2004, the real earnings of NIT workers and professional workers grew at about 1.7 percent while the earnings of all workers grew at 0.4 percent. In 2005 and 2006, the real earnings of all workers declined. The real earnings of all workers and NIT workers rebounded and grew by 1.3 percent and 0.6 percent, respectively, while the real earnings of professional workers declined by 0.3 percent. Overall, the fluctuations in real earnings do not appear to help in determining the state of the NIT labor force. Choosing a single year comparison can lead to specious conclusions because the nominal changes and the rate of inflation are of nearly the same magnitude. Therefore, we cannot say whether real earnings provide any indication of the state of the NIT labor market. However, some experts argue that there are shortages of NIT workers in the United States but their wages are being held down due to offshoring of NIT work to countries with lower wages.

2.3.2.3 Unemployment

Unemployment is another indicator commonly used to judge the state of a labor market. The unemployment data provided by the BLS do not include detailed labor categories so we can only look at the unemployment rate in the two broad categories that include NIT occupations: computer and mathematical occupations and architecture and engineering occupations. Since 2003, both of these occupational categories have had unemployment rates lower than the rate for all workers. As shown in Figure 2.48, the unemployment rate for architecture and engineering occupations was higher than for professional occupations in 2003 but dropped below the unemployment rate for professional occupations in 2004-2007. The unemployment rate in computer and mathematical occupations was approaching that of all workers (six percent) in 2003. However, it dropped significantly to nearly two percent in 2007, matching that of professional occupations.

Figure 2.48: NIT Occupations Unemployment Rate Comparison (2003-2007)



Source: Current Population Survey

2.3.2.4 Lack of Highly Skilled Workers

Many reports and experts expressed concern about the supply of "highly-qualified" NIT workers.[110] Industry experts almost unanimously identified a lack of "highly-skilled" NIT workers who not only have programming and design skills but also soft skills such as the ability to work in teams. As high quality workers are always in high demand, they are likely to remain in high demand. Most reports addressing this issue argued that action should be taken. A recent report on the IT R&D ecosystem recommended that "To build the skilled workforce that it will need to retain high-value IT industries, the United States should invest more in education and outreach initiatives to nurture and grow its IT talent pool."[111] Most studies on the S&E workforce issue drew similar conclusions. Some experts raised concerns about the quality of NIT workers without NIT degrees. They argued that while these individuals are able to find jobs, they are not properly prepared to succeed in NIT careers and put their firms at a disadvantage compared to others who are able to staff their positions with individuals possessing NIT degrees. There is no literature comparing the skill levels or achievements of those with and without NIT degrees in the NIT workforce.

Lastly, some experts expressed concern about the state of the labor market for older IT workers. This was a focal point of the 2001 NRC study on the IT workforce,[112] which found little conclusive evidence either way. The concern was that older workers were more likely to have lower wages and higher unemployment as firms choose to hire graduates with the latest skills rather than invest in retraining existing workers.

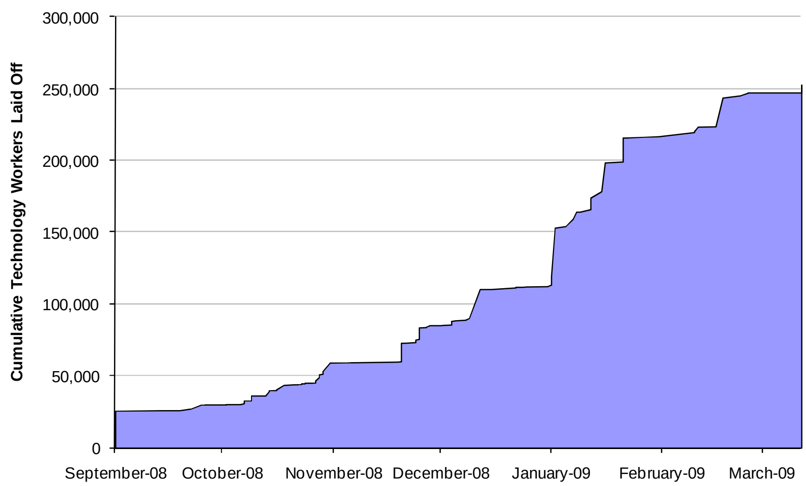
2.3.2.5 Recent Economic Downturn

In considering the future demand and supply, it is also important to keep in mind that the recent economic downturn is likely to slow growth in NIT occupations relative to the

[110] Robert Half Technology (2008a)
[111] NRC (2009), p. S-7
[112] NRC (2001)

BLS projections.[113] Wired magazine has been tracking the number of technology workers laid off due to the recent economic downturn. Figure 2.49 shows the cumulative number of technology workers laid off between September 2008 and March 2009. About 250,000 technology workers have been laid off as of late March 2009. Wired magazine's definition of a technology worker is broad and likely includes both category 1 and 2 NIT workers as well as workers outside of NIT occupations working in NIT firms.

Figure 2.49: Cumulative Number of Technology Workers Laid off (2008-2009)



Source: Wired Magazine[114]

These layoffs are in part caused by decreasing demand for IT services. Forrester Research estimates that US purchases of computer equipment decreased by four percent in 2008 and are expected to decrease by six percent in 2009. Similar trends are forecasted for communications equipment and IT consulting and systems integration services. However, Forrester Research predicts growth in all of these sectors in 2010.[115]

Another indication of the weakening NIT labor market is starting salaries. In early 2009, the National Association of Colleges and Employers reported that starting salaries for undergraduate computer science majors decreased by 3.6 percent in 2009 to $57,693.[116] This was driven primarily by an 11 percent decline in starting salaries for software design and development positions. Despite the economic downturn, starting salaries for undergraduate computing engineering graduates increased 1.8 percent to $61,017 in 2009. Starting salaries across all undergraduate majors were down 2.2 percent to $48,515 in 2009.

It is also important to consider how recent conditions will affect students' career choices and their perceptions of NIT careers. As one interviewee stated: "For kids in their early twenties, hearing that Microsoft is laying off is like hearing that the sky is falling." All

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[113] Schwartz (2008)
[114] http://blog.wired.com/business/2008/10/the-wiredcom-te.html
[115] Forrester Research (2009)
[116] NACE (2009)

agree that professional NIT occupations will undoubtedly remain essential in the economic recovery, but it remains to be seen which academic disciplines and career options over the next several years will emerge as additional rivals to NIT careers in the minds of young people. Lastly, some experts pointed out that the recent economic downturn may lead to an increase in offshoring as companies trim expenses. Some evidence exists of jobs being offshored during the recession but it is difficult to assess whether this would have been the case otherwise.[117]

2.4 Access to Foreign Talent

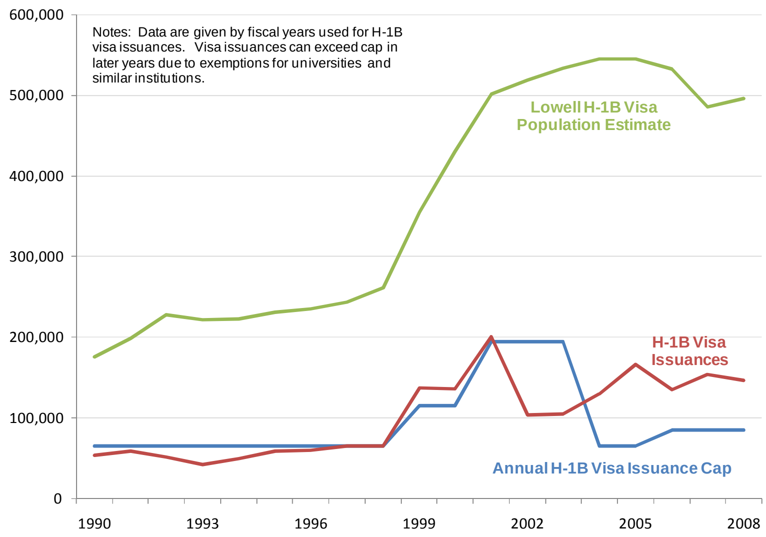
A significant amount of the literature concerning the NIT workforce discusses the role of foreign workers. Foreign workers are discussed in two contexts: foreign workers working in the United States on visas and foreign workers doing work for US companies abroad, often referred to as offshoring. There is a significant debate about the need for and effect of foreign workers. The following two subsections look at these issues.

2.4.1 Foreign Workers in the United States

The H1-B visa is the traditional immigration tool used by US firms desiring to hire high-skilled foreign workers to work in the United States. This visa allows the worker to work in the United States for up to six years. The worker receiving the H1-B visa must have skills in a "specialty occupation" requiring "both theoretical and practical application of a body of highly specialized knowledge … and attainment of a bachelor's degree or higher."[118] The US Congress places a limit on the number of new H1-B visas that can be issued every year. When the H1-B visa was created in 1990, the cap was set at 65,000. In response to a concern about shortages in the IT workforce,[119] Congress raised the cap to 115,000 in 2000 and later to 195,000 in 2001.[120] The cap reverted back to 65,000 in 2004. Also in 2004, an exemption was provided to allow 20,000 additional foreign workers with master's degrees and higher to enter the United States under the H1-B program. Therefore, as of 2008, the effective H1-B cap was 85,000. Figure 2.50 shows the size of the H1-B cap, H1-B issuances, and an estimate of the H1-B population between 1990 and 2008.

[117] Mishra (2009)
[118] NRC (2001), p. 161
[119] CRS (2001), Reinert (1998)
[120] Matloff (2003)

Figure 2.50: H1B Visa Cap, Population, and Issuances (1990-2008)



Source: Kerr and Lincoln (2008)[121]

The total population of H1-B workers expanded to nearly 0.5 million workers by 2008. Not all of these workers were in NIT occupations. The most recent estimates of the occupational breakdown of H1-B admissions are for 2005. Table 2.14 shows the top five admitted occupations, of which three are NIT occupations.

Table 2.14: H1B Admissions by Occupation

Occupation	Percentage
Occupations in Systems Analysis and Programming	**38%**
Occupations in College and University Education	8%
Accountants, Auditors and Related Occupations	5%
Electrical/Electronics Engineering Occupations	**4%**
Computer-Related Occupations	**4%**

Source: USCIS (2006)

Systems analysts and programmers, electrical and electronic engineers, and other computer-related occupations comprised 46 percent of H1-B admissions in 2005. This is consistent with earlier studies indicating that the H1-B visa is utilized primarily for NIT workers. If we assume that 50 percent of the H1-B population is NIT workers, then we estimate the number of H1-B workers in the United States to be about 250,000 in 2008. This is about seven percent of the category 1 NIT workforce estimated using CPS data.

The largest proportion (34 percent) of H1-B admissions come from India with more than five times as many admissions as the next country, as shown in Table 2.15. Canada and the United Kingdom are the next most represented countries, followed by Mexico, China, Japan, France, Germany, and South Korea.

[121] Data beyond 2000 are estimates only.

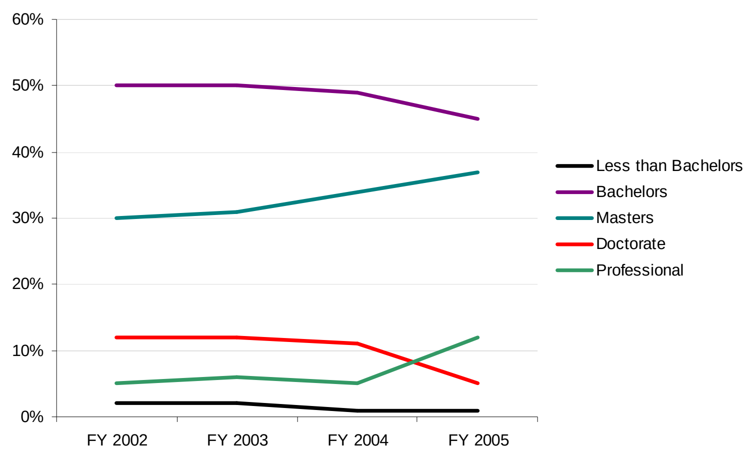
Table 2.15: Home Country of H1B Admissions

Country	Percentage of Admissions
India	**34%**
Canada	6%
United Kingdom	6%
Mexico	4%
China	4%
Japan	3%
France	3%
Germany	3%
South Korea	2%

Source: US DHS (2007)

The H1-B program requires at least a bachelor's degree for admission. Almost half of H1-B admissions have only a bachelor's degree, although this number declined from 50 percent in 2002 to 45 percent in 2005. This decrease occurred at the same time as the increase in the fraction of H1-B admissions with master's degrees, which grew from 30 percent in 2002 to 37 percent in 2007. In 2005, the fraction of doctoral degrees decreased as the fraction of professional degrees increased. Figure 2.51 shows trends in the fraction of H1-B admissions by educational qualification.

Figure 2.51: Percentage of H1B Admissions by Highest Level of Education (2002-2005)



Source: USCIS (2006)

There have been a significant number of studies on the impact of the H1-B program. Some argued that H1-B workers have a negative impact on domestic workers. In 2003, Matloff argued that the H1-B program displaces American workers, lowers wages, and discourages on-the-job training.[122] He also argued that the program has a disproportionate effect on older workers. In 2000, Salzman found that "H-1B workers in jobs requiring lower levels of IT skill received lower wages, less senior job titles, smaller signing bonuses, and smaller pay and compensation increases than would be typical for the work

[122] Matloff (2003)

they actually did."[123] However, in 2003, Zavodny found that the presence of H1-B workers has no effect on the earnings of domestic workers.[124] Others argued that the H1-B program has positive impacts such as spurring innovation. In 2008, Kerr and Lincoln found that the presence of H1-B workers increases patenting and argued that they benefit the US economy.[125] Others argued that H1-B workers create jobs. In 2008, Bill Gates testified to the US Congress that "Microsoft hires four additional workers to support each H1B worker hired."[126] The National Foundation for American Policy (NFAP) has made similar arguments.[127] Miano debated these claims.[128] In 2009, legislation is being proposed to increase oversight and enforcement of the H1-B program. Such legislation is supported by IT workers groups such as the Programmers' Guild but was opposed the last time it was proposed by the corporate interest group Compete America.[129]

Overall, there is great debate about the impact of and need for the H1-B program. Obviously, any expansion of the supply of workers, such as H1-B recipients, in the short run means more competition for jobs and reduced wages. What is less clear, given the complex feedback loops in the labor market, are the long-term effects. On the one hand, lower wages and increased competition for jobs may make the field less attractive for US citizens to enter the job market. On the other hand, the ability of employers to hire may lead to an expansion of the industry, and, in the long run, increase jobs for US citizens.

In 2008, the population of H1-B NIT workers comprised only about 15 percent of the overall NIT workforce. While it is an important concern, the number of H1-B workers is significantly smaller than estimates of the number of workers threatened by offshoring discussed in the next section. In interviews, many experts also noted that offshoring has replaced H1-B visas as the key concern relating to foreign workers facing the NIT workforce.

2.4.2 Offshoring

Offshoring is defined by the NRC as "the transfer of work previously performed in the United States to affiliated and unaffiliated entities abroad."[130] Offshoring has become an increasing concern to US policy makers over the past few years, especially in 2003-2004 when news reports surfaced of companies simultaneously expanding abroad and cutting staff in the United States. Hira argued that these trends are continuing in 2009 without as much media attention.[131] Offshoring is particularly a concern in the NIT industry where offshoring was first observed for hardware manufacturing and then in software services. Experts have cited two main reasons for offshoring: reducing costs by hiring cheaper labor and accessing talent.[132] Interviewees from industry commented that their rational for

[123] Salzman (2000)
[124] Zavodny (2003)
[125] Kerr and Lincoln (2008)
[126] Gates (2007)
[127] NFAP (2008)
[128] Miano (2008)
[129] Herbst (2009)
[130] NRC (2008), p. 7
[131] Hira (2009)
[132] Expert interviews

offshoring was typically a combination of these two factors. They explained that it is easier to find highly qualified US workers in hardware areas than it is in software-related areas. Therefore, most of the current growth in offshoring is seen in software and services. Table 2.16 shows the average annual salary of computer programmers from different countries in 2002. Computer programmer salaries were significantly lower in many countries outside of the United States.

Table 2.16: Average Salary of Computer Programmers (2002)

Country	Average Annual Salary	Ratio to US
Russian Federation	$6,250	9%
Poland and Hungary	$6,400	9%
Philippines	$6,564	9%
Malaysia	$7,200	10%
India	$8,440	12%
China	$8,952	13%
Israel	$26,500	38%
Canada	$28,174	40%
Ireland	$28,500	41%
United States	$70,000	100%

Source: Garner (2004)

There are many potential offshoring locations for US firms. The choice of location depends on the type of the work to be done. Table 2.17 lists a number of popular offshoring locations compiled in a recent report published by the Association for Computing Machinery (ACM).[133]

Table 2.17: Main Destinations for IT Offshoring Services by Strategy

Strategy	Principal Examples	Others
Cost and Capacity	China India	Malaysia
Language Skills	Philippines Mexico Costa Rica India	South Africa Tunisia Morocco Senegal Madagascar Mauritius
Nearsourcing	Canada Poland Czech Republic Hungary Slovakia	Ukraine Belarus Romania Latvia China
Special High-End Skills	Israel Ireland Australia United States	China India Russia

Source: ACM (2006)

[133] One expert discussed the increasing use of "near-sourcing," moving jobs to rural areas of the United States where labor costs are lower. This requires government investment in bandwidth.

China and India are two of the most common offshoring locations discussed in the literature. This has been primarily due to the volume of work offshored to these locations because of the large populations of these countries. However, these countries are also now considered attractive locations for R&D. Surveys by both the Economist magazine and the United Nations Conference on Trade and Development found that India is the most popular choice for R&D site selection worldwide followed by the United States and China.[134] Recently, the offshoring industry in Israel has been growing rapidly in the areas of security and elsewhere where strong intellectual property is important. Table 2.18 compares some statistics on the IT export industries for a selected group of countries in 2003.

Table 2.18: Comparison of Offshoring Locations

Parameter	India	Canada	Ireland	Israel	Philippines	South Africa
IT export industry size (US $, million)	8,955	3,780	1,920	900	640	96
Active export focused IT professionals	195,000	45,000	21,000	15,000	20,000	2,000
IT employee cost (US$, per year)	5,000-12,000	36000	25,000-35,000	25,000	7,000	18,000

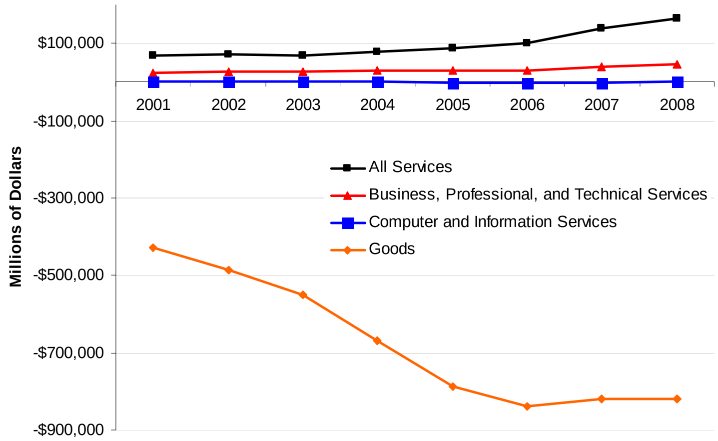
Source: NASSCOM (2003)

In 2003, India had the largest offshoring industry with nearly 200,000 workers, more than four times as large as the next largest country on this list. Canada also has a significant NIT export market, as does Israel. In 2005, Freeman argued that the emergence of China and India in the global economy has doubled the size of the global workforce and that this will drive down wages in both developed and developing countries.[135]

One of the major problems in assessing the effect of offshoring on the US NIT workforce is the lack of consistent data. In 2008, the NRC found that “More and better data on offshoring and other issues …. such as the effects on the engineering workforce and engineering education, are necessary for discerning overall trends. As has been pointed out in other recent reports,[136] better US and international statistics on trade in services and employment would give us a much better grasp of basic trends.”[137] The trade balance can be measured at many different levels including for goods versus services, and by types of services. Figure 2.52 shows the balance of trade for the United States between 2001 and 2008 in all goods, all services, and two specific types of services, derived from Bureau of Economic Analysis (BEA) data. Computer and information services are a subset of business, professional, and technical services. We see that while the trade balance in goods has been negative and declining since 2001, the trade balance in all services and business, professional, and technical services has been increasing. The trade balance in computer and information services was positive from 2001-2004 (average $393 million) but was negative over the time period 2005-2007 (average -$2.1 billion).

[134] Hira (2009)
[135] Freeman (2005)
[136] See GAO (2004)
[137] NRC (2008), p. 2

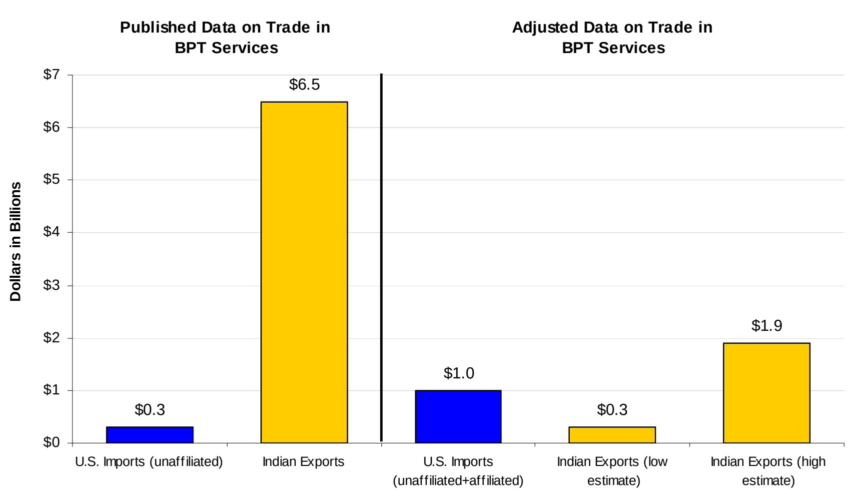
Figure 2.52: Trade Balance in NIT Areas



Source: BEA

Many have called into question the BEA estimates of trade in services. A common example is the difference in the estimates of trade in services between the United States and India.[138] Figure 2.53 compares estimates from the BEA and India's NASSCOM industry group for trade in business, professional, and technical (BPT) services. The numbers on the left compare the BEA estimate of imports from India with the NASSCOM estimate of Indian exports. Many reports have cited this difference as an important example of the lack of good data on offshoring.[139] However, the BEA contends that once the data are adjusted to use the same definitions, the differences are less evident, as shown in the adjusted data on the right.

Figure 2.53: Inconsistency in US/India Estimates of Trade in Services



Source: BEA[140]

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[138] GAO (2005)

[139] GAO (2005), ACM (2006), NRC (2008)

[140] http://faq.bea.gov/cgi-bin/bea.cfg/php/enduser/std_adp.php?p_faqid=324&p_created=1163013475

While there is an ongoing debate about these specific trade data, all recent studies that looked at outsourcing concluded that there is clearly a lack of good data available.[141] The lack of good data presents significant hurdles to identifying trends in NIT offshoring.

Overall, the NRC found that “there has been much debate over how many US IT jobs can and will be sent offshore. Methodologies for such studies are complex and inconsistent … Trying to match up projected ‘offshorable’ jobs to suitable labor supply in developing countries is like gazing into a crystal ball.”[142] A similar finding was expressed by a 2006 ACM panel looking at the globalization and offshoring of software: “While offshoring will increase, determining the specifics of this increase is difficult given the current quantity, quality, and objectivity of data available. Skepticism is warranted regarding claims about the number of jobs to be offshored and the projected growth of software industries in developing nations.”[143]

Even given the ACM finding, it is worth presenting some of the projections about offshoring to give a sense of what its effect *could* be. Many different organizations have attempted to estimate the potential effect of offshoring. The 2006 ACM report compiled some of these estimates, which are shown in Table 2.19.

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[141] GAO (2004), GAO (2005), ACM (2006), Sturgeon (2006), NAPA (2006), NRC (2008), Hira (2009)
[142] NRC (2008)
[143] ACM (2006), p. 10

Table 2.19: Estimates of the Effect of Offshoring

Source	Measure	Estimate
Estimates of Recent Offshoring		
Evalueserve (2004)	IT jobs offshored year ended March 2004	212,000 (60% to India)
Meta Group (2004 Annual IT Staffing and Compensation Guide)	US companies using offshore labor in software	19%
Seeley (2003)	Jobs lost in 2002 in the US software services sector	30,000 (compared to 146,000 the year before)
Seeley (2003)	Jobs lost in 2002 in the US software industry	150,000
Associated Press (2005)	Jobs lost in the US IT sector March 2001 to April 2004	403,300
Bajpai et al. (2004)	Percentage of companies that have offshored work (survey is mostly but not exclusively of US companies)	25%
Bajpai et al. (2004)	Percentage of companies that have already or plan to offshore work	79%
Estimates of Workers Vulnerable to Offshoring		
Bardhan and Kroll (2003)	US workers in service jobs vulnerable to offshoring	14,000,000
Atkinson (2004)	US IT jobs vulnerable to offshoring	12,000,000
Projections of Offshoring		
Pink (2004)	Service jobs leaving the US each year for the foreseeable future	200,000
Prism (2004) meta-analysis	Percent of IT jobs lost from US over the next five years	7% to 8%
Forrester (2004) report cited in GAO (2004)	US service jobs that may move offshore	3,300,000
Goldman Sachs (2003 report cited in GAO 2004)	Services and manufacturing jobs lost over coming decade	Up to 6 million jobs
Evalueserve (2003)	All jobs lost 2003-2010	1.3 million worst case
Evalueserve (2004)	Total jobs offshored in IT and non-IT business process operations (BPO) in 2010	775,000 IT jobs 1,414,000 non-IT BPO jobs
Shaw Quoted in McDougall (2005)	IT jobs moving offshore in 30 years	30% of IT jobs offshore within 25-30 years
Gartner quoted in McDougall (2005)	Percent of US IT jobs offshored in 2005 and 2015	Will increase from 5% in 2005 to 30% in 2015

Source: ACM (2006)

These estimates vary widely and estimate different effects. A widely cited 2005 McKinsey Global Institute (MGI) study concluded that offshoring was more prevalent in the IT sector than in any other sector.[144] It also estimated that the theoretical maximum number of jobs that could be offshored is about 44 percent of total industry employment. However, MGI predicted that only about 13 percent would be offshored due to barriers such as management attitudes, business process suitability, scale, and intellectual property protection.

[144] MGI (2005)

In 2006, economist Alan Blinder argued that while the United States has not yet experienced a significant amount of services offshoring, the pace of offshoring may accelerate in the future and affect workers at all levels of education.[145] In 2007, Blinder estimated the vulnerability to offshoring of each of the BLS standard occupation categories and found that nearly all STEM occupations (35 of 39) are "offshorable" and many are "highly vulnerable."[146] Of the top ten major occupations (those with more than 300,000 workers) that ranked highest in Blinder's index of offshorability, five were NIT occupations, as shown in Table 2.20.

Table 2.20: Top Ten Occupations Ranked by Offshorability

Occupation	Offshorability Index Number	Number of Workers
Computer Programmers	**100**	**389,090**
Telemarketers	95	400,860
Computer Systems Analysts	**93**	**492,120**
Billing and Posting Clerks and Machine Operators	90	513,020
Bookkeeping, accounting, and Auditing Clerks	84	1,815,340
Computer Support Specialists	**92**	**499,860**
Computer Software Engineers, Applications	**74**	**455,980**
Computer Software Engineers, Systems Software	**74**	**320,720**
Accountants	72	591,311
Welders, Cutters, Solderers, and Brazers	70	358,050

Source: Blinder (2007)

While most studies explored the negative impacts of offshoring on the US workforce, ITAA (2004b) argued that the use of offshoring lowers inflation, increases productivity, and lowers interest rates. ITAA argued that this creates more jobs than it displaces and leads to increases in real wages. These results were not published in the peer-reviewed literature, which makes the claims hard to assess.

Given the lack of consistent and accurate data, it is difficult to comment on trends in offshoring. A 2008 Robert Half survey indicated that the rate of offshoring in IT is low but others argued that it may increase rapidly in the future.[147] Many experts commented that growth in offshoring in India will decrease due to a coming shortage in the number of NIT professionals. Some argued that offshoring has reached a steady state, where the significant growth rates once seen will be significantly lower over the coming years. In addition, salaries in offshoring locations are rising. This will make offshoring generally less attractive. On the effects of offshoring, the evidence is even less convincing and was best summarized by the NRC in 2008: "Plausible scenarios have been developed showing that offshoring either helps, is neutral, or hurts engineering in the United States. Only continued discussions and further studies will lead to a thorough understanding of the potential benefits and costs of offshoring."[148]

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[145] Blinder (2006)
[146] Hira (2009)
[147] Robert Half Technology (2008b), Blinder (2006)
[148] NRC (2008), p. 3

2.5 Concerns and Programs to Increase Participation in NIT Careers

In response to ongoing concerns about the quantity and quality of NIT workers, there have been many programs and initiatives targeted at increasing participation in NIT careers. These initiatives and programs are categorized by the types of concerns they are designed to address: computing education, perceptions of IT careers, K-12 STEM education, and transitions from non-traditional pathways. This section discusses these concerns and describes the programs and initiatives created in response to each concern. Where possible, we discuss trends in funding for these programs. However, funding information for non-government programs is often not available. In addition, we examine initiatives and programs in other career fields that might be applicable to NIT.

2.5.1 Computing Education

Computing education is the continuously evolving process of identifying and delivering a changing set of critical concepts for a growing number of computing-related disciplines. The development of effective computing curricula for undergraduate education and K-12 education is, therefore, an iterative process. In addition to the constant changes inherent in computing education, the field is under increasing scrutiny by the community of computing educators, industry, and government as a result of growing demands for US competitiveness in computing-related fields.

For more than a decade, the major professional computing societies – the Association for Computing Machinery (ACM), the Association for Information Systems (AIS) and the IEEE Computer Society (IEEE-CS) have been engaged in targeted efforts to identify and reform core computing curricula and the best pedagogical practices for university-level computing education. Similar efforts such as the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST), are attempting to address the issue at the primary and secondary school levels. Throughout the educational pipeline, there is a wide range of opinions on what the core computational concepts are and what the best practices for delivering them to students are. In addition, computing education and computational thinking are emergent concepts rising out of the disciplines of computer science and computer engineering as the application of those skills is spreading so widely.[149]

What has been agreed upon is that computing education is facing several significant challenges that need to be, and can be, successfully addressed. In 2005, the ACM, the AIS, and the IEEE Computer Society sponsored the development of The Joint Task Force on Computing Curricula 2005.[150] The report identified some of the significant challenges facing computing education. It noted that broad industrial sectors that have not traditionally been associated with computing or computer science are increasingly dependent on workers with computing competency. This is a result of a global trend where individuals competent in various computing skills are required for the generation and adoption of new technologies and new business practices.[151] This means that the

[149] Wing (2006)
[150] Joint Task Force on Computing Curricula Report (2005)
[151] OECD Science, Technology and Industry Scoreboard 2007

stereotypical image of a computer professional as a programmer working in isolation is less true than it may have been in the past. Professionals trained in computing disciplines have to be involved in team-based problem solving and skilled in the basic technical collaboration required for innovation and new product and process development.[152]

The educational challenges associated with the changing professional identity and demands are not trivial. According to the body of stakeholders, post-secondary education in the United States has to be reformed to reflect these changes and adequately encourage and prepare students for this reality. Primary and secondary schools may have a more daunting challenge of not only adapting to the new standards of computing education, but also of incorporating computing education into their core STEM curricula in ways that many school districts currently do not.

There are essentially two major challenges confronting computing education. As the Joint Task Force Report pointed out, there is a disconnect between industrial expectations for professional NIT workers and the computing education they receive in preparation for those careers. The other major challenge is a concurrent disconnect between computing education as it is currently delivered and students' interests. This second challenge accounts, in part, for the precipitous decline in student enrollment in computing-related majors in recent years. These issues might be summarized as the perception and preparation challenges of computing education. The community of computing educators and professionals must change the image of computing so that more young people will perceive it as something engaging, interesting, and exciting. The community must also address the substantive issues surrounding students' preparation for a changing set of professional expectations and requirements for success in NIT-related fields.

The following sections look at issues and initiatives related to computing education at various points in the NIT pipeline.

2.5.1.1 K-12 Computing Education

In the United States, computer science is not a core component of K-12 education at any level. The Computer Science Teacher's Association (CSTA) focuses its efforts at the middle school level on problem solving and algorithmic thinking skills.[153] At the high school level, computer science courses exist but are not a core part of the curriculum. CS courses often count as math or business credits and only about 33 percent of students at schools with CS teachers are required to take CS classes.[154] This figure is likely to be significantly lower across all schools since not all schools have CS teachers. The main issues facing computer science education at the high school level are the fit of computer science within a state's high school graduation requirement, CS curricula, and teacher certification.

The amount of time devoted to computer science at the high school level is driven primarily by high school graduation requirements. In Texas, graduation requirements

[152] Joint Task Force on Computing Curricula Report (2005)
[153] http://www.csta.acm.org/
[154] CSTA (2007)

lump computer science with other technology applications such as desktop publishing and multimedia. When Texas first announced its plan for a four-by-four graduation requirement (four years of science and four years of math), AP computer science was not on the list to fulfill any of the science or math requirements until concerns were raised by the computing community. Other states, such as Virginia, count AP Computer Science towards the graduation requirement in mathematics. In California, computer science is often crowded out of a tight curriculum. However, admission to the highly competitive University of California (UC) system allows computer science to be counted as an elective, and typically the curriculum for a UC-bound student permits one elective each semester. These examples typify the treatment of computer science at the high school level. While CS courses are offered, they are nearly always electives and are crowded out by other required coursework.

There is no accepted standard for high school CS curricula in the United States except for the computer science AP course. A 2007 CSTA survey reported that 42 percent of CS teachers said that they have a state-mandated CS curriculum and only 75 percent of those reported that curriculum standards are enforced.[155] In 2003, CSTA found that "even for states that offer any computer science courses, there is much divergence in the number and content of these courses."[156] A number of model high school CS curricula have been proposed over the last two decades by the ACM,[157] Deek and Kimmel,[158] and the CSTA.[159] However, none of these has been widely adopted.

The other major issue facing K-12 computer science education is teacher certification. A CSTA 2002 survey reported that 38 percent of high school computer science teachers were from states where no certification was required to teach computer science. In 2008, CSTA found that "for computer science teachers … the challenge of becoming and remaining exemplary educators is exacerbated by systems of pre-service education and teacher certification that are profoundly disconnected from the discipline of computer science and the needs of teachers and students."[160] They found that many states did not offer computer science certification and that "because they cannot be certified as computer science teachers, new teachers find that they must first meet the certification requirements in some other discipline, requiring them to develop and prove teaching proficiency in a field in which they do not actually wish to teach. In some cases, where teachers can actually receive an additional endorsement to teach computer science, the content they are required to master may have no more than a tangential relationship to what is needed to teach in a computer science classroom."[161] CS teachers in the United States are not required to have majored in computer science or to pass any sort of technical examination. This raises concerns about their abilities to teach the rigor of computer science.

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[155] CSTA (2007)
[156] CSTA (2003), p. 6
[157] ACM (1993)
[158] Deek and Kimmel (1999)
[159] CSTA (2003)
[160] CSTA (2008), p. 11
[161] CSTA (2008), p. 12

While there is little standardization of high school CS curricula or certification in the United States, other countries have adopted standards in both of these areas. The most prominent example is Israel, which has had a CS curriculum in place since the 1970s.[162] In Israel, there are two types of high school CS electives: a three-credit course designed to expose students to computer science and a five-credit course designed for students who are considering a career in computer science. Computer science is considered a core scientific subject in Israel and is treated as such in the curriculum requirements. Other countries that have adopted a K-12 CS curriculum include Canada, Scotland, Russia, South Africa, New Zealand, and Australia.[163] Israel requires all K-12 computer science teachers to have a bachelor's degree in computer science and to be certified by the Ministry of Education. Scotland also requires certification of CS teachers and a four-year degree with some exposure to computer science. Neither of these is required in the United States.

Notwithstanding the lack of standardization in computer science education in K-12 in the United States, there is a movement afoot to increase the number of US students pursuing NIT education. There are a number of programs aimed at increasing participation and improving the quality of NIT education at the K-12 level. Some of these programs focus on improving teacher training while others focus on increasing student participation. The following paragraphs summarize these programs.

There are a few programs aimed at increasing the knowledge of high school computer science teachers. One of the most prominent examples is summarized by Blum and Cortina,[164] who organized a summer workshop at Carnegie Mellon University (CMU) "to provide compelling material that the teachers can use in their classes to emphasize computational thinking and the many possibilities of computer science."[165] Survey results from the participants showed that the teachers who were involved changed their perception of computer science and thought they could include a broader range of topics in their classes. The survey results also showed that "teachers fear that many CS courses at the high school level will disappear before national standards can be developed to address the need for some form of K-12 computer science education." Other schools have partnered with CMU to run similar summer workshops at Columbus State University,[166] the University of Texas,[167] and the University of Washington.[168] These programs were all organized under the name "CS 4 HS." These programs required about $35,000 in funding at CMU and the University of Washington.[169] At the same time, the Computer Science Teachers Association (part of ACM) has been working since the late 1980s to reform high school computer science and improve CS teaching at the high school level.[170] More broadly, the International Technology Education Association provides professional

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[162] Gal-Ezer and Harel (1999)
[163] CSTA (2003)
[164] Blum and Cortina (2007)
[165] http://www.cs.cmu.edu/cs4hs/
[166] http://csc.colstate.edu/cs4hs/
[167] http://www.cs.utexas.edu/~firstbytes/teachers/index.html
[168] http://cs4hs.cs.washington.edu/
[169] http://www.cs.cmu.edu/~tcortina/expanding_cs4hs.ppt
[170] Schollmeyer (1996)

development and allows technology teachers to share best practices and experiences[171] and the American Society for Engineering Education (ASEE) organizes robotics competitions and provides a variety of resources for K-12 educators.[172]

There are also programs in the United States to increase student participation in computer science at the K-12 level. One such program, *Andrew's Leap*, is a seven-week long summer program at CMU that covers an expansive set of topics, from cryptography to graph theory and security.[173] The course relies on guest contributions from professors and students get to work on real computer science problems. The program costs students a tuition fee of about $2,000 for the seven-week course. Other schools offer similar programs such as:

- The University of Alabama-Birmingham's computer science summer camps for middle and high school students;[174]
- Syracuse University's summer college in engineering and computer science;[175]
- The University of Texas at Arlington's engineering and computer science summer camps;[176]
- The University of Cincinnati's summer camp in computer science;[177]
- Purdue University's K-12 outreach program in computer science;[178]
- The University of Utah's High School Computing Institute.[179]

In addition to computer science programs targeted specifically at high school students, many colleges and universities open their summer computer science and engineering classes to advanced high school students. Government and university initiatives have been undertaken in some areas such as the Commonwealth Information Technology Initiative (CITI) in Massachusetts, which aims "to increase the number of 'information technology-fluent' workers" by "bringing together industry and public education institutions to improve information technology education at the K-12 and postsecondary levels."[180] In 2007, CITI provided about $470,000 for K-12 and higher education grants.

Another program to increase participation in NIT careers is the NSF Innovative Technology Experiences for Students and Teachers (ITEST) program.[181] This program is directed at creating programs across the K-12 spectrum to offer technology experiences

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171 http://www.iteaconnect.org
172 http://www.engineeringk12.org
173 http://www.cs.cmu.edu/~leap
174 http://www.cis.uab.edu/programs/camps
175 http://summercollege.syr.edu/engineering.html
176 http://www.uta.edu/engineering/summer_programs/#
177 http://www.cs.uc.edu/~rbhatnag/currentsummercamp
178 http://www.cs.purdue.edu/external_relations/k-12_outreach
179 http://www.eng.utah.edu/~hsci
180 http://citi.mass.edu
181 http://itestlrc.edc.org

to all students. This program has sponsored a number of projects and identifies the following characteristics of success:

- hands-on activities
- working in cooperative teams
- looking at the real world with a scientific view
- personal mastery and confidence building through problem solving
- exposure to a diverse set of professional scientists and engineers

Some examples of ITEST-sponsored programs are using computers and math to evaluate social science questions, getting a "computer in a box" and learning to work with computer hardware for diagnosis, upgrading, and repair; web design; and game design. Many colleges have developed new courses through ITEST that they offer to both their own students and, via an outreach program, to middle and high schools. One such program, at Lehigh University, brings middle and high school students onto the college campus and teaches them to write animations in Adobe Flash. Skills such as user interface design and problem solving are emphasized in the class. Interestingly, these students went back to their schools and requested access to the software at their school. This had the effect of encouraging teachers to learn to use it. ITEST funds 25 to 40 projects in each year with up to 12 continuing awards depending on the availability of funds. ITEST provides about $35 million in annual funding for all of these projects. While not funded through ITEST, the Tech Corps program is another example of a program that focuses on providing high-quality experiences with technology in the classroom.[182]

A variety of tools are available to both educators and students at the K-12 level to increase interest in computer science. The most popular of these tools include:

- Alice is a free educational software for 3D animation programming provided by CMU;[183]
- Scratch is a free educational software for 2D web game/application programming provided by MIT;[184]
- Turtle Graphics is a module for python: free python programming environment with Turtle graphics module aimed at introducing programming to kids;[185]
- Lego Mindstorm Robotics is a commercial robotics and software package available from Lego.[186] There is also the FIRST Lego League, which organizes robotics competitions for children ages 9-14 and a junior FIRST Lego League for

[182] http://techcorps.org
[183] http://www.alice.org
[184] http://scratch.mit.edu
[185] http://docs.python.org/library/turtle.html
[186] http://mindstorms.lego.com/eng/Cpoenhagen_Dest/Default.aspx

younger children (ages 6-9).[187] Using regular Lego blocks to teach basic computing principles has also been proposed.[188]

Some colleges and universities, such as Georgia Tech's Savannah campus provide workshops using the above technologies.[189]

2.5.1.2 Undergraduate Computing Education

There is particular concern about the quality and attractiveness of US undergraduate computing education. As noted earlier, it is facing a crisis of imagery. From the point of view of computing educators, the dramatically decreasing levels of enrollment and interest in computing demonstrate that computing curricula and pedagogy are not attractive to students faced with many educational options. Introductory computing courses have surfaced as being particular turn-offs to undergraduate freshman and other undeclared students. According to the Integrative Computing Education and Research Report (ICER), "These courses have often served to confirm student assumptions that Computer Science is just about programming, and that programming is a difficult and esoteric enterprise."[190] The report goes on to list the substantive changes that must happen in computing education if it is to increase the participation of US students and more closely meet industrial needs, which include:

- Change introductory courses for both majors and non-majors;
- Reduce core requirements by identifying the bare essentials and enduring fundamentals underlying the computing discipline;
- Change the pedagogies and teaching methods;
- Create opportunities for integrated curricula, so that computing builds bridges to adjacent disciplines.

Its summary is an adequate reflection of the consensus regarding the current state of computing education.[191] Part of the consensus is that undergraduate computing courses need to shift to include more dynamic pedagogies rooted in problem-based learning and team approaches to problem solving. At present, US undergraduate computing education itself serves as a deterrent to young people and can legitimately be viewed as a limiting factor on the pathways to NIT careers.

Some feel that the change to more problem-based, collaborative styles of teaching that promote the ability to work in teams and highlight the potential of computing to solve real world problems is dependent on turnover in computing faculty. Based on anecdotal evidence, their view is that older faculty, in general, resist this type of fundamental pedagogical change and indeed may simply not be effective instructors in the more dynamic and iterative learning environments that are now being promoted. Others

[187] http://www.usfirst.org/firstlegoleague/community/HomePage.html
[188] Hood and Hood (2005)
[189] http://www.gtsav.gatech.edu/go/mast
[190] ICER (2005), p. 11
[191] Patterson (2006)

suggest that on the contrary, the field of computer science itself is relatively young, dating back only about 50 years, and therefore can change with appropriate incentive structures and aggressive experimentation with new pedagogies – "There simply needs to be the will to do it."[192]

A number of initiatives are underway to address the concerns about undergraduate computing education. The NSF's CISE Pathways to Revitalized Undergraduate Computing Education (CPATH)[193] program exemplifies the kind of broad national efforts designed to address the array of challenges facing undergraduate computing education. CPATH is a relatively new funding stream at the NSF and offers $10 million annually in awards with 12 to 30 new awards made each year. The goals of the program are fashioned directly out of the growing consensus regarding undergraduate computing education. The program highlights the promotion of computational thinking as the sum of the critical concepts and analytical thinking skills that computing education is built on. As a result, the program sponsors projects that are designed to identify the core concepts in computational thinking and to develop innovative, effective, and replicable tools and pedagogies for delivering those concepts to students. CPATH specifically encourages broad thinking about the challenges of computing education and supports a tremendous variety of projects that range from institutional reformation designed to make computing-related majors more attractive and relevant, to non-traditional alliances between universities, museums, and community centers to improve young people's access to computing. It also supports the core effort of reforming fundamental computing courses to make them more accessible, engaging, and effective for undergraduate students.

One often cited CPATH-funded initiative is the redesign of introductory computing courses at Georgia Tech, which have been expanded to include multimedia courses.[194] In addition to redesigning the introductory courses, Georgia Tech's College of Computing has developed a new system of course bundles for computing majors called "Threads."[195] The intention is to have computing-based majors be more closely linked with the applications and real world problems that students find compelling. As in many fields, the focus on applications and group work in computing curricula is an important component of computing education reform.[196] In another related effort in 2004, Berenson, Slaten, Williams, and Ho proposed a course designed to counter the notion that computer science is a solitary profession.[197] They adopted, for an upper division course, a collaborative programming method called "pair programming," and a collaborative lifecycle management approach called "agile software development." Analyzing interview responses of students showed that they valued the face-to-face collaboration required by the need to work in groups, they believed that the quality of the end product increased as did their satisfaction with it, and their confidence and interest in IT careers increased.

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192 Expert interviews

193 http://www.nsf.gov/cise/funding/cpath_faq.jsp

194 Guzdial (2004)

195 http://www.cc.gatech.edu/education/what-is-threads

196 Furst et al. (2007)

197 Berenson, Slaten, Williams, and Ho (2004)

A complement to CPTAH is the Association for Computing Machinery's Special Interest Group on Computer Science Education (SIGSCE), which does not provide funding but has emerged as a major platform for educators to share, discuss, and critique their collective efforts to revamp undergraduate computing education. This complementary duo is an example of functioning parts of an infrastructure in place to improve computing education and ultimately to increase the numbers of NIT workers and scholars with relevant computational thinking competencies.

There are innumerable local efforts to address the improvement of undergraduate computing education. Several programs, both university- and industry-based, are designed to address the circumstances of particular institutions and their specific contexts. The expectation is that these local problems, or components of them, are shared and therefore successful solutions can be replicated. The Association for the Advancement of Computing in Education, for example, has a mission of improving computing education by "advancing Information Technology in Education and E-Learning research, development, learning, and its practical application."[198] University-industry partnerships have formed to ensure that computing curricula remain relevant to industry needs. The Global Wireless Education Consortium is one such example that focuses on wireless education while the SEMATECH Partnering for Workforce Development focuses on the nanotechnology workforce.[199] Other industry initiatives, such as Cisco's Networking Academy[200] and the Oracle Academy[201] focus on direct skill transfer. Scholarship programs, such as Microsoft's College Careers programs, provide monetary incentives for students to pursue computing careers.[202] The variety of programs and initiatives designed to address undergraduate computing education suggest that while there is general consensus on the challenges faced by the field, the proposals for meeting those challenges are vast.

2.5.2 K-12 Math and Science Education

While there are many programs that focus on computing experiences at the K-12 level, K-12 education in math and science is also thought to be important preparation for NIT careers. There are a plethora of programs aimed at increasing participation and preparation in science and math. Summarizing all of these programs is beyond the scope of this report. However, examples of often-cited programs include:

- The MATHCOUNTS foundation encourages participation and excellence in middle school math. Corporations and individuals donate \$1.5 million to \$1.7 million annually to the national program and over \$500,000 to the local and state programs.[203]

198 http://www.aace.org
199 http://www.sematech.org/research/nwdi/index.htm
200 http://www.cisco.com/web/learning/netacad/index.html
201 https://academy.oracle.com
202 http://www.microsoft.com/college/ss_overview.mspx
203 https://mathcounts.org/Page.aspx?pid=195

- The JASON project, a subsidiary of the National Geographic Society, encourages students to explore science by connecting students to scientists and events in science around the world.[204]
- The Christopher Columbus award for teams of middle school students solving important science problems facing their community.[205]
- The Junior Engineering Technical Society (JETS), a non-profit organization that aims to promote engineering and technical careers among high school students.[206]
- The Algebra project that "uses mathematics as an organizing tool to ensure quality public school education for every child in America."[207]
- Raytheon's MathMovesU website "designed to engage middle school students with math at an age when their interest in the subject typically declines." The program also awards more than $1 million in grants and scholarships annually.[208]
- US FIRST which aims to inspire young people's interest in science and technology.[209] The budget for all programs administered by US FIRST in 2008 was $28 million.
- Botball which organizes robotics competitions in 13 regions across the United States.[210]
- The Science Olympiad which aims to improve K-12 science education by providing standards and a competitive mindset to get students excited about science.[211]
- The MESA schools program "serves middle and senior high school students throughout the state so they will excel in math and science and go on to college in math-based majors."[212]
- Odyssey of the Mind, a program where students (kindergarten through college) work together over the course of a couple of months to solve one of five problems and then come together in regional and world competitions to compare technical solutions. "Team members apply their creativity to solve problems that range from building mechanical devices to presenting their own interpretation of literary classics."[213] This program is more about problem solving than it is specifically about science or math.

The US government has also undertaken a number of efforts to increase preparation and participation in science and math. One of the largest government organizations, the

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[204] http://www.jason.org/public/home.aspx
[205] http://www.christophercolumbusawards.com
[206] http://www.jets.org
[207] http://www.algebra.org/whoweare.php
[208] http://www.mathmovesu.com
[209] http://www.usfirst.org
[210] http://www.botball.org
[211] http://soinc.org/mission
[212] http://www.ucop.edu/mesa/programs/schoolprogram.html
[213] http://www.odysseyofthemind.com

Department of Defense (DoD), has had a long-standing interest in science and math education. The DoD has numerous research labs working on mathematics, engineering, basic sciences, and IT. The DoD, like industries and higher education institutions, has been affected by the decrease in STEM graduates, more so than others because they require US citizens to perform sensitive work. The DoD has recently started an outreach program that builds on the grass roots outreach that their scientists and engineers have already done in their local community, whether from being in their own children's classroom or sponsoring a career day or "chemistry week" based on their membership in a professional society. The National Defense Education Partnership (NDEP) is a congressionally authorized program supported by the DoD Directorate of Defense Research and Engineering. This program targets students throughout the STEM pipeline to provide positive experiences and encourage students to pursue STEM careers.

The same need for STEM workers is evident at other federal agencies including the National Security Agency (NSA), which supports the Mathematics Education Partnership Program (MEPP),[214] Math and Related Sciences (MARS) camps,[215] summer institutes for math and science teachers,[216] and the Stokes Educational Scholarship Program,[217] among other programs. The MEPP program is one of the NSA's most prominent programs, helping local schools through three main programs:

- the Mathematics Speakers Bureau arranges for volunteer speakers to visit schools and present a variety of interactive math and science talks to both students and teachers;
- the School Partnerships Program maintains relationships between schools and volunteers who spend part of their work week providing tutoring, computer help, or math and science enrichment activities;
- providing judges for local math and science fairs.

The NSA undertakes a number of other efforts beyond the MEPP. The MARS program is a two-week residential summer enrichment program for middle and high school students at the University of Maryland Eastern Shore providing a variety of courses teaching math and science problem-solving skills.[218] The NSA also provides funding, planning, and staffing for various summer institutes for math and science teachers. Teachers who participate in the summer institutes write "learning units" (lesson plans) for classroom use which are designed in accordance with the National Council of Teachers of Mathematics (NCTM) standards. These learning units are then made available for any teacher to use. The Stokes Educational Scholarship Program aims to facilitate the recruitment of individuals, particularly minority high school students, who have demonstrated skills critical to the NSA, which are generally in NIT fields. Lastly, the

[214] http://www.nsa.gov/academia/early_opportunities/math_edu_partnership/index.shtml
[215] http://www.nsa.gov/academia/early_opportunities/math_edu_partnership/mars/index.shtml
[216] http://www.nsa.gov/academia/early_opportunities/math_edu_partnership/simt/index.shtml
[217] http://www.nsa.gov/careers/opportunities_4_u/students/high_school/stokes.shtml
[218] http://www.umes.edu/MARS/

NSA supports a variety of summer programs for undergraduate and graduate students in STEM fields including:

- Computer Science Intern Program (CSIP)[219]
- Cryptologic Access Summer Intern Program (CAP)[220]
- Director's Summer Program (DSP)[221]
- Summer Intern Program for Information Assurance (SIP/IA)[222]
- Mathematics Summer Employment Program (MSEP)[223]
- Co-operative Education program (not just in summer)[224]
- Graduate Mathematics Program (GMP)[225]
- Summer Program for Operations Research Technology (SPORT)[226]

The NSA's FY2009 budget for its Mathematical Sciences Program is $4 million, although this covers many activities beyond those discussed above.[227] The NSA and the Department of Homeland Security (DHS) also jointly sponsor the National Centers of Academic Excellence in Information Assurance (IA) Education (CAEIAE) and CAE-Research (CAE-R) programs.[228] The goal of these programs is to reduce vulnerability in our national information infrastructure by promoting higher education and research in IA and producing a growing number of professionals with IA expertise in various disciplines, many of which are related to NIT. Other agencies are undertaking similar efforts in areas relevant to their needs. For example, the US Department of Energy organizes the National Science Bowl.[229] We do not attempt to list all federal STEM workforce efforts in this report since the focus is on NIT. However, the examples above provide a snapshot of some of the efforts being undertaken.

There are also many programs to improve K-12 teacher preparation for science and math courses in the United States. Examples of these programs include the centers funded by the NSF, such as the Texas Collaborative for Excellence in Teacher Preparation (eight-year $6,000,000 grant awarded in 2000),[230] the Maryland Collaborative for Teacher Preparation (four-year $623,000 grant awarded in 1998),[231] and the New York Collaborative for Excellence in Teacher Preparation (five-year, $597,000 grant awarded

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219 http://www.nsa.gov/careers/opportunities_4_u/students/undergraduate/csip.shtml
220 http://www.nsa.gov/careers/opportunities_4_u/students/undergraduate/cap.shtml
221 http://www.nsa.gov/careers/opportunities_4_u/students/undergraduate/dsp.shtml
222 http://www.nsa.gov/careers/opportunities_4_u/students/undergraduate/sip.shtml
223 http://www.nsa.gov/careers/opportunities_4_u/students/undergraduate/msep.shtml
224 http://www.nsa.gov/careers/opportunities_4_u/students/undergraduate/co-op.shtml
225 http://www.nsa.gov/careers/opportunities_4_u/students/graduate/gmp.shtml
226 http://www.nsa.gov/careers/opportunities_4_u/students/graduate/sport.shtml
227 AAAS (2008b)
228 http://www.nsa.gov/ia/academic_outreach/nat_cae/index.shtml
229 http://www.scied.science.doe.gov/nsb/default.htm
230 http://www.sci.tamucc.edu/txcetp
231 http://www.towson.edu/csme/mctp/mctp.asp

in 2001).[232] Another example is the Research Experiences for Teachers (RET) program supported by the NSF, which "supports the active involvement of K-12 teachers and community college faculty in engineering research in order to bring knowledge of engineering and technological innovation into their classrooms."[233] The NSF awards about five RET awards annually with a maximum award of $500,000 over three years. In addition, the MESA Learning Loop and Mathematics-Physics-Technology Institutes (MPTI) provide professional development for math and science teachers.[234]

Like the ACM for computer science, a variety of professional organizations have also undertaken efforts to improve science and math education in the United States. We do not list all of these organizations as it would be very long. The STEM departments at many US universities are also involved in outreach efforts. Some of those related to computer science were discussed in the section on high school CS but there are many focused on other STEM areas. Examples include the American Society of Mechanical Engineers' Pre-college K-12 program,[235] and a variety of programs offered to high school students by the American Chemical Society.[236]

2.5.3 Perceptions of NIT Careers

Another critical component of the NIT workforce challenge is young people's perception of the field. As cited earlier, one of the major reasons students opt out of NIT pathways revolves around perception – their perception of the field and their perception of their identity relative to it. There is also a common idea that computing is a field where expertise can be derived on one's own, and higher education is unnecessary. In addition, according to a leading advocate for computing education reform, "The field is still weighed down by its geek image." Again, the perception is that computing is analogous to programming and programming is analogous to an isolated life of tedium in front of a computer working on abstract algorithmic challenges. These perceptions, as might be expected, include disproportional disincentives for women and minorities. Another lingering perception of professional NIT fields is that they are the purview of white and increasingly Asian men. The perception of NIT careers is sufficiently negative that many young people are not inclined to follow those paths. In an article addressing the challenges of the computer science department at Drexel University in Philadelphia, Agosto et al. refers to these perceptions as "mental models."[237] Changing those mental models and developing the coping mechanisms to deal with them is a critical element in ensuring that more students remain on the pathways to NIT careers.

Changing these perceptions will not be a trivial undertaking, not only because changing perceptions never is, but because perceptions go beyond just the image of an NIT professional's work functions to the kind of lives they lead. According to Tapia et al., one of the predominant perceptions is that "IT workers are expected to pare down their non-

[232] http://depthome.brooklyn.cuny.edu/education/nycetp
[233] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5736
[234] http://www.ucop.edu/mesa/programs/index.html
[235] http://www.asme.org/education/precollege/TeemUp_K12.cfm
[236] http://portal.acs.org/portal/acs/corg/content
[237] Agosto et al. (2008)

technical lives, to become tireless pioneers on the technical frontier, and to prioritize work life over all other things."[238] Whether the reality of NIT education and professional life match these perceptions is a question to be answered. What is agreed upon by the community of vested stakeholders is that the perceptions are largely negative and are having a detrimental effect on the field.

This issue has been taken up by a community of prominent computing scholars, policy makers, and industry leaders in the 2009 Rebooting Computing Summit.[239] The opening lines of the Rebooting Manifesto summarize the perception of computing and the community's acknowledgement of those perceptions:

> "It is a time of challenges for the computing field. We are tired of hearing that a computing professional is little more than a program coder or a system administrator; or that a college or graduate education is unnecessary; or that entering the computing field is a social death. We are dismayed that K-12 students, especially girls, have such a negative perception of computing. We are alarmed by reports that the innovation rate in our field has been declining and that enrollments in our degree programs have dropped 50% since 2001. Instead of the solo voice of the programmer, we would like to hear from the choir of mathematicians, engineers, and scientists who make up the bulk of our field."[240]

Efforts to address the perception of computing as a professional field are intertwined with efforts to change computing education. Part of the challenge of changing the perception of the field is changing the style of education that students receive and what they understand the field to be. For example, Carter found misunderstandings among high school math students about what computer science is as a professional field.[241] She found that an "alarming number of students (80 percent) had no idea what computer science majors learned."[242] She also found that students would consider CS as a major if they could combine it with another field such as medicine or if they could work on computer games. Her findings are consistent with the kind of recommendations that are being offered by initiatives such as CPATH-funded projects, Rebooting Computing, and the 2005 ICER report.[243] These initiatives include offering interdisciplinary courses, appealing to various media messages to change the public image of computing, and improving the quality of CS teachers in secondary school so that they can offer more competent and creative instruction in computing courses. These are all recommendations that are essentially designed to encourage young people to take interest in computing that goes beyond playing with the expansive array of communication and gaming gadgets that inundate their lives.

[238] Tapia et al. (2003), p. 154
[239] http://www.rebootingcomputing.org
[240] http://rebootingcomputing.org/manifesto
[241] Carter (2006)
[242] Carter (2006)
[243] ICER (2005)

There are many of initiatives designed to address this fundamental perception problem. As mentioned earlier, several of these efforts to address perception cannot be clearly distinguished from efforts designed to address educational preparation. Some of the prominent efforts, such as the Image of Computing Task Force,[244] serve as information sources for computing programs, opportunities, and other initiatives designed to change the public view of what computing is. Other programs to increase knowledge and improve the image of technical professions include the Sloan Foundation's Initiative in Public Understanding of Science and Technology.[245] Meares and Sargent cited the DoD Directorate for Programs and Community Relations as a successful example of an initiative to improve the image of a profession.[246] Some programs also provide information on all technical careers, such as the Sloan Foundation Career Cornerstone Center[247] and 3M's Technical Teams Encouraging Career Horizons (TECH).[248]

Another way to target misconceptions about NIT careers is by creating mentorship programs. Mentorship and role models are effective tools in helping students succeed in fields where they are relatively isolated.[249] The home environment and exposure to role models in computing can help students to construct a mental picture of a NIT professional that is more expansive than the public image of an isolated programmer.[250] Mentors not only influence students' decisions to pursue NIT academic pathways but they can be helpful in retention as well.[251] Mentors, through their close personal relationships with mentees, can help bolster confidence and importantly help transform students' views of themselves relative to the field. Another unintended consequence of effective mentorship is that it helps identify issues that might not otherwise surface in particular learning communities. The mentors, often faculty members or teachers, learn something about the experiences of students that they could not learn through other avenues. This is critically important for the community of computer science and computer engineering educators as it attempts to transform the perception of the field. Examples of NIT mentorship programs include the University of Minnesota's IT mentor program[252] and the MentorNet program providing e-mentoring to individuals interested in STEM.[253]

2.5.4 Facilitating Other Pathways to NIT Careers

A significant number of IT workers come from pathways other than non-profit four-year degree programs, such as for-profit educational institutions, community colleges, and job training programs. Programs targeted at these groups can differ significantly from those targeted at the "traditional" pathways to the NIT workforce.

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[244] http://www.imageofcomputing.com
[245] http://www.sloan.org/program/3
[246] Meares and Sargent (1999), p. 58
[247] http://www.careercornerstone.org
[248] http://multimedia.mmm.com/mws/mediawebserver.dyn?6666660Zjcf6lVs6EVs66SFh4COrrrrQ-
[249] Thompson and Sekaquaptewa (2002)
[250] Zur et al. (2005)
[251] Stephenson et al. (2007)
[252] http://it.umn.edu/alumni/itas/mentor
[253] http://www.mentornet.net

As we saw earlier, a large number of computer science bachelor's degrees are awarded by for-profit educational institutions. There do not appear to be many programs or initiatives focused on facilitating transitions into for-profit educational institutions, although Malcom et al. pointed out that this is an important pathway for increasing diversity in the IT workforce.[254] There is a lack of literature exploring the dynamics of this sector as well as programs targeting individuals taking these pathways.

Community colleges are an important supplier of category 2 IT workers. In 2000, Lerman et al. discussed the role of community colleges in supplying information technology workers.[255] They surveyed employers in 2000 and found that community colleges were not adding significantly to the supply of IT workers. However, they found that community colleges contribute to retaining workers already in IT jobs, those switching careers in mid-life, and those with previous bachelor's degrees in other areas. The NSF's Advanced Technological Education (ATE) program focuses on the education of technicians for high-technology fields with a focus on two-year colleges.[256] One of the most prominent centers supported by this program is the Northwest Center for Emerging Technologies (NWCET) located at Bellevue Community College in Bellevue, Washington.[257] NWCET has done a significant amount of work describing the skills needed for community college IT graduates and studying the dynamics of the category 2 IT workforce. The ATE program awards about $46 million through about 75 awards each year.

In 2000, Foster-Bey et al. found that the shift to a digital economy benefited groups at all levels of education but that it benefited those with college degrees to a greater extent.[258] To increase the benefits of technology for those without college degrees, many IT job training programs have been created over the last few decades. Job training programs are focused on mainly category 2 IT workers. In 2000, Chapple et al. reviewed 26 programs focused on training and facilitating job transitions of low-income persons and persons with disabilities.[259] They found that successful programs provide soft-skill training in additional to technical skills, pay careful attention to teacher quality, and constantly adapt curricula to meet industry needs. This work was funded by the Bay Area Video Coalition (BAVC), which at the time had a program called MediaLink to provide IT job training to low-income adults.[260] This program appears to no longer exist, although the BVAC does continue to provide IT job training through California's Labor and Workforce Development Agency's Employment Training Panel. In 2001, Creaturo outlined other programs that provide IT job training to low-income adults in cities across the United States including:[261]

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254 Malcom et al. (2005)
255 Lerman et al. (2000)
256 http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5464
257 http://www.nwcet.org
258 Foster-Bey et al. (2000)
259 Chapple et al. (2000)
260 http://www.bavc.org
261 Creaturo (2001)

- Byte Back (Washington, DC) provides "affordable, hands-on computer training" enabling "economically disadvantaged adults to acquire marketable skills and thus, jobs."[262]
- Homeboyz Interactive (Milwaukee, WI) provided apprenticeship for low-income, at-risk youth from Milwaukee's inner city. Focus was on web design but professional development in a community based work environment was also provided.
- ICStarts (Chicago, IL) "uses project-based learning and full immersion teaching, [and] provides an opportunity for change-driven, future leaders to develop skills in business and technology."[263] The program is focused on adults with a high school diploma or GED and is supported by many large technology firms such as Insight and SAP.
- Playing2Win (New York, NY) "leads the next generation of technology users to the forefront of economics, social and educational opportunities."[264] This program provides technology training to both youth and their parents.

Most of these programs focus on urban areas where populations are primarily underrepresented minorities. While this is an important area to focus efforts, some interviewees mentioned that it is also important to provide IT training in low-income rural areas.

A number of state governments provide funding for IT workers to receive skills training. Iowa's Information Technology Training Program is a good example of a program focused specifically on IT workers.[265] Other programs are not specifically focused on IT workers but provide funding to train IT workers. California's Labor and Workforce Development Agency's Employment Training Panel[266] provides funding to the Bay Area Video Coalition to provide training to IT workers. It is likely that job training programs in many states provide training to IT workers through other mechanisms.

Another important set of programs targets individuals transitioning from non-computing to computing professions. Many of these programs target workers that have been laid off from manufacturing jobs and provide them with the skills required to transition to new careers, many of which are in NIT. For example, the dislocated worker program at Yakima Valley Community College in Washington State provides tuition and funds for fees and books for one quarter per year.[267] Similar programs across the United States, provided primarily through local colleges, prepare workers for new careers in category 2 NIT occupations.

[262] http://www.byteback.org
[263] http://www.icstars.org
[264] http://community.seas.columbia.edu/cslp/partner.cgi?id=15
[265] http://www.iowalifechanging.com/Business/ic/ITfunds.html
[266] http://www.etp.cahwnet.gov
[267] Hoang (2009)

2.5.5 Lessons from Other Fields

A number of different programs and initiatives have been undertaken to increase participation in a variety of different career fields. However, a review of recent press articles found that few occupational shortages have been widely cited over the last decade outside of NIT. Of the occupations other than NIT that are often cited as having shortages, the majority of them are in healthcare.

Nursing is the most prominent example of a career field that has faced perceived shortages of qualified workers and has undertaken efforts to increase participation. The nursing field has faced a series of shortages and surpluses over the past decade and some project a 20 percent shortage in the registered nurse workforce by 2020.[268] One of the key issues facing both nursing and IT careers is image. While computing is seen as isolating and male dominated, nursing is often seen as a female-only profession that lacks the prestige of being a physician. One of the most prominent initiatives undertaken in the nursing profession to improve its image is the Campaign for Nursing's Future funded by Johnson and Johnson Health Care Systems. This campaign has advocated nursing careers through television ads, promotional materials for high schools, and a website, "discover nursing," that describes the benefits of a nursing career as well as provides links to scholarships and accredited nursing programs.[269] Those looking to develop materials to improve the image of NIT careers may look to the "discover nursing" website as an example.[270] A number of initiatives focused on remedying the nursing shortage have also been focused on increasing educational capacity,[271] such as the Robert Wood Johnson Foundation New Careers in Nursing Scholarship.[272] These initiatives are similar to many of the scholarship programs provided in NIT areas. Studies of programs in the nursing area have also found that "children must be reached earlier than high school because 'students often have their minds made up by fifth grade about desirable and undesirable careers.'"[273] Those looking at undertaking programs focused on the NIT workforce may also consider early interventions. The University of Maryland School of Nursing has developed a "career academy" which "helps prepare high school students for college by integrating career themes into their academic courses."[274] Such a career academy may also be useful in increasing participation in NIT careers. Stakeholders in the nursing area have also attempted to create strategic partnerships to align and leverage stakeholder resources. An example of this is the Center to Champion Nursing in America, which is a joint initiative of the AARP and the Robert Wood Johnson Foundation.[275] This organization "serves as a focal point for advocacy and educational efforts at both the state and national levels."[276] This type of organization is important in nursing where there are dozens of interest groups and labor organizations with overlapping interests. Like NIT, nursing is also facing a need to redesign curricula. While the specifics are not relevant to

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[268] Goodin (2003)
[269] Sochalski (2002)
[270] http://www.discovernursing.com
[271] Nursing Education Capacity Summit (2008)
[272] http://www.rwjf.org/applications/solicited/cfp.jsp?ID=20301&c=EMC-CA137
[273] Goodin (2003)
[274] Goodin (2003)
[275] http://www.championnursing.org
[276] Joynt and Kimball (2008)

IT, curricula reform appears to be progressing on a school-by-school basis in nursing in the same way we observe in NIT.[277]

There are also many differences between nursing and NIT that make other programs less relevant. Nursing faces a shortage of faculty members to train new nurses because many nurses do not pursue advanced education and the nursing faculty population is aging.[278] Additionally, nursing is highly regulated due to the fact that nearly all nurses are in the health care industry. NIT does not appear to face a faculty shortage, nor is it a highly regulated industry. In 2008, Joynt and Kimball reviewed a variety of other state and local programs aimed at nursing careers but many of these have little relevance to IT.[279]

Another healthcare occupation that is often referenced in regards to shortages is pharmacy. DHHS concluded in 2008 that "only under an optimistic supply projection combined with a conservative demand projection is future supply [of pharmacists] adequate to meet demand."[280] In response to this shortage, as many as ten new schools of pharmacy are expected to open by 2010 and current pharmacy programs are also increasing enrollments.[281] The lack of faculty and facilities to train pharmacists is not a problem in NIT areas, where the infrastructure exists to train many more NIT graduates but enrollments have been declining. Another initiative underway for pharmacists is increasing the use of technology to supplement manpower.[282] Such initiatives are rarely discussed in NIT fields, although the emergence of development platforms that require less technical knowledge could slightly reduce the need for some traditional NIT occupations.

While nursing and pharmacy have undertaken some novel programs and initiatives to increase supply, many of the issues facing these fields are different from those facing NIT. The main bottleneck facing these occupations is a lack of educational capacity, something that does not appear to be a problem in NIT areas. However, initiatives to address image problems in nursing and the use of technology to supplement the existing pharmacy workforce both offer novel ways to address worker shortages. There are initiatives being undertaken to increase participation in nearly every career field, such as efforts to improve the image of manufacturing in Oregon[283] and to increase the number of primary care physicians nationwide.[284] However, these largely local and disconnected efforts often address concerns not very relevant to NIT.

277 Joynt and Kimball (2008)
278 Joynt and Kimball (2008)
279 Joynt and Kimball (2008)
280 DHHS (2008), p. v
281 Kenreigh and Wagner (2006)
282 Kenreigh and Wagner (2006)
283 Hunsberger (2004)
284 Pear (2009)

3. UNDERREPRESENTED GROUPS

Consistent with the participation rates in other STEM fields, African American and Hispanic people are underrepresented in the NIT workforce relative to their proportion of the overall workforce and in the population. Women are also underrepresented in the NIT workforce despite having made tremendous gains in other STEM fields over the last decade. From all indications, Native Americans and persons with disabilities are significantly underrepresented, but face the compounded challenge of a lack of comprehensive data on their educational and professional participation. This chapter describes the representation of these groups at various points in the NIT pipeline and outlines programs and initiatives to increase their participation.

3.1 Women

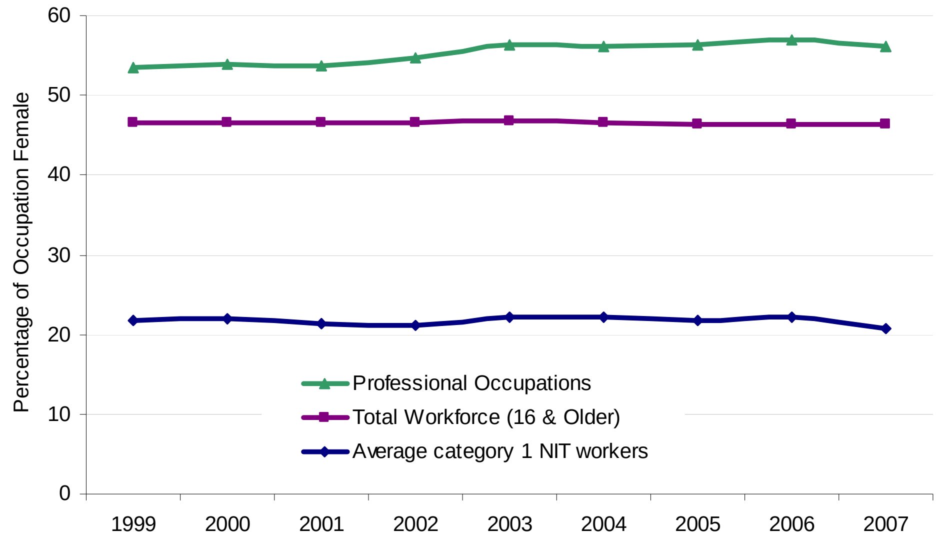
The experience of women along NIT pathways warrants particular attention because it is the one STEM field where women's participation has not improved significantly despite the tremendous effort to increase their participation in STEM fields over the last decade. Women are significantly underrepresented both in the NIT workforce and among NIT degree recipients relative to their population in the overall workforce and their proportion of the population. The point at which women tend to visibly shy away from NIT careers is at the undergraduate degree level, where women tend to choose non-NIT majors at a higher rate than men. While this is where career choices first become visible, the literature points to earlier experiences of women at the K-12 level that lead them to make these decisions.

3.1.1 Women in the NIT Workforce

Women are significantly underrepresented in NIT occupations relative to their representation in the overall workforce and in the population. The Census Bureau estimates that women comprised about 51 percent of the population in the United States in 2007. Women also comprised about 46 percent of the total workforce and 56 percent of professional occupations in 2007. In contrast, women represented only 21 percent of the category 1 NIT workforce in 2007.[285] This level of underrepresentation has remained relatively constant since 1999, as shown in Figure 3.1.

[285] Using NSF SESTAT data, we calculated the fraction of women in NIT occupations to be 23 percent in 2006, very close to the estimates derived from the CPS.

Figure 3.1: Female Underrepresentation in the NIT Workforce (1999-2007)



Source: Current Population Survey

While the representation of women in professional occupations increased since 1999, it has been stable in both the total workforce and the category 1 NIT workforce. Table 3.1 shows the trends in female representation across NIT occupations.

Table 3.1: Percentage of Women in the Workforce by Occupation (1999-2007)

Occupation	1999	2000	2001	2002	2003	2004	2005	2006	2007
Computer systems analysts and scientists	29	29	27	28	30	29	30	32	27
Computer programmers	26	27	27	26	28	27	26	25	25
Electrical and electronics engineers	10	10	10	10	7	8	7	8	9
Computer software engineers					24	25	22	22	21
Computer hardware engineers					10	13	11	16	10
Network systems and data communications analysts					24	22	25	26	26
Computer and information systems managers					31	31	32	27	28
Average category 1 NIT workers	**22**	**22**	**21**	**21**	**22**	**22**	**22**	**22**	**21**
Total Workforce (16 & Older)	**47**	**47**	**47**	**47**	**47**	**47**	**46**	**46**	**46**
Professional Occupations	**54**	**54**	**54**	**55**	**56**	**56**	**56**	**57**	**56**

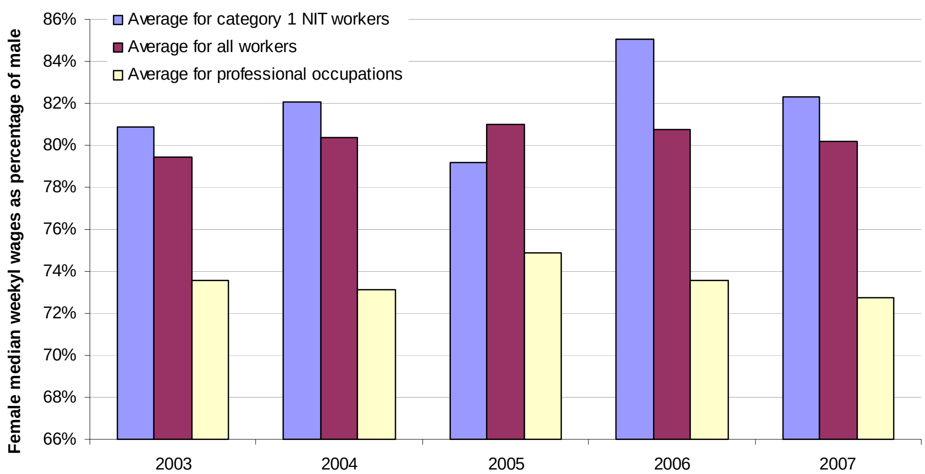
Source: Current Population Survey

Women are underrepresented to a greater degree in hardware-related occupations than in software-related occupations. Women comprise only 10 percent of the electrical and electronic engineering workforce while they comprise about 25 percent of the computer programming workforce. Nonetheless, women remain underrepresented across all NIT occupations.

Women are also underrepresented in top leadership positions in the technology industry. In 2007, only six percent of CEOs, five percent of CTOs, and two percent of COOs in the top 100 IT-related Fortune 500 companies are women.[286] Female representation on company boards is also low, with 13 percent of board seats of Fortune 100 IT companies going to women while 17 percent are filled by women across all sectors.[287]

An interesting trend emerges from the CPS earnings data in NIT occupations. While women in the overall workforce tend to have average earnings that are 20-25 percent less than men, the gap in the NIT workforce is slightly smaller. In 2007, women across the entire workforce earned about 20 percent less than men; the wage gap was larger in professional occupations where women earned about 27 percent less than men. In NIT occupations, women earned only 18 percent less. Women in NIT occupations had a smaller wage gap than professional occupations in every year going back to 2003 as shown in Figure 3.2. We are unable to determine if this difference is statistically significant without access to the micro-level data.

Figure 3.2: Female Wage Gap in the NIT Workforce (2003-2007)



Source: Current Population Survey

In 2007, the National Center for Women and Information Technology (NCWIT) found that the percentage of IT patents obtained by female inventors increased from 1.7 percent in 1980 to 6.1 percent in 2005. Women accounted for more computer software patents than for any other IT patent category.[288]

3.1.1.1 Women in the Federal Workforce

Women are underrepresented in federal NIT occupations as they are in the NIT workforce as a whole. In 2008, women comprised 44 percent of the federal workforce but only 29 percent of the federal NIT workforce. Women had greater representation in the occupations of information technology and computer science than they did in electrical, computer, and electronics engineering, as shown in Table 3.2.

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[286] NCWIT (2007a)
[287] Klawe et al. (2009)
[288] NCWIT (2007b)

Table 3.2: Female Representation in the Federal Workforce (2008)

Occupation	% Female
Information Technology	36%
Electrical Engineering	13%
Computer Engineering	18%
Electronics Engineering	10%
Computer Science	28%
Total Federal NIT Workforce	**29%**
Total Federal Workforce	**44%**

Source: US Office of Personnel Management FedScope Database (2009)

3.1.2 Women in NIT Education

Women are underrepresented throughout the NIT education pipeline. The following sections describe women's representation at various points in the NIT career pipeline.

3.1.2.1 K-12 Students

A 2007 survey by the Computer Science Teachers Association (CSTA) found that women comprised 32 percent of high school computer science classes.[289] Additionally, women comprised only 18 percent of AP Computer Science A test-takers and only 10 percent of AP Computer Science AB test-takers. These are the lowest percentages of women among all AP exams. The exam with the next lowest percentage (AP Physics B) had more than double the rate of female representation at 35 percent. Female participation in the Intel Science and Engineering Fair is also lowest in the field of computer science while it is near (or exceeds) parity in other STEM fields. Data from the SAT also show that women who intend to major in computer science have among the lowest average math scores of those intending to major in scientific disciplines.[290]

3.1.2.2 Higher Education Students

The underrepresentation of women in NIT is also a phenomenon that we observe in higher education. In 2006, women received about 59 percent of all degrees (bachelor's and higher) awarded in the United States and about 50 percent of degrees in science and engineering fields. In contrast, women received only about 20 percent of degrees in NIT fields. In addition, while the fraction of degrees awarded to women in all disciplines and in science and engineering has been increasing, the fraction of NIT degrees awarded to women has been decreasing. This trend is shown in Figure 3.3.

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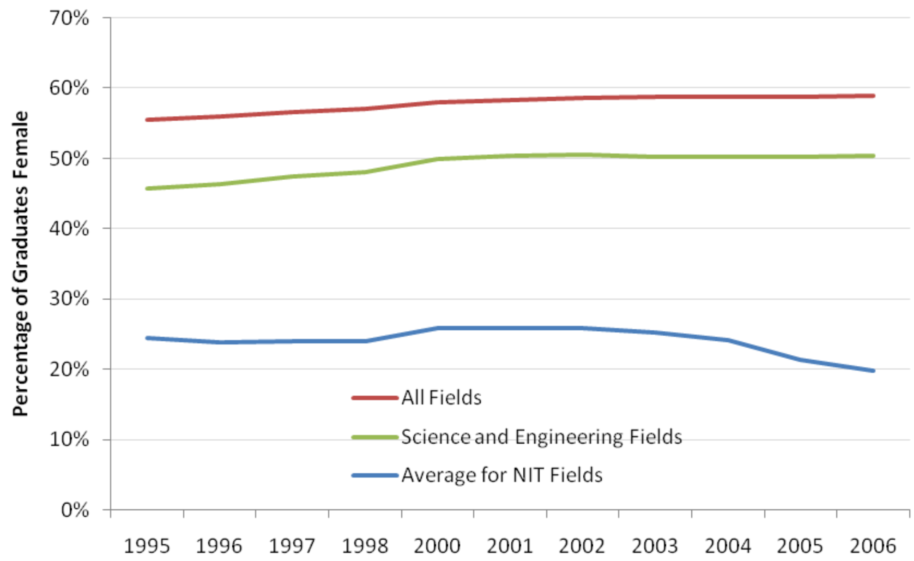
[289] CSTA (2007)
[290] NCWIT (2007a)

Figure 3.3: Percentage of Degrees Awarded to Women (1995-2006)



Source: NCES

At all degree levels, the fraction of women receiving degrees in electrical and computer engineering is significantly lower than the fraction receiving computer science degrees. Table 3.3 shows the female representation at each degree level for CS and EE in 2006. This continues the trend recognized in the NIT labor force data where women are underrepresented to a greater degree in hardware areas than they are in software areas.

Table 3.3: Percentage of Females Receiving Degrees by NIT Degree Field (2006)

Degree Level	Computer Science	Electrical and Computer Engineering	Average for NIT Degree Fields
Bachelor's	20 %	12 %	19 %
Master's	26 %	16 %	24 %
Doctorate	23 %	11 %	20 %

Source: NCES

Women are underrepresented to a slightly greater degree at the bachelor's and doctoral level than they are at the master's level. Computer science and electrical engineering are two of the only STEM fields where the fraction of degrees awarded to women has been declining.[291]

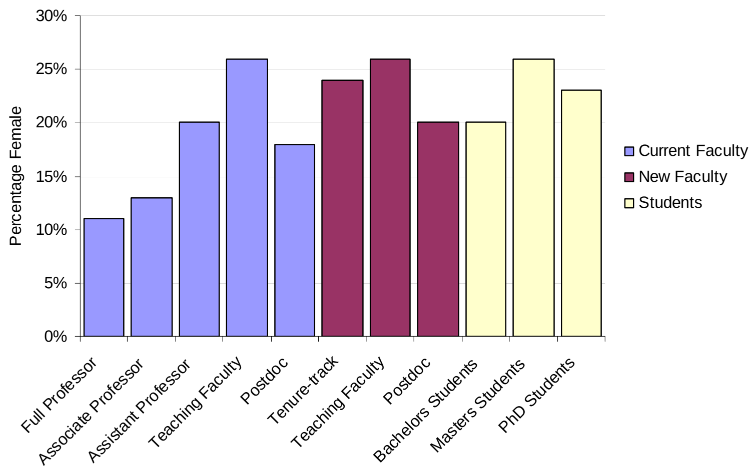
3.1.2.3 Faculty

The CRA's Taulbee survey also shows that women are underrepresented among CS faculty: 11 percent of full professors and 13 percent of associate professors in CS are female. However, Figure 3.4 shows that women are underrepresented to a greater extent among current faculty (those with more than one year in their position) than they are among new faculty (those hired in the last year) and students. The trend seems to show an increasing representation of women among CS faculty. As new faculty move through the

[291] Vegso (2005)

tenure process it appears as though the representation of women will increase unless women leave CS faculty positions at a greater rate than men do.[292] This is confirmed by the fact that the proportion of women in full CS professorships has more than doubled between 1995 and 2007, from five percent to 11 percent. Additionally, the fraction of female university presidents has increased from 18 percent in 1995 to 23 percent in 2007.[293]

Figure 3.4: Percentage of CS Faculty and Students in the United States and Canada who are Female (2006-2007)



Source: Zweben (2008)

There are no data available on the representation of women among EE faculty. However, given the degree and workforce data, one could hypothesize that women are underrepresented to an even greater extent among EE faculty than among CS faculty.

3.1.2.4 High School Completion and College Attendance

A larger proportion of women than men have been completing high school and attending college for the last few decades. Since about 1976, women have been completing high school and attending college at a greater rate than men, as shown in Figure 3.5 and Figure 3.6.

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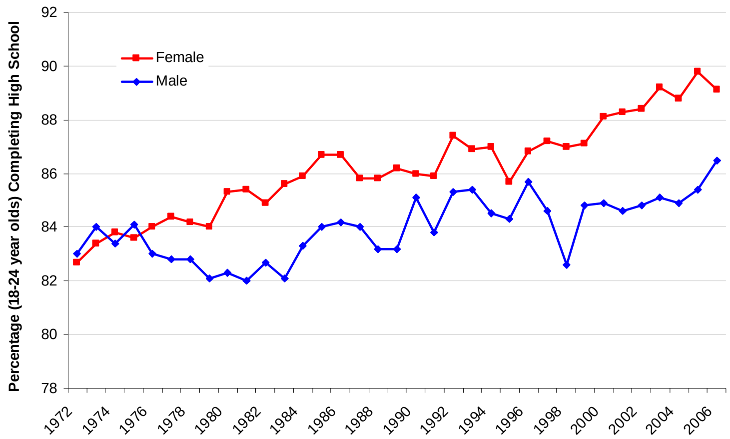
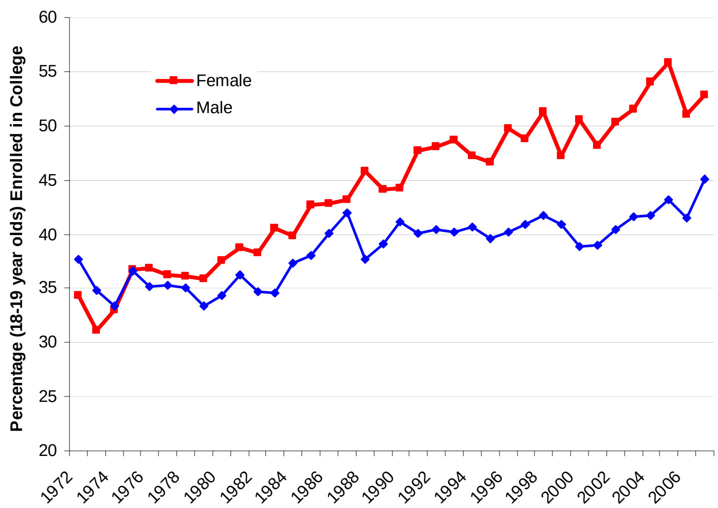
[292] Klawe et al. (2009) appears to assume that this is the case in recommending programs to facilitate the career progression of women CS faculty members.
[293] Klawe et al. (2009)

Figure 3.5: Percentage of 18-24 Year Old Women and Men Completing High School (1972-2006)



Source: NCES (2008b)

Figure 3.6: Percentage of 18-19 Year Old Women and Men Enrolled in College (1972-2006)



Source: Current Population Survey

Given these trends, women are not underrepresented in the workforce because they are underrepresented in higher education. Instead, women complete high school and attend college at higher rates than men. Women's choice not to major in NIT degree fields at the undergraduate level is the primary reason why women are underrepresented in the NIT workforce.[294] While we have seen that not all NIT workers have NIT degrees, about half of NIT workers do have NIT degrees and the significantly lower rate at which women receive NIT degrees has a major impact on the availability of women in the NIT workforce. Additionally, the factors that contribute to women's decisions not to obtain NIT degrees may also influence the decisions of women with other types of degrees to enter NIT careers.

[294] Congressional Commission on the Advancement of Women and Minorities in Science (2000)

3.1.3 Concerns and Programs to Increase Female Participation in NIT Careers

Educational preparation is no longer the primary obstacle to women's participation in STEM fields. Significant gains have been made by the STEM policy community and educators from K-12 through university in addressing similar issues concerning stereotype threats and gender biases in mathematics and science fields.[295] Women reached parity with men in the number of bachelor's degrees earned in science and engineering fields in 2000.[296] The persistent reluctance of women to pursue degrees in computing suggests that there are specific characteristics of computing that affect women's choices, which result in this gender imbalance. Several works have examined this long-standing gender imbalance.[297] We begin by summarizing what was found in these studies.

One of the most prominent works on women and computing, Margolis and Fisher's *Unlocking the Clubhouse: Women in Computing* uses the voices and perspectives of female students to examine the experience of computing.[298] They use data from four years (1995-99) worth of interviews with students who were studying computer science at CMU. The findings of Margolis and Fisher's work agree with other studies that for young women: the influences on their pathways to computer science vary according to their stage of development.

According to Margolis and Fisher, in their early years, girls are subject to gender biases regarding their toys (including computers) and how they "play" with them. While boys are encouraged to be aggressive and assertive in their tinkering, girls are encouraged to think that being aggressive and assertive is to be like a boy. This trend continues through girls' educational evolution. This disparity is compounded by other related gender-based factors. In the middle stages (though certainly not exclusively) of their schooling, girls' are subject to significant gender-based differences in encouragement from their teachers and peers regarding course selection and scholastic aptitude. At the high school-university juncture, girls' perception of computer science and computing fields is often at odds with their desire for resonance between education and personal purpose. Ultimately, in computing fields, women are still faced with the challenges of being pioneers in a male-dominated field of study. Margolis and Fisher's work is corroborated by other works that attempt to identify the primary factors affecting girls and young women such as the Anita Borg Institute's 2005 comprehensive review, *Where are the Women in Information Technology?*[299] and the NSF's series *New Formulas for America's Workforce (2): Girls in Science and Engineering*.[300]

In Margolis and Fisher's work, many of the women interviewed chose computer science because they see a connection between computing and the social and human conditions that they are concerned about. This finding is consistent with other results that suggest

[295] Shaywitz and Hahm (2004)
[296] Chubin et al. (2005)
[297] Xie and Shauman (2003), Fox et al. (2006), Aspray (2007)
[298] Margolis and Fisher (2001)
[299] Ramsey and McCorduck (2005)
[300] NSF (2006)

that women are more interested in the applications of science than in the abstract development of complex technical functions.[301] In 2000, the American Association of University Women (AAUW) stated, "Girls have reservations about the computer culture and with good reason."[302] Part of that reasoning is that they perceive the computer culture as being inconsistent with their personal convictions. In a longitudinal study of adolescent girls, Linver et al. found that values are more important than (real or perceived) level of skill with mathematics or math-based sciences in career choices.[303] Simply showing girls that they can "be good at math" is not likely to influence the choices young women and girls make regarding their participation in NIT fields.

These findings are particularly significant because they highlight one of the principal problems of computing pointed out by several experts interviewed for this study, that "computer science has an image problem." Margolis and Fisher's study was with women who were already enrolled in computer science. However, the public perception of computer science is that it is an isolating field that is relatively disconnected from pressing social problems that young women are inclined to want to solve. For women, this perception is an effective deterrent. Women are more inclined at an earlier stage to want their education to serve a purpose. For young men, interest in computers themselves, along with gaming and gadgetry, are supposedly sufficient motivating factors. According to one of Margolis and Fisher's interviewees, she feels that she has to use her computer science skills "to make a contribution…just making video games is not worth the energy and talent that it takes."[304]

The emphasis on purpose leads to another critical point in the pathway to NIT education and careers for women. High school computer science classes are instrumental in forming students' perceptions of the field. While these classes have the potential of presenting the versatility of the field, they often amount to standard programming of, as one CS faculty member described, "the programming language *du jour*." This style of computer science course has a disproportionately negative effect on young women whose budding academic interests are closely tied to their personal convictions and desire to make substantive social contributions.

According to Margolis and Fisher's work, young women develop a concern for social relevance and purpose-driven work earlier than young men. Turner et al. used a survey to discover what factors influence women to pursue NIT careers.[305] Drawing a self-selected group from the systers listserv, they found that women reported influences by significant people in their lives, experiences with technology, and internal motivators.[306] Family members and teachers influenced women to pursue degrees in IT, suggesting that they can serve as aids to transitions along the career path. Many of these women with undergraduate degrees mentioned an introductory computer science course as a

[301] Cassell and Jenkins (1998)
[302] AAUW (2000)
[303] Linver et al. (2005)
[304] Margolis and Fisher (2001), p. 53
[305] Turner et al. (2002)
[306] The systers.org email list was started in 1987 by Anita Borg and is now part of the Anita Borg Institute for Women and Technology.

significant influence on their choice, and reported that they were drawn toward a career that they saw as exciting and that matched their interests in math, logic, and puzzle solving. These are all factors that are commonly understood to affect all young people regardless of gender.

The results of the 2001 study by Margolis and Fisher were influential to subsequent program development and have been cited by many subsequent studies on women in computing. Their work helped to clearly articulate the issues facing women in computing and contributed to the development of programs and discussions to help improve the experience of computing education for all students. This effort to make computing more attractive to women is coincident with the broader efforts to transform computing education to be more problem-based and to employ more dynamic learning practices. The broad intentions of this national effort and conversation are to recast computing education as a pump, not a filter. Some examples of the programs that have been implemented as a result of this national discourse are discussed in the section below.

3.1.3.1 Programs and Initiatives for Women

The programmatic response to the underrepresentation of women in NIT education and careers has been responsive to academic work attempting to understand the factors that influence women the most. There is a vast array of programs designed to improve the experience of women in computing and to encourage more women and young girls to opt for NIT pathways. These programs are structured around one or several of the major elements – changing perceptions, mentoring, recruitment, funding, exciting new exposures, and building communities around computing.

At the national level, the National Science Foundation has taken steps toward encouraging women to pursue STEM careers. Starting in 1993, the NSF's Program for Women and Girls, renamed Research on Gender in Science and Engineering (GSE) in 1999, supports programs to develop new teaching methods (hands-on, cooperative, real world, applied, and problem-based) in both informal and formal settings.[307] The GSE is the largest funding source in the nation for programs designed specifically for the development of women and girls in STEM fields. The objective has been to develop and support an infrastructure for girls throughout K-12 that is conducive to their success. That infrastructure includes welcoming environments, establishing relationships with role models, the development of support communities, and the identification of new pedagogies and pathways into IT careers.[308] The GSE program awards about 15 to 22 grants per year for a total of $5 million annually. One example of a grant funded through this program is "Girls on Track" which incorporated best practices of basing math and IT learning on real problems (including careers and salaries), offering a 2-week summer camp for girls only, addressing teacher and guidance counselor practices with professional development, and involving parents. "Girls on Track" is just one example of the kind of program supported by NSF, but also demonstrates how program development has been responsive to social science inquiries into the factors that prevent women and

[307] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5475&org=HRD
[308] NSF (2003)

girls from pursuing NIT pathways. The program incorporates features that address all of the major factors. The 2005 report on NSF programs for women and girls in STEM fields stated that over 350 grants had been awarded for innovative projects to increase access and choice. Other non-profit organizations provide similar support for women in STEM careers such as the Expanding Your Horizons Network[309] and Sally Ride Science.[310] The American Association for the Advancement of Science (AAAS), L'Oreal, and the United Nations Educational, Scientific and Cultural Organization *(*UNESCO) have also joined together to provide information on STEM careers targeted at women through their publication of the L'Oreal-UNESCO Women in Science Booklet.[311]

As mentioned earlier, one of the principal challenges of the computing field is young people's perception of computing. For young girls, their perception of the field as isolating and abstract is often compounded by a lack of confidence and a hesitation to manipulate computers to serve their interests. Programs designed to counter this perception often involve speaking directly about the field and trying to debunk myths that young women might have. In keeping with this strategy, Blank, Hiestand, and Wei created an interactive multimedia presentation at Lehigh University that shows a diverse set of speakers talking about common misconceptions about computer science and teaching basic computing concepts. The authors found that the interaction with multimedia improved students' responses on a survey about the misconceptions about the field of computer science.[312]

There are also specific attempts to address the issues surrounding women's confidence regarding computing. One such effort adheres to the philosophy that academic gender separation helps girls develop confidence in fields that are typically dominated by boys. As such, the development of same sex classes is another programmatic style that is employed to address women's issues. For example, Crombie et al. reported positive results from the use of all-female CS courses.[313] They report that students have more positive perceptions of teacher support, self-confidence in CS ability, and greater intention to pursue future CS-related work when they develop in a single gender environment. Other researchers have recommended more modest programs intended to change attitudes. After surveying secondary school students in advanced math classes, Moorman and Johnson found low interest among females in computer science as a course of study in college and a low perception of their present skills in computing relative to others.[314] These students more frequently mentioned a male relative at home providing them with computer experiences, which led the authors to propose a computer club for elementary girls and their mothers. They have already had success with an all-female summer workshop that teaches an object-oriented programming language. Students' success at mastering the language contributed to females reporting, on the post-workshop survey, that they believe they could succeed in programming courses.

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309 http://www.expandingyourhorizons.org
310 http://www.sallyridescience.com
311 http://sciencecareers.sciencemag.org/tools_tips/outreach/loreal_wis_2009
312 Blank, Hiestand, and Wei (2004)
313 Crombie et al. (2002)
314 Moorman and Johnson (2003)

One of the more high profile programmatic changes in computer science education occurred at CMU after the publication of the book by Margolis and Fisher. CMU created multiple entry points into the first year courses, increased their interdisciplinary focus, changed their admission requirements, and fostered groups that supported women in the discipline. The percentage of women entering the School of Computer Science rose from 8 percent in 1995 to 42 percent in 2000. In addition to CMU initiatives, other noteworthy programmatic innovations are having considerable impact on young women's choices to pursue NIT education and careers. The First Bytes Program[315] at the University of Texas, Austin is an outreach program designed to intrigue and encourage high school girls to pursue educational careers in computing. It offers high school girls a residential summer experience to spend time exploring hands on computing exercises. It also offers high school teacher training to help teachers be more aware of the challenges to girls and techniques to overcome them. MIT's Women's Technology Program[316] is based on a similar premise and offers high school girls who have an aptitude for math and science an opportunity to learn more about computing. It is also a residential program that offers a primarily female environment to facilitate confidence building and comfort in addition to substantive exposure to computing.

Innovative outreach programs are programs that seek to develop a cross-sectional community to bring women from all stages of the NIT pathway together. In 2007, Hayward, Oja, and Werth reported on an ongoing program at Pennsylvania State University (funded by the CRA-W and the NSF) that aims to build a "learning community centered on computing."[317] Their community is uniquely conceived and includes high school girls, lower and upper class undergraduates, and graduate students and professionals. The idea of the community is to create a socially connected group for mentoring, a critical factor in convincing young women to pursue NIT pathways. A critical step in the program is their outreach into high schools in order to connect high school girls with women farther along in their NIT educational and career development. Participants in the program engage in an array of computing exercises designed to develop their skills and forge positive relationships with other members of the community. The program also hosts focus groups with girls on applications they find interesting.

The technical component of engaging girls and young women in computing is also supported by a set of programs and web-based resources. Girltech,[318] for example, is an online community for young girls to discover, purchase, critique, and discuss electronic gadgetry. Similarly, Womengamers[319] is a site designed to encourage female participation in the gaming industry. Gaming is an enormous industry in the United States and is often overlooked in the policy discussions surrounding increased US participation in

[315] http://www.cs.utexas.edu/~firstbytes/index.html
[316] http://wtp.mit.edu
[317] Hayward, Oja, and Werth (2007)
[318] http://www.girltech.com
[319] http://www.womengamers.com

computing. Gaming, however, is a significant attractive force for young people in their early development of interest in computing. According to the Womengamers site, that interest and participation is disproportionately skewed towards young men and boys, but it need not be. It is another untapped avenue that ought to be utilized to increase the participation of women in computing.

In keeping with the untapped avenue for girls and young women in gaming, the open source software community is another expansive field that is attracting many young people into computing. In the literature, there are very few research studies investigating the participation of women in the open source community. One such study in the European Union, conducted a survey and ethnographic study of men and women participating in a (often exclusively online) volunteer software development community.[320] They found striking results that the community actively (and perhaps unwittingly) discouraged women's participation. Unlike formal organizations, these volunteer communities do not have the authority to police for actions that, in companies, would be construed as harassment. The authors found that women in these communities (and they are few or hidden behind a male identity) are not only tasked with marginally contributing activities but are also subject to offensive or "flaming" emails and do not have the means to bring social or legal pressure to bear to correct other's behavior. This is especially exacerbated in the open source community due to the ethical values that community members bring: the freedom to choose. In many cases, women are subject to "boorish behavior" in the community.[321] The results of the study are consistent with the general conclusion that the perception of computing is not hospitable to women and not welcoming to girls. Notwithstanding that, online gaming and open source communities are critical areas of the computing landscape that deserve attention since they have the potential to be powerful attractive forces for young women and girls to develop interest in computing and NIT pathways.

The programmatic efforts to increase female participation in computing naturally include funding sources. There are scholarship programs for both undergraduate education and post-graduate education such as those offered by the American Association of University Women[322] and the Society of Women Engineers.[323] Program efforts and funding sources are products of an increasingly strong infrastructure designed to improve the circumstances of women in computing. Some of the prominent organizations that include advocacy groups, professional societies, and research platforms are listed here as examples of the elements of the structure.

- American Association of University Womem[324]
- Anita Borg Institute for Women and Technology[325]
- Association for Computing Machinery's Committee on Women in Computing[326]

[320] Nafus, Leach, and Krieger (2006)
[321] Ramsey and McCorduck (2005)
[322] http://www.aauw.org/education/fga/fellowships_grants/selected.cfm
[323] http://societyofwomenengineers.swe.org
[324] http://www.aauw.org
[325] http://www.anitaborg.org

- AT&T internships for women and minorities[327]
- Clare Booth Luce Program[328]
- Computing Research Association Committee on the Status of Women in Computing[329]
- Elsevier New Scholars Grants[330]
- Expanding Your Horizons[331]
- Grace Hopper Celebration of Women in Computing[332]
- National Center for the Study of Women and Information Technology[333]
- Society of Women Engineers[334]

3.2 African Americans, Hispanics, and Native Americans

African Americans, Hispanics, and Native Americans are also underrepresented in the NIT workforce. While we have seen that women are underrepresented in the NIT workforce due in large part to the fact that they are underrepresented among NIT degree recipients, minority groups are underrepresented in higher education. Once in college, African Americans, Hispanics, and Native Americans are as likely as the general population to choose NIT degrees.

3.2.1 Minorities is the NIT Workforce

In 2007, the US Census Bureau estimated that African Americans comprise about 13 percent of the population of the United States. CPS data shows that African Americans comprised 11 percent of the total workforce and nine percent of professional occupations in 2007. In the same year, African Americans comprised only seven percent of the NIT workforce. These percentages have remained relatively stable since 2003, as shown in Figure 3.7.

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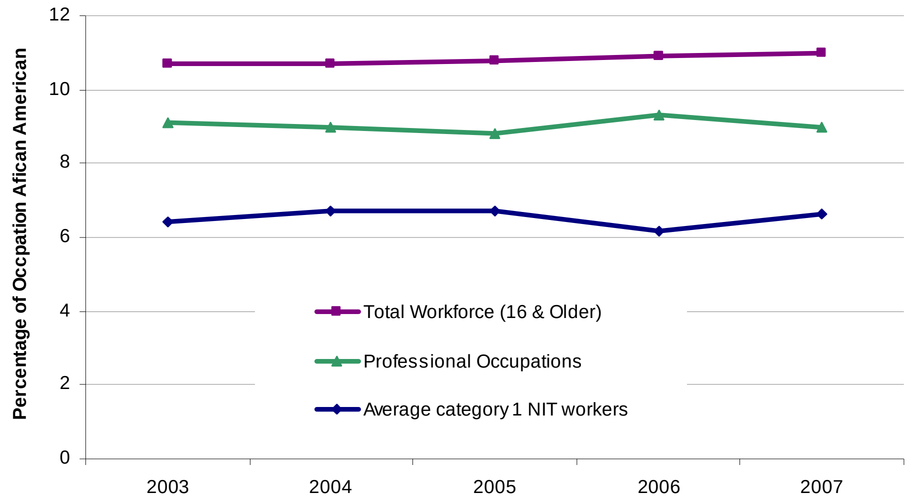
326 http://women.acm.org
327 http://www.research.att.com/internships
328 http://www.hluce.org/cblprogram.aspx
329 http://www.cra-w.org
330 http://www.elsevierfoundation.org/scholar.html
331 http://www.expandingyourhorizons.org
332 http://www.gracehopper.org
333 http://www.ncwit.org
334 http://societyofwomenengineers.swe.org

Figure 3.7: African American Representation in the NIT Workforce (2003-2007)



Source: Current Population Survey

Table 3.4 shows African American representation in 2003-2007 by NIT occupation. African American representation has been highest among computer systems analysts and scientists since 2003 and lowest among computer software engineers. African American representation among computer programmers has been declining while representation among electrical and electronics engineers and computer and information systems managers has been increasing.

Table 3.4: Percentage of African Americans in the Workforce by Occupation

Occupation	2003	2004	2005	2006	2007
Computer systems analysts and scientists	10	10	8	10	9
Computer programmers	7	7	5	4	5
Electrical and electronics engineers	4	5	6	6	7
Computer software engineers	6	5	5	6	5
Computer hardware engineers	6	7	8	4	6
Network systems and data communications analysts	7	8	9	8	7
Computer and information systems managers	4	5	6	6	8
Average category 1 NIT workers	**6**	**7**	**7**	**6**	**7**
Total Workforce (16 & Older)	**11**	**11**	**11**	**11**	**11**
Professional Occupations	**9**	**9**	**9**	**9**	**9**

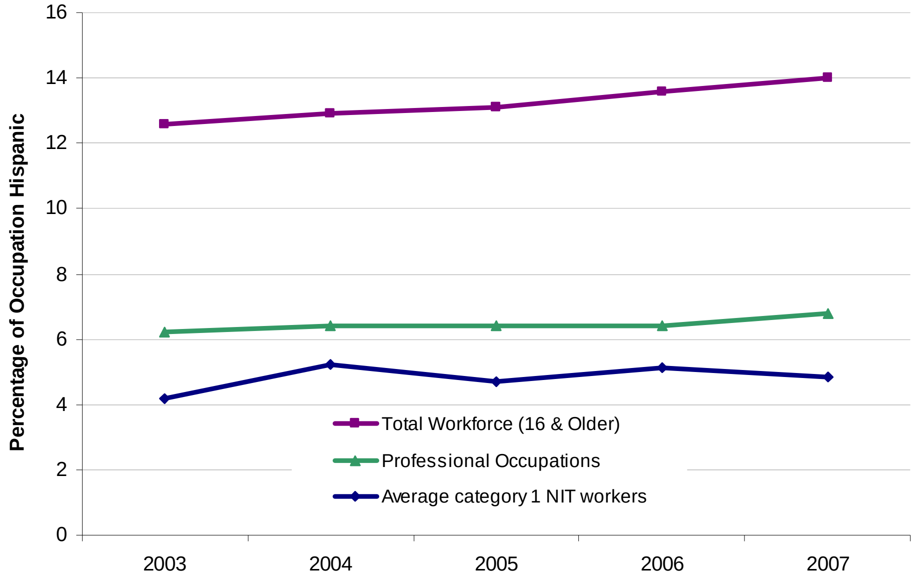
Source: Current Population Survey

In government, the representation of African Americans among NIT workers is higher. In 2008, African Americans comprised 14 percent of the federal NIT workforce, higher than their representation in the overall NIT workforce and in the population. However, this was lower than the representation of African Americans in the federal workforce as a whole (17 percent).[335]

[335] OPM FedScope Database

According to the Census Bureau, the Hispanic population of the United States comprised 15 percent of the total population in 2007. Hispanics also represented 13 percent of the overall workforce and seven percent of professional occupations. In contrast, Hispanics comprised only five percent of category 1 NIT occupations. While Hispanic representation in the total workforce and among professional occupations has increased since 2003, representation in the NIT workforce has remained relatively constant, as shown in Figure 3.8.

Figure 3.8: Hispanic Representation in the NIT Workforce (2003-2007)



Source: Current Population Survey

Table 3.5 shows the breakout of Hispanic representation by NIT occupation. Among NIT occupations, Hispanics are most underrepresented among computer software engineers and computer and information systems managers. Representation has been decreasing among computer software engineers since 2003.

Table 3.5: Percentage of Hispanics in the Workforce by Occupation

Occupation	2003	2004	2005	2006	2007
Computer systems analysts and scientists	5	7	5	5	6
Computer programmers	5	4	6	5	6
Electrical and electronics engineers	2	4	3	4	4
Computer software engineers	5	4	4	3	3
Computer hardware engineers	2	6	6	7	5
Network systems and data communications analysts	6	7	7	6	7
Computer and information systems managers	4	5	3	5	3
Average category 1 NIT workers	**4**	**5**	**5**	**5**	**5**
Total Workforce (16 & Older)	**13**	**13**	**13**	**14**	**14**
Professional Occupations	**6**	**6**	**6**	**6**	**7**

Source: Current Population Survey

The representation of Hispanics among NIT workers in government is about the same as in the overall NIT workforce. In 2008, Hispanics comprised about four percent of the federal NIT workforce, which was lower than their representation in the federal workforce as a whole (seven percent).[336]

No recent data are available on Native American representation in the NIT workforce because the publicly available BLS data do not include Native Americans in their breakout of detailed occupations by race. ITAA (2003) reported that in 2002, Native Americans comprised 0.6 percent of IT occupations compared to 0.9 percent of all occupations. The Census Bureau estimates that in 2002, the percentage of Native Americans in the US population ranged from 0.9 percent (for Native American only) to 1.5 percent (for Native American in combination with another race). No matter which estimate is used, Native Americans were underrepresented in the NIT workforce relative to both the population and all occupations in 2002. In 2008, Native Americans comprised about one percent of the federal NIT workforce compared to two percent of the federal workforce as a whole.

3.2.2 Minorities in NIT Education

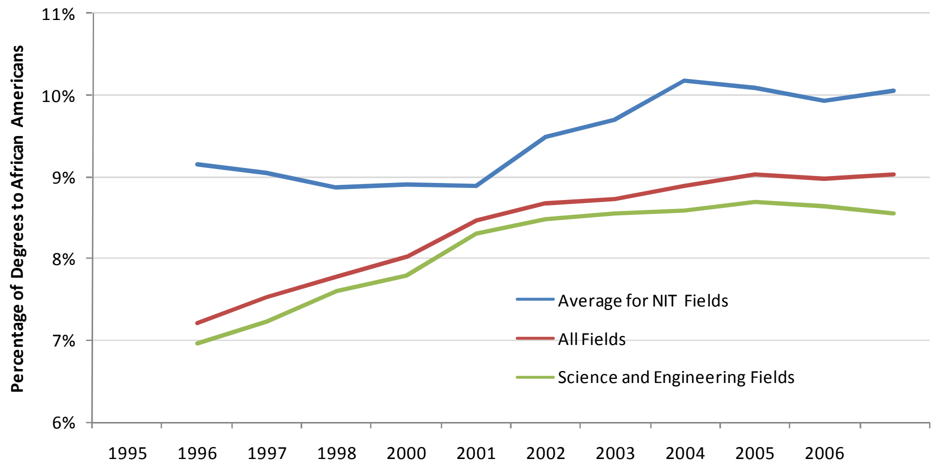
African Americans, Hispanics, and Native Americans are not underrepresented to the same degree among NIT degree recipients as they are in the workforce. Unlike the relatively stable underrepresentation of these groups in the workforce since 2001, the fraction of NIT degrees awarded to these groups has been increasing. However, minority faculty remain significantly underrepresented in NIT fields and there are few signs that this is improving.

3.2.2.1 Students

The fraction of NIT degrees awarded to African Americans is slightly higher than the fraction of all degrees awarded to African Americans and the fraction of all science and engineering degrees awarded to African Americans, as shown in Figure 3.9. The fraction of NIT degrees awarded to African Americans has been increasing since about 2001.

[336] OPM FedScope Database

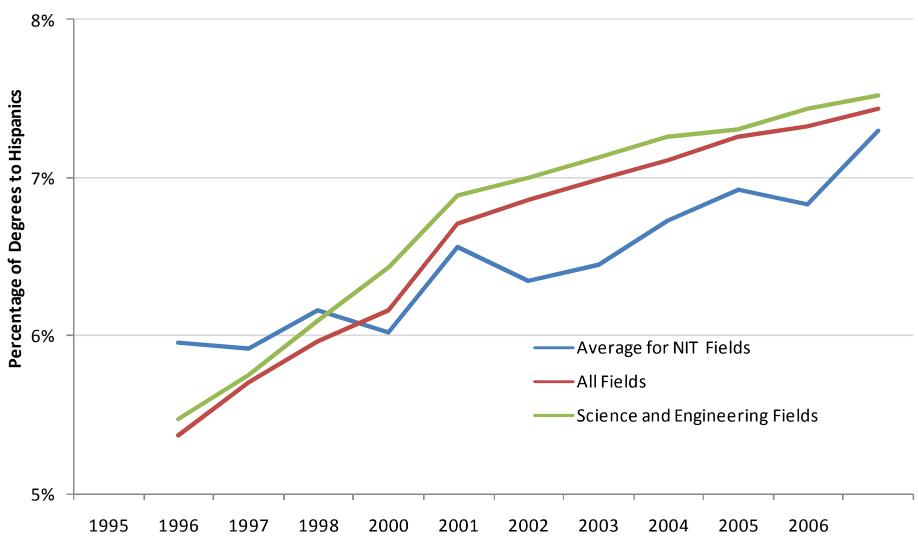
Figure 3.9: Percentage of Degrees Awarded to African Americans (1995-2006)



Source: NCES

Hispanic degree recipients were slightly underrepresented among NIT degree recipients relative to all fields and science and engineering fields from 2001 through 2006 as shown in Figure 3.10. The fraction of NIT degrees awarded to Hispanics has been increasing since 2001.

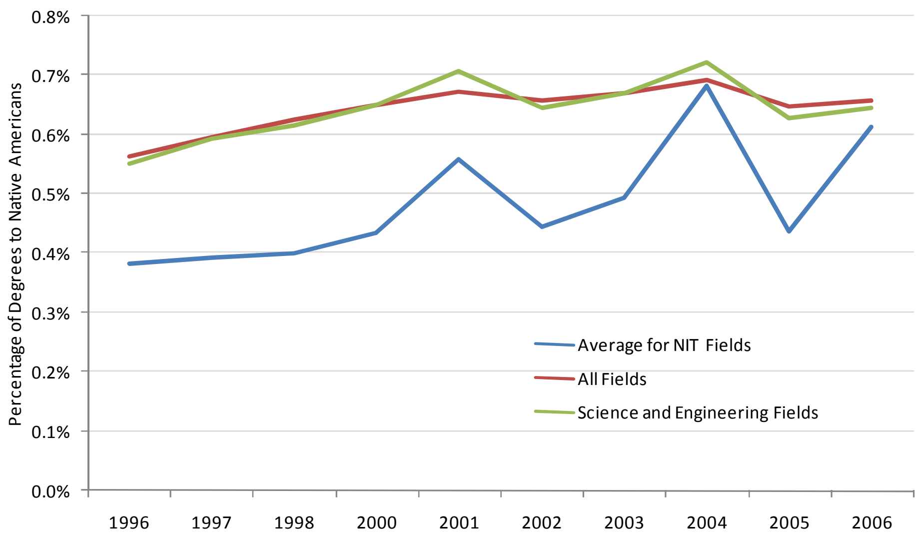
Figure 3.10: Percentage of Degrees Awarded to Hispanics (1995-2006)



Source: NCES

Native Americans are also slightly underrepresented among NIT degree recipients relative to all fields and science and engineering fields, as shown in Figure 3.11. In 2006, Native Americans received 0.6 percent of NIT degrees, nearly the same fraction as in all fields and in science and engineering fields. However, the fraction fluctuated anywhere from 0.4 percent to near 0.7 percent over the last decade, nearly always below the level in all fields and in science and engineering fields.

Figure 3.11: Percentage of Degrees Awarded to Native Americans (1996-2006)

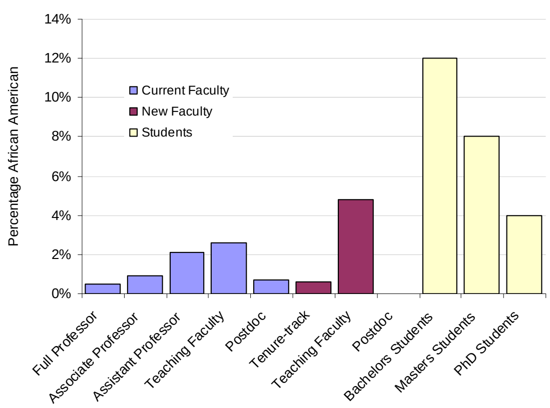


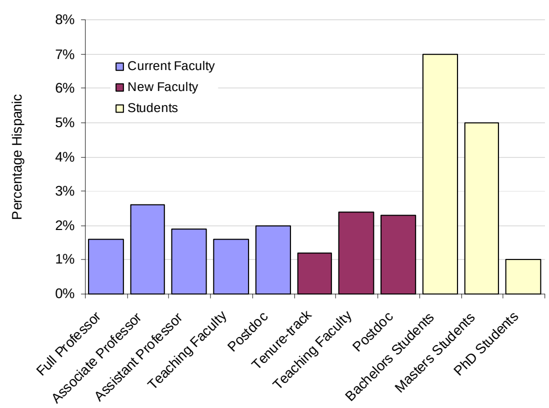
Source: NCES

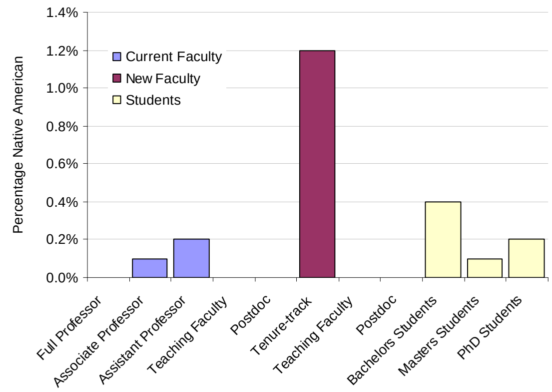
3.2.2.2 Faculty

African Americans, Hispanics, and Native Americans are significantly underrepresented among computer science faculty as shown in Figure 3.12. Less than one percent of senior CS faculty and about two percent of junior CS faculty are African Americans. This is significantly lower than the rate of representation of students of about ten percent. There has been no increase in representation of African Americans among newly hired faculty except in the case of teaching faculty. Hispanics represent between one and three percent of CS faculty, much lower than the representation among bachelor's and doctoral students, and there is little difference in Hispanic representation among new faculty. Native Americans are also significantly underrepresented among CS faculty, comprising less than 0.2 percent of current faculty. No new tenure-track Native American CS faculty were hired in 2006-2007.

Figure 3.12: Percentage of CS Faculty in the United States and Canada who are African American, Hispanic, and Native American (2006-2007)







Source: Zweben (2008)

It is important to consider the absolute numbers as well as the trends in academic choice and degree completion in CS and CE. For example, according to the 2007 Taulbee Survey, there were 20 African American and 20 Hispanic students who received Ph.D.s in CS and CE in the entire United States that year. There were only four Native Americans who received CS/CE Ph.D.s in 2007.[337]

3.2.3 Concerns and Programs to Increase Minority Participation in NIT Careers

There are many factors that are thought to contribute to the underrepresentation of African Americans, Hispanics, and Native Americans in the NIT workforce. These overlap with concerns discussed about computing careers in general and with concerns about the underrepresentation of women. Two issues unique to minorities are a lack of access to education and the digital divide. Concerns about perceptions and a lack of role models are also important, although these are not unique to minorities.

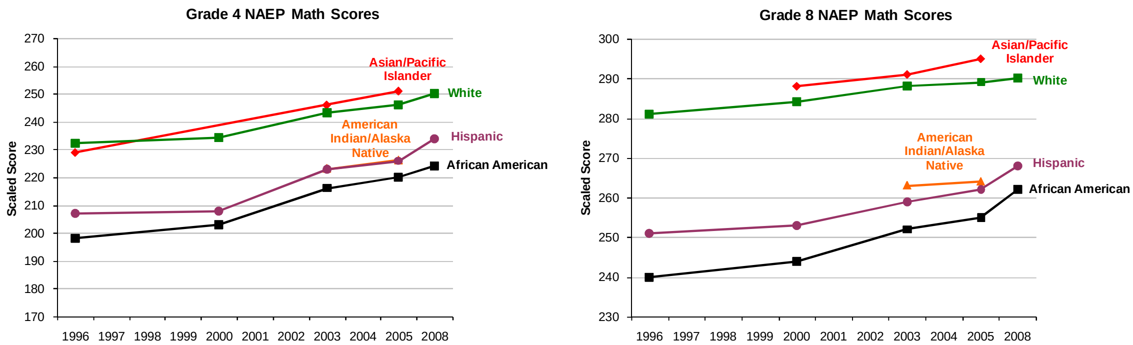
3.2.3.1 Access to Education

One of the outcomes of the ongoing effort to broaden minority participation in STEM fields has been an increased awareness within the STEM community of the educational isolation of African American and Hispanic students.[338] This isolation, coupled with a lack of resources, has led to low levels of instruction in math and science as well as poorer academic preparation.[339] Efforts to broaden participation in NIT disciplines face the same challenge.

Math scores from the National Assessment of Educational Progress (NAEP) exam show significant disparities between underrepresented minorities and other groups at both the fourth and eighth grade levels, as shown in Figure 3.13.[340]

[337] Zweben (2008)
[338] Kozol (2005)
[339] Moses and Cobb (2001)
[340] Dillon (2009)

Figure 3.13: Grade 4 and 8 NAEP Mathematics Scores by Race (1996-2005)



Source: NCES (2005) and Nation's Report Card (2009)[341]

African Americans, Hispanics, and Native Americans have significantly lower math scores than whites or Asians. These gaps remained but narrowed slightly over the period 1990 through 2008. A 2009 McKinsey report shows that these gaps remain even after controlling for income.[342] Since math is considered one of the primary requirements at the K-8 level to pursue NIT careers, this shows that underrepresented minorities are disadvantaged early on in the NIT career pipeline.

The isolation of minority students at the K-12 level is best shown by example. The educational circumstances of African American students in Atlanta, Georgia serves as an illustrative example of the national problem of educational access and "the sobering fact, that secondary schools are more segregated today than they were 15-20 years ago."[343] The public schools in Fulton County, which encompasses most of downtown Atlanta, have a demographic balance of 40 percent African American students and 40 percent white students.[344] The segregation between African American and white students, however, is nearly complete and is representative of the national pattern of racial segregation in schools demonstrated by Jonothan Kozol in, *The Shame of the Nation: Restoration of Apartheid Schooling in America*.[345] In Fulton County in 2006, 70 percent of all African American students attended schools that were more than 80 percent African American and 84 percent of all white students attended schools that were more than 60 percent white. Nationwide, predominantly minority schools receive lower levels of resources and exhibit lower test scores than other schools.[346] In 2006, in Fulton County, the average SAT score of African American students who attended essentially all black schools was 846 compared to an average SAT score of 1114 for their white counterparts. This difference reduces the opportunities for minority students to attend institutions of higher education, which closes off one of the primary pathways to category 1 NIT careers. This

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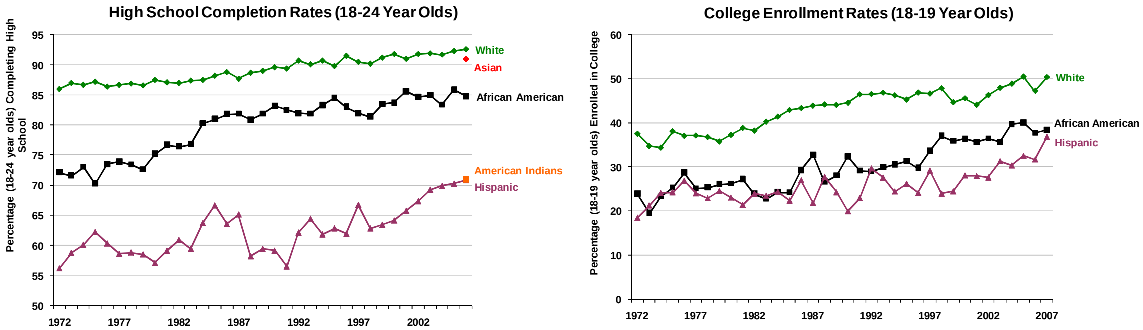
[341] http://nationsreportcard.gov/ltt_2008
[342] McKinsey (2009)
[343] Bowen et al. (2005), p. 159
[344] Georgia Governor's Office of Student Achievement (2009)
[345] Kozol (2005)
[346] Noguera (2003)

is substantiated by the data shown in Figure 3.14. These graphs show that African Americans, Hispanics, and Native Americans have significantly lower high school completion rates and college attendance rates than Whites and Asians.

Figure 3.14: High School Completion and College Enrollment Rates by Race (1972-2006)



Source: NCES (2008b), Ryu (2008), and Current Population Survey

The concern about access to education for minorities differs from the concerns related to women that were discussed earlier. While women graduate from high school and attend college at rates greater than men, they choose not to enter NIT degree fields during college. We saw in the previous section that underrepresented minorities in higher education choose NIT degree fields at rates close to those for the entire population. However, they are underrepresented in institutions of higher education.

There are a variety of programs aimed at increasing educational opportunities for minority students. Most of the programs at the K-12 level do not explicitly address NIT careers. Programs in higher education tend to focus more on specific career fields, especially STEM careers.

There are a number of programs focused on increasing the educational opportunities of minority students at the K-12 level. While the scope of this report does not allow us to review all of these programs, we discuss some of the most prominent ones. The most well known program in this area is the Head Start program run by the US Department of Health and Human Services (HHS).[347] While Head Start is not primarily focused on minority children, African American and Hispanic children comprised about 65 percent of total enrollments in 2008.[348] The purpose of this program is to provide assistance to children early in life and promote "school readiness by enhancing the social and cognitive development of children through the provision of educational, health, nutritional, social and other services to enrolled children and families." This program does not address education disparities directly but intervenes in key periods of social and cognitive development to ensure that children have equal opportunity to learn once in a formal educational environment. Head Start receives about $6.8 billion in federal funding annually.

[347] http://www.acf.hhs.gov/programs/ohs/
[348] Head Start Program Factsheet (2008)

The No Child Left Behind (NCLB) Act[349] is another government initiative with the goal of making K-12 education more equitable and reducing racial disparities.[350] While it is the subject of contentious debate, it is one of the largest nationwide efforts aimed at making K-12 education more equitable. In 2008, the Department of Education requested $24.4 billion for NCLB.[351] The Upward Bound Program, funded by the Department of Education, also aims to prepare students from disadvantaged backgrounds for college.[352] In FY 2009, the Upper Bound Program was budgeted to receive $313 million in federal funding. The Educational Development Center's Gender, Diversity, and Technology program has goals similar to those for Upward Bound.[353]

Many other K-12 programs that focus on minority opportunity are organized at the state and local level, such as the Minority Achievement in Maryland program organized by the Maryland Department of Education.[354] Malcom et al. list a number of state-based equal opportunity standards that guide education policies at the local level.[355] These types of policies at the state and local level, and how they are implemented, are key factors affecting the opportunities available to minority students.

Many programs aim to increase opportunities for minorities in higher education. The Level Playing Field Institute "promotes innovative approaches to fairness in higher education and workplaces by removing barriers to full participation."[356] The Institute has a number of different programs ranging from summer academies to scholarships. Many programs focus on key transition points such as the decision to attend college. The most common of these types of programs are scholarships for students who would not otherwise be able to afford college. Some of these programs target STEM areas directly while others target minorities in all fields. One prominent example in a STEM field related to NIT is the National Action Council for Minorities in Engineering (NACME)'s Scholars Program.[357] This program provides more than $4 million annually in block grants to colleges and universities to provide scholarships to talented underrepresented minorities enrolled in engineering programs. Other prominent scholarship programs are listed below.

- The Gates Millennium Scholars Program aims to increase the representation of minority students in the disciplines of education, engineering, library science, mathematics, public health, and the sciences.[358]
- The Advancing Hispanic Excellence in Technology, Engineering, Math, and Science (AHETEMS) Scholarship Program is "designed to enhance and achieve

349 http://www.ed.gov/nclb/landing.jhtml
350 Dillon (2009); http://www.ed.gov/nclb/accountability/achieve/nclb-aa.pdf
351 http://www.ed.gov/about/overview/budget/budget08/summary/appendix1.pdf
352 http://www.ed.gov/programs/trioupbound/index.html
353 http://eec.edc.org/programs/gdt.asp
354 http://www.marylandpublicschools.org/MSDE/programs/minorityachievement
355 Malcom et al. (2004)
356 http://www.lpfi.org
357 http://www.nacme.org/scholars
358 http://www.gmsp.org

the potential of Latino students pursuing degrees in engineering, math, and science."[359]

- The Hispanic Scholarship Fund (HSF)'s mission is to double the rate of Hispanics earning college degrees to 18 percent by 2010.[360] During the 2007-2008 academic year, HSF awarded almost 4,100 scholarships exceeding $26.7 million.
- The United Negro College Fund (UNCF) administers more than 400 scholarship, fellowship, and institutional grants that support African American students at the undergraduate, graduate, and doctoral levels.[361]
- The National Society of Black Engineers provides scholarships, research opportunity, community activities, and academic support to African Americans.[362]
- The Development Fund for Black Students in Science and Technology (DFBSST) is an endowment fund that provides scholarships to African American undergraduate students enrolled in scientific or technical fields of study at Historically Black Colleges and Universities (HBCUs).[363]
- The Leadership Alliance/Schering-Plough Fellowship supports "underrepresented graduate students in the physical or life sciences, by providing supplemental dissertation awards for students to pursue professional development opportunities as they near completion of their Ph.D."[364]
- The National Consortium for Graduate Degrees for Minorities in Engineering and Science's mission is to provide "graduate fellowships in engineering and science to highly qualified individuals from communities where human capital is virtually untapped."[365]

In addition to funding, other types of programs provide academic and social support for minorities. The Meyerhoff Scholars Program at the University of Maryland at Baltimore County is a good example of this type of program.[366] This program targets STEM students planning to pursue advanced education. The program is considered a national model because it provides a positive social and academic environment. The program is highly structured, offering a pre-college residential program as well as regular social events and support for research abroad. Another program offering academic and social support is the Mathematics Workshop Program developed at the University of California-Berkeley.[367] The goal of this program is to "reverse the low success rate in entry level calculus, and the high attrition rate in math-related fields, for African American and Latino/Latina students who entered the university interested in careers in math, science,

[359] http://www.ahetems.org/scholarships
[360] http://www.hsf.net
[361] http://www.uncf.org
[362] http://national.nsbe.org/?tabid=81#scholarships
[363] http://dfbsst.dlhjr.com
[364] http://www.theleadershipalliance.org
[365] http://www.gemfellowship.org
[366] http://www.umbc.edu/meyerhoff
[367] http://education.washington.edu/cme/math.htm

or engineering." Many similar programs exist at various colleges and universities around the country, especially in science and engineering fields.

Another way of targeting minorities in higher education is through programs focused on specific underrepresented groups. The NSF Historically Black Colleges and Universities Undergraduate Program (HBCU-UP) does exactly this for STEM fields by providing funding for implementation projects, planning grants, targeted infusions, and more.[368] In FY 2009, the NSF provided about 20 grants totaling $10 million to the HBCU-UP. In addition, colleges can collaborate with HCBUs to improve minority representation. For example, a small college was able to increase representation in its graduate programs by partnering with a nearby HBCU, targeting likely-to-succeed undergraduates and educating them about the costs and benefits of a graduate degree. They also worked to build these students' confidence in performing research and hired mentors to provide the students with social and academic support. The partnering institutions also worked together to get accreditation for the HBCU's computer engineering program. These types of collaborations offer novel approaches to increasing minority representation in higher education.[369] The NSF's program Model Institutions for Excellence (MIE) also provided $3.4 million in funding to primarily minority-serving institutions to increase minority participation in STEM careers in 2003.[370] For Native Americans, the NSF's Tribal Colleges and University Program (TCUP) aims to enhance STEM instruction and bridge the digital divide.[371] Typical TCUP projects include "curriculum enhancement, faculty professional development, undergraduate research and community service, academic enrichment, and infusion of technology to enhance STEM instruction."[372] In FY 2009, the NSF planned to award four grants totaling $2 million.

Another pathway to higher education is through community colleges. Some minority students who are not prepared for college after high school or cannot obtain financing to attend a four-year institution may attend a community college. These students are not completely closed off from category 1 NIT careers because they can transfer to a four-year college. In 2001, NCES reported that only about 25 percent of students who began their studies at community colleges in 1989-90 transferred to four-year institutions by 1994. Minority students were the least likely to transfer.[373] The Mathematics Engineering Science Achievement (MESA) community college program aims to increase transfer rates for minority students.[374] In 2007, Casale et al. reported on the success of this program in California, where it succeeded in increasing the transfer rate for minority students from 15 percent to 95 percent.[375] Given this success, MESA and Hewlett-Packard (HP) implemented the program in six other states. At the same time that HP and MESA were expanding into six new states, three other states adopted similar programs with guidance, but no funding, from HP and MESA. Another MESA program, the

[368] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5481
[369] Tolley (2002)
[370] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5739&org=OISE&sel_org=OISE&from=fund
[371] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5483
[372] http://www.nsftcup.org
[373] NCES (2001), p. 22
[374] http://www.ucop.edu/mesa/programs/mesacccp.html
[375] Casale et al. (2007)

Engineering Program, also "provides support to educationally disadvantaged students at four-year institutions to attain engineering or computer science baccalaureate degrees."[376]

There are undoubtedly many more programs aimed at increasing minority students' access to education. This list covers some of the most prominent programs in a variety of areas. In addition to the programs outlined here, the NSF provides funding for broadening participation in STEM through the Alliances for Broadening Participation in STEM program (ABP)[377] and in NIT through the Broadening Participation in Computing (BPC) program.[378] In FY 2009, the NSF plans on awarding 20 ABP grants totaling $12.5 million, and 10 to 16 BPC grants totaling $14 million. At the Ph.D. and faculty level, the NSF's Alliances for Graduate Education and the Professoriate (AGEP) program aims to increase the number of minority Ph.D. recipients and minority faculty representation.[379] This program has been credited with increasing the number of minority science Ph.D. recipients between 2001 and 2008 by 34 percent.[380] In FY 2004, this program awarded three to six grants totaling $6 million. In addition, many of the STEM professional societies provide resources to increase the participation of minorities in STEM careers, for example, through the American Chemical Society's Scholars Program.[381]

3.2.3.2 The Digital Divide

The second major concern unique to minority representation in NIT careers is the differential access to technology often referred to as the digital divide. As discussed in the section on pathways to NIT careers, experiences with technology are important to developing an interest in and preparing for NIT careers. Access to technology is often measured through basic access to computers and the Internet. Despite increasing access to computers among all US households, the digital divide, while closing, persists as access to computers and the Internet are still strongly correlated with race.[382] According to data from the CPS, 46 percent of African American households and 37 percent of Hispanic households had Internet access in 2003. That is in contrast to 65 percent and 63 percent of white and Asian households, respectively, as shown in Table 3.6.

376 http://www.ucop.edu/mesa/programs/mesaep.html
377 http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13646
378 http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13510
379 http://www.agep.us
380 Lempinen (2009)
381 Bonetta (2009)
382 Marriott (2006)

Table 3.6: Internet Users by Gender and Race (2001, 2003)

	Internet Users (Percent)	
	2001	**2003**
Total Population	55.1	58.7
Gender		
Male	55.2	58.2
Female	55.0	59.2
Race		
White	61.3	65.1
African American	41.1	45.6
Asian Amer. & Pac. Isl.	62.5	63.1
Hispanic (of any race)	33.4	37.2

Source: US Bureau of the Census, CPS Supplements (September 2001 and October 2003)

These disparities are also evident in access to computers at home. Fairlie estimated that in 2000, 71 percent of white adults had a computer at home while only 41 percent of African American adults and 39 percent of Hispanic adults had a computer at home.[383] There is also a disparity in underrepresented minorities' access to computers at school: 64 percent of instructional rooms with 50 percent or more minority enrollment were connected to the Internet while 85 percent of instructional rooms with less than six percent minority enrollment were connected to the Internet.[384] The average number of students per computer was also higher in schools with large concentrations of minority students.[385] In addition, while the digital divide has been closing somewhat, inequity remains in skill development and benefits gained from computer access.[386] All of these disparities in access to technology impact the preferences and opportunities of minority students for NIT careers.

There are a number of initiatives underway to "bridge the digital divide." Most of these were created to address equity issues in society as a whole rather than for reasons specifically related to NIT careers. A number of federal government agencies have taken action to close the digital divide including the Departments of Agriculture, Commerce, Education, Health and Human Services, Housing and Urban Development, Justice, and Labor.[387] The Universal Service Administrative Company is the largest of these initiatives, funded through contributions made by telecommunications service providers. These funds are used to provide discounted service to areas/persons/organizations based on economic need and location.[388]

While a number of grass-roots organizations are working to bridge the digital divide in the United States, two of the most prominent national organizations are the Alliance for Digital Equity[389] and Connected Nation.[390] Connected Nation lists two initiatives for

[383] Fairlie (2004)
[384] Fairlie (2004), p.29
[385] Fairlie (2004), p.29
[386] DiMaggio and Hargittai (2001); Leigh (2002)
[387] Fairlie (2004), p. 1
[388] http://www.universalservice.org
[389] http://www.alliancefordigitalequality.org

bridging the digital divide: the No Child Left Online initiative does this "by placing computers in the hands of disadvantaged populations so that they have access to abundant technological resources and can perform basic computing functions," and the Computer 4 Kids program in Tennessee which has similar goals. A number of state programs are undertaking similar efforts including:

- Connect Kentucky[391]
- Connected Tennessee[392]
- Connect Ohio[393]
- Connect West Virginia[394]
- Connect Minnesota[395]
- Connect South Carolina[396]

In addition to these ongoing efforts, the Obama administration included funding to expand broadband access in the 2009 economic stimulus package. The spending bill called on the Federal Communications Commission (FCC) to create a national broadband plan to increase access and affordability by February of 2010.[397]

The Technology Access Foundation (TAF) is an example of a program targeted at bridging the digital divide beyond just increasing Internet access.[398] The mission of TAF is to prepare "underserved children of color for higher education and professional success by providing a rigorous and relevant K-12 curriculum." They do this through two main programs: TechStart, which provides after school training to K-8 students in STEM, and the TAF academy, which focuses on students in grades 6-12.

3.2.3.3 Perceptions and Role Models

While access to education and the digital divide are two unique factors affecting minority pathways to NIT careers, negative perceptions and a lack of role models are also important issues facing minority students. Both of these factors can lead minority students to become discouraged about their prospects for success in NIT careers. A number of programs have been created to address these issues.

Many minority students are still embroiled in what Claude Steele referred to as the "stereotype threat."[399] That is, they are threatened by the stereotype that suggests that they

[390] http://www.connectednation.org
[391] http://www.connectkentucky.com
[392] http://www.connectedtennessee.org
[393] http://www.connectohio.org
[394] http://www.connectwestvirginia.org
[395] http://www.connectmn.org
[396] http://www.connectsc.org
[397] Kang (2009)
[398] http://www.techaccess.org
[399] Steele and Aronson (1995); Steele (1997); Steele (1998)

will not perform well in certain subjects. Negative stereotype threats are compounded by a lack of counterfactual evidence. With respect to pathways to computer science, the extremely limited number of African American and Hispanic computer scientists and the limited exposure students have to them contributes to the cycle of poor preparation, poor performance, and low expectations. The engineering disciplines have developed a roadmap informed by nearly 30 years of experience to address this problem and have engaged an increasingly large number of students in the effort through organizations such as the National Society of Black Engineers and the Society for Hispanic Professional Engineers.[400]

The computing community has also undertaken efforts to provide support and role models through a variety of different programs. One of the most prominent programs is the Richard Tapia Celebration of Diversity in Computing Conference, held annually with the goal of "providing a supportive networking environment for under-represented groups across the broad range of computing and information technology." [401] The Tapia conference includes a technical program of seminars and presentations, a robotics competition, and several networking events. Another organization actively involved in trying to diversify the NIT workforce is the Coalition to Diversify Computing.[402] This organization undertakes a number of diversification efforts through collaborations with other organizations such as the CRA-W. Its focus is on diversifying the NIT student body at the graduate level. Many programs with similar goals exist at universities across the United States, although there are too many to list in this report. One example of this type of program is Texas A&M's Computing Sciences and Alliance for Minority Participation Program.[403]

A number of broader diversity programs also aim to help individuals already in the NIT workforce. Black Data Processing Associates (BDPA) supports a number of programs providing technical training, mentorship, and a variety of other resources to minorities in the IT industry.[404] The Career Communications Group is a consulting firm providing corporations with advice on diversity programs, especially for STEM workers.[405] Although not focused directly on the NIT workforce, the INROADS program has a mission of developing and placing minority youth in business.[406] In addition, most NIT employers have diversity programs, such as the MITRE Corporation,[407] Northrop Grumman,[408] Microsoft,[409] and Oracle,[410] among others.

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[400] George (2001)
[401] http://tapiaconference.org
[402] http://www.cdc-computing.org
[403] http://csamp.wordpress.com
[404] http://www.bdpa.org
[405] http://www.ccgmedia.com
[406] http://www.inroads.org
[407] http://www.mitre.org/employment/diversity.html
[408] http://www.northropgrumman.com/corporate-responsibility/diversity/
[409] http://www.microsoft.com/about/diversity/default.mspx
[410] http://www.oracle.com/corporate/community/workforce/diversity.html

3.3 Persons with Disabilities

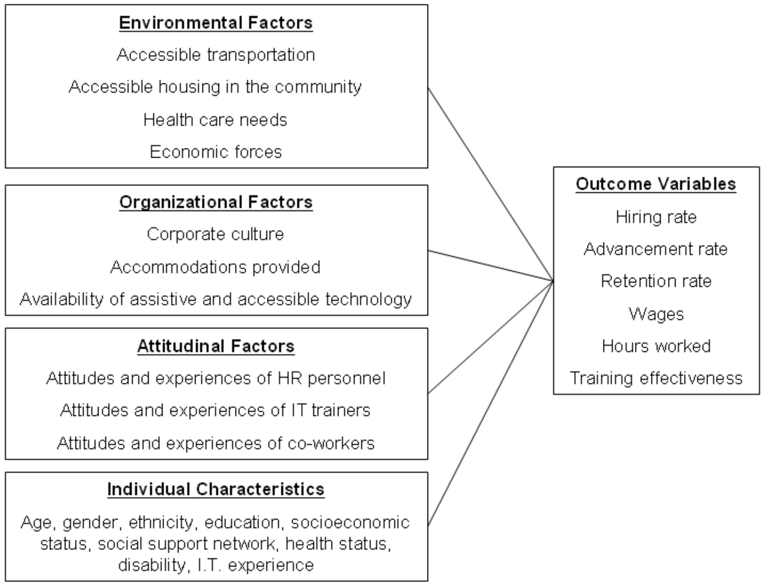
Persons with disabilities are underrepresented at all levels of the NIT career pipeline relative to their representation in the population. According to the Census Bureau, in 2000, persons with disabilities comprised 20 percent of the US population.[411] In 2004, persons with disabilities comprised 5.5 percent of the science and engineering workforce and 4.6 percent of workers in the field of computer and information science.[412] The representation of persons with disabilities in NIT-related fields is lower than both their representation in the population and across all S&E fields.

In 2004, at the undergraduate level, 13 percent of students enrolled in computer/information sciences programs were persons with disabilities. While this is lower than the representation of persons with disabilities in the population, it is the highest level of representation among S&E fields at the undergraduate level. At the doctoral level, the number of CS degree recipients in 2004 was much lower at one-half of one percent. This is lower than the average rate for all S&E degrees (one percent) and is around the same rate as for many engineering degrees (including electrical engineering) which have the lowest rate of representation for persons with disabilities.[413]

The literature on barriers facing persons with disabilities for NIT careers is limited. In 2002, Schartz et al. reviewed the literature on barriers to IT careers for persons with disabilities.[414] These barriers include factors such as accessible transportation, attitudes of firm personnel, and available technologies. Based on the empirical literature, the authors conceptualized the theoretical model of the factors that affect the IT job prospects of persons with disabilities shown in Figure 3.15.

[411] http://factfinder.census.gov/jsp/saff/SAFFInfo.jsp?_pageId=tp4_disability
[412] NSF (2007)
[413] NSF (2007)
[414] Schartz et al. (2002)

Figure 3.15: Theoretical Model of Factors Affecting NIT Job Prospects of Persons with Disabilities



Source: Schartz et al. (2002)

Schartz et al.'s review of the literature found that managers' lack of knowledge about the requirements and cost of providing accommodations and about the differences among types of disabilities is a major factor affecting the job prospects of persons with disabilities. Additionally, the lack of role models and knowledge about legal requirements prevents workers from perceiving the possibility of working in an IT career. Schartz et al. recommended tax policy as an overlooked incentive for IT firms to hire IT workers.

Overall, Schartz et al. found the research in this area to be sparse and pointed to the most significant work in this area in the "IT Works" program at the University of Iowa.[415] This program, funded by the Department of Education, takes a longitudinal, interdisciplinary approach to understanding the dynamics of the IT labor market for persons with disabilities. Chapple et al. reviewed 26 IT training programs targeting disadvantaged persons (including persons with disabilities) and found some commonalities among successful programs such as providing soft-skills training and keeping pace with changes in industry.[416] Together with the IT Works program, in 2003 the ITAA launched the IT Works Ability Awards, a national awards program recognizing IT firms that have developed effective strategies to promote the employment and advancement of people with disabilities.[417] It is unclear whether this program still exists. The literature on persons with disabilities in IT has remained relatively sparse since the early 2000s.

There are a number of programs to increase the participation of persons with disabilities in IT careers, although most focus on all career areas. The University of Washington's Disabilities, Opportunities, Internetworking, and Technology (DO-IT) program runs a

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[415] http://disability.law.uiowa.edu/itworks/
[416] Chapple et al. (2000)
[417] http://www.itaa.org/policy/competitiveness/headline.cfm?ID=495

one-week summer camp for children with disabilities to learn more about technology. The program emphasizes a one-to-one ratio of students to facilitators.[418] The International Association of Jewish Vocational Services provides computer-based training to persons with disabilities through its disAbility Employment Initiative.[419] The Job Accommodation Network at West Virginia University provides persons with disabilities with information on job accommodations, entrepreneurship, and related subjects.[420]

In addition, a number of employers support persons with disabilities, for example, IBM's programs called Project Able, Project View, and Entry Point.[421] While other programs focusing on persons with disabilities in IT careers likely exist, it is difficult to identify specific programs focused on this issue because the programs are usually embedded in larger programs focusing on workers with disabilities more generally. The ACM has a special interest group focused on IT and persons with disabilities, although this group is focused more on utilizing technology to assist persons with disabilities than it is on disabled persons in the NIT workforce.[422]

3.4 Lessons from Other Fields

Diversity initiatives are being undertaken across the workforce. Many of these do not target specific professions but the workforce as a whole, for example:

- The DiversityJobs.com network provides forums, blogs, and news on diversity in the workforce.[423]
- The Workforce Diversity Network is "dedicated to professional development, understanding, promotion, and management of diversity as an essential part of business success."[424]
- Equal Opportunity Publishers publishes career magazines for women, minorities, and persons with disabilities.[425]

While there are many more organizations targeting diversity throughout the workforce, we choose instead to focus on examples of successful programs in specific career fields that could provide lessons for NIT. Relevant fields range from nursing to law.

The field of nursing provides some examples of diversity efforts that may be applicable to NIT. Nursing experiences an underrepresentation of men rather than women. About five percent of registered nurses in the United States are men. In response to such low levels of representation, the American Assembly for Men in Nursing have organized conferences and award ceremonies, and they host a website with links to resources.[426]

418 http://www.washington.edu/doit
419 http://www.iajvs.org/services/disabilities.htm
420 http://www.jan.wvu.edu
421 http://www-03.ibm.com/able/access_ibm/execbrief.html#providing
422 http://www.sigaccess.org
423 http://network.diversityjobs.com
424 http://www.workforcediversitynetwork.com
425 http://www.eop.com
426 http://www.aamn.org

They also produced a video entitled "Career Encounters: Men in Nursing."[427] These programs provide examples of gender image initiatives that might be applicable to NIT, although there have been few assessments of the impact of such programs. Beyond gender disparities, MinorityNurse provides scholarships and links to resources for both men and underrepresented minorities.[428] Similar websites already exist in NIT fields. As in the NIT field, non-traditional educational institutions such as the Excelsior College of Nursing claim to be better at developing a diverse student body than their traditional counterparts.[429] Leveraging these non-traditional institutions to increase diversity is something that is not widespread in any of the career fields we examined. There are also a number of groups providing funding for minorities and men to pursue nursing careers, many specifically targeted at increasing the number of underrepresented faculty.[430] Many of these organizations reach out to America's youth through "schools, counselors, youth organizations, and other outlets to encourage a more diverse population of nursing students."[431] Specific programs target guidance counselors and target middle school children through career days and high school students through shadow days.[432] There is much concern in nursing outreach about the need to target students at a young age. While we have seen this concern raised a few times in the NIT literature, it is not as prominent. Coupled with the lack of literature on NIT career pathways before college, this appears to be an area where future focus might be warranted.

Minorities and women are underrepresented in medicine as they are in NIT occupations. However, the representation of women in medicine has increased over time. According to BLS data, women comprised 16 percent of the physician workforce in 1983 and that fraction grew to 31 percent by 2008. African Americans and Hispanics comprised five and four percent of the physician workforce in 2008. A number of initiatives have been undertaken to increase the representation of both women and minorities in medicine. For minorities, the Association of American Medical Colleges (AAMC) has set up a website to provide resources and best practices for increasing minority participation in medicine.[433] We saw similar websites in nearly every career field we examined. Daley et al. reviewed a number of programs that they categorized as successful in increasing minority faculty participation.[434] They found that areas important to success include mentoring, providing an environment conducive to success, and sustaining support. All of these are areas we have seen mentioned in diversity programs for NIT careers. In 2005, the AAMC and the American Dental Education Association (ADEA) announced a joint effort to increase diversity by providing a summer enrichment program for minority undergraduates planning to pursue medical or dental careers.[435] We have seen that there are a variety of similar NIT programs at both the high school and undergraduate level.

[427] http://www.davisgrayinc.com/page6/page10/page10.html
[428] http://www.minoritynurse.com
[429] Excelsior (2007)
[430] http://www.aacn.nche.edu/Diversity/index.htm
[431] Goodin (2003)
[432] Goodin (2003)
[433] http://www.aamc.org/diversity/aspiringdocs/start.htm
[434] Daley et al. (2008)
[435] http://www.aamc.org/newsroom/pressrel/2005/050302.htm

Although there are many other initiatives to increase diversity in medicine, none stand out as particularly informative to NIT.

The legal profession is another field in which both women and minorities are underrepresented and initiatives might provide insights for NIT. In 2008, 34 percent of lawyers were women, five percent were African American, and four percent were Hispanic. In 2005, Parker outlined five reasons why women and minorities are underrepresented in the legal profession, including: insufficient aspiration and knowledge of the possibilities offered by a legal career, high school and college preparation that is inadequate for law school entrance and success, poor performance in law school (a lack of "persistence"), and low bar passage rates.[436] Parker argued that efforts to increase diversity need not be that costly and can include simple things such as:

- donations of used law books and replaced computers;
- inviting high school students to visit the law school campus for a day of law school classes designed for them and lunch in the law school cafeteria;
- a similar visit to the college campus;
- a weekly one hour law student mentoring program;
- a speakers program, taking advantage of previously scheduled law school events and volunteer alumni presentations;
- periodic receptions and visioning sessions for high school teachers and mentors;
- a monthly Saturday seminar at local law firms and courts.

In addition to programs such as these that are organized at the university level, there are a variety of scholarship programs for minority students.[437] Most of the programs and initiatives to increase the diversity in the legal profession that we examined were similar to those found in other career fields, such as scholarships, mentorship, and social support networks.

Overall, we find that diversity efforts in NIT are very similar to diversity efforts in other career fields. There are very few programs and initiatives in other fields that stand out as novel approaches that could be applied in NIT. In regard to minorities, many of the issues related to disparities in K-12 education affect all career fields including NIT. Therefore, it is no surprise that many of the efforts undertaken to increase minority participation are similar across career fields. Gender disparities remain in many professions, although to a greater extent in NIT than in medicine or law. In nursing, gender disparities are reversed and even more substantial than in NIT despite many efforts. As in NIT, gender roles and perceptions appear to be one of the major factors affecting these disparities in all occupations. While efforts have been undertaken to provide a more balanced gender image in many of these professions, long-standing stereotypes remain.[438]

[436] Parker (2005)
[437] http://www.wcl.american.edu/outsidescholarships/diversity.cfm
[438] White and White (2006)

4. INTERNATIONAL COMPARISONS

The final section of this report focuses on comparing the NIT workforce in the United States to the NIT workforces of its current and future global competitors. The countries/regions chosen as competitors include the European Union, Japan, South Korea, Singapore, Taiwan, China, and India. While these are not all of the US competitors, they comprise a large fraction of the global NIT workforce. We also include information on a few other countries where there are unique aspects of their workforces that are relevant to the United States.

Consistent data on the NIT labor force outside of the United States are lacking. The data that are available are either at too high a level of aggregation or not consistent with our definition of the category 1 NIT workforce. Discussions of programs and initiatives focused on NIT at the country level are more readily available, although they often do not describe levels of funding. The literature in areas relating to NIT pathways, career choice, and expansion of other scientific disciplines is missing for all of the countries studied. This section begins by making comparisons of the size of the NIT labor force across various countries. The remaining sections characterize the NIT workforce in each country and outline programs and initiatives undertaken by those countries.

4.1 Cross-Country Trends

This section compares workforce trends among the countries we studied. While much of the available data are not consistent across countries, a few sources provide useful comparisons.

4.1.1 Size of the NIT Workforce

We begin by attempting to estimate the size of the NIT workforce in the countries chosen for this study, using a number of different sources.

4.1.1.1 International Labor Organization

The International Labor Organization (ILO) attempts to collect consistent labor force data across countries. The ILO utilizes the International Standard Classification of Occupations (ISCO-88). This classification system has major groups, sub-groups, and minor groups. In order to achieve a high level of consistency, the ILO labor market data are only available at the level of major groups. The two major groups that include NIT occupations are Major Group 2: Professionals, and Major Group 3: Technicians and Associate Professionals. The relevant NIT groups, sub-groups, and minor groups are:

- Major Group 2: Professionals
    - Sub-group 21: Physical, mathematical, and engineering science professionals
        - Minor group 213: Computing professionals
- Major Group 3: Technicians and associate professionals
    - Sub-group 31: Physical and engineering science associate professionals
        - Minor group 312: Computer and associate professionals

Although the ILO data do not allow us to break out NIT occupations, the data provide a general sense of the size of the professional labor force in the countries of interest. Table 4.1 shows the number of workers in Major Groups 2 and 3 for many of the countries studied. Data are not available for China, India, and Taiwan.

Table 4.1: ILO Labor Force Estimates

Rank	Country	Groups 2&3 (thousands)	Per Million Inhabitants
1	United States	30,872	102
2	Japan	14,350	113
3	Germany	13,700	166
4	France	7,966	124
5	United Kingdom	7,825	128
6	Italy	7,289	125
7	Spain	5,063	125
8	South Korea	4,641	96
9	Poland	4,161	108
10	Sweden	1,770	196
18	Israel	926	130
19	Finland	872	166
22	Ireland	645	155
23	Singapore	631	137
-	China	n/a	n/a
-	India	n/a	n/a
-	Taiwan	n/a	n/a

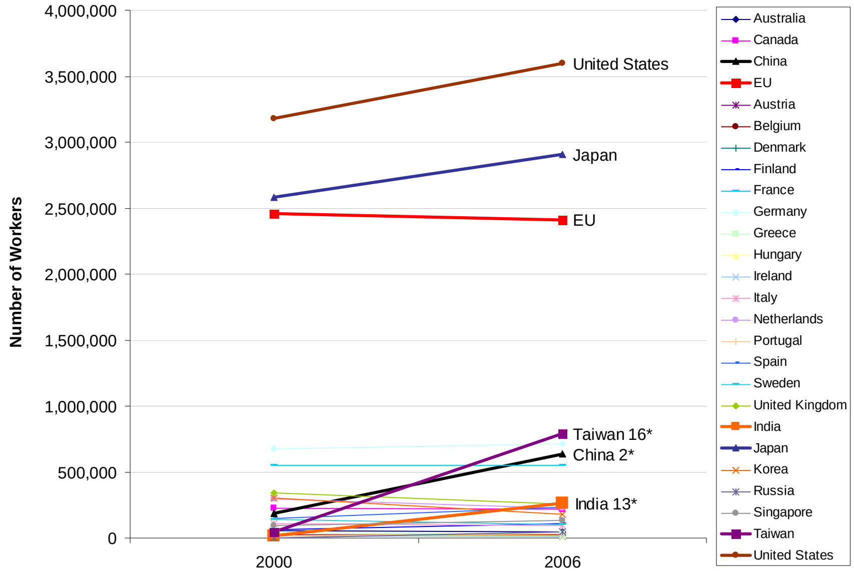
Source: International Labor Organization and CIA World Factbook

The United States has the largest professional and technical labor force, followed by Japan and Germany, each with about half as many workers as the United States. Countries with the largest number of professional and technical workers per capita include Sweden, Germany, and Finland. The ILO data are not very useful for making inferences about the size of the NIT workforce. Our estimate for the size of the category 1 NIT workforce in the United States represents only about 10-15 percent of the professional and technical workforce in the United States estimated by the ILO. Therefore, in order to get a better picture of the global NIT workforce, we must look to other estimates.

4.1.1.2 OECD Estimates for Employment of Top 250 ICT Firms

Another source that can provide insights about the relative size of the global NIT labor force is employment data collected by the OECD for the Top 250 ICT firms. The OECD compiled employment data for these firms by country in 2000 and 2006. Figure 4.1 compares the employment estimates for each of the countries represented in the OECD data. These estimates capture both NIT and non-NIT workers in the top 250 ICT firms, which makes it difficult to compare these estimates to those for the NIT workforce. Nonetheless, it allows us a consistent metric to use to compare countries.

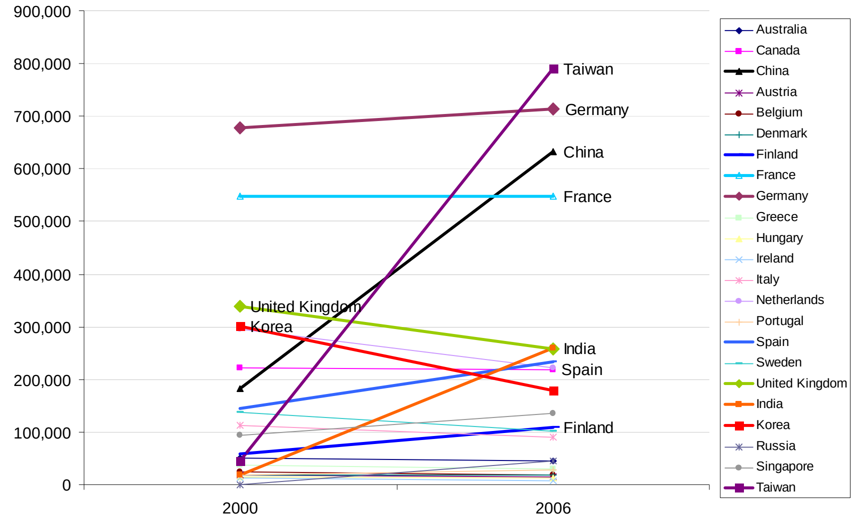
Figure 4.1: Employment in Top 250 ICT Firms (2000, 2006)



Source: OECD (2008)

The United States has the largest number of workers in the top 250 ICT firms, with more than 3.5 million workers in 2006. Next are Japan, with almost three million workers, and the EU with about 2.5 million. The declining number of workers in the EU is possibly due to a shift in the types of ICT firms employing NIT workers, rather than a real decline in the number of workers. Between 2000 and 2006, the three countries with the fastest growing number of workers in the top 250 ICT firms are Taiwan (a 16-fold increase), India (a 13-fold increase), and China (a 2-fold increase). Figure 4.2 shows the same data excluding the United States and Japan, and breaking out the EU data by country. In this figure we see a significant increase in the Taiwanese, Indian, and Chinese workforces in the top 250 NIT firms. We also observe declines for some countries that are likely due to a shift in the composition of the NIT workforce rather than a real decrease in the size of the NIT workforce. It is important to note that small countries with large ICT firms will be overrepresented in these numbers.

Figure 4.2: Employment for Smaller Countries in Top 250 ICT Firms (2000, 2006)

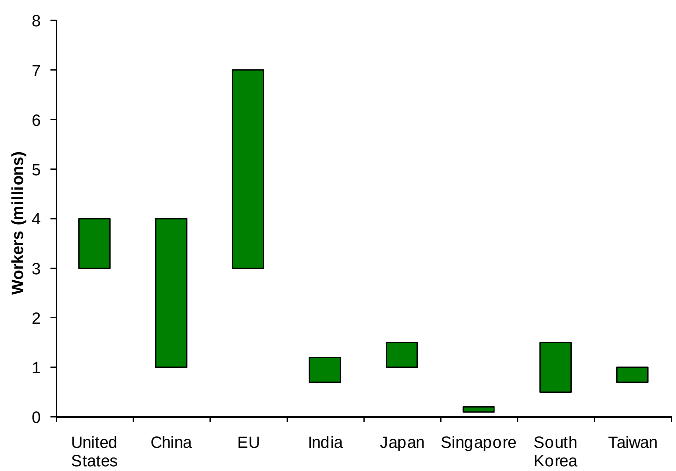


Source: OECD (2008)

4.1.1.3 Comparison of Country-Specific Estimates

We compiled labor force data from a variety of different country-specific sources for each country included in this study. Using these data, we estimate a range for the size of each country's NIT workforce, as shown in Figure 4.3. Each estimate is based on a compilation of country-specific estimates utilizing different definitions of the NIT workforce. The estimate for the United States ranges from the OES estimate of 2.8 million to the CPS estimate of 3.5 million. Estimates for other countries are discussed in the following sections.

Figure 4.3: Global NIT Workforce Range Estimate Comparisons



It is clear from this figure that the United States has a NIT workforce larger than any but the EU's. The EU NIT workforce is estimated to be between 6.5 and 7.5 million, but this estimate is inclusive of both category 1 and 2 workers. Therefore, the EU category 1 NIT workforce is likely significantly smaller, possibly even smaller than that of the United States. While estimates for the size of China's NIT workforce range as high as four million, this appears to be inclusive of both category 2 NIT workers and IT-enabled workers. The category 1 NIT workforce in China is likely much smaller. Table 4.2 shows the sources and estimates used to derive the range estimates above.

Table 4.2: Comparison of Country-Specific Estimates for NIT Workforce Size (Millions of Workers)

Country/Region/Definition	2001	2002	2003	2004	2005	2006	2007	2008	Range Estimate	Source
United States									**2.8 - 3.5**	
NIT Category 1 Workforce	3.28	3.05	3.21	3.17	3.26	3.34	3.53			Current Population Survey
NIT Category 1 Workforce	2.33	2.30	2.38	2.60	2.60	2.66	2.76			Occupational Employment Survey
NIT Category 1 Workforce			2.28			2.42				SESTAT
China									**1.0 – 4.0**	
ICT workforce			4.10							World Bank (2004)
Software Services			0.60							World Bank (2004)
Manufacturing			3.50							World Bank (2004)
Software Services					0.75					NRC (2008)
EU									**3.0 – 7.0**	
ICT specialists (narrow)							6.69			OECD (2008)
IT employment							7.43			EITO and Eurostat (2007)
India									**0.7 – 1.2**	
IT Software and Services	0.36	0.42	0.49	0.59	0.70			1.2		NASSCOM
Software Export			0.26	0.51		0.71				NRC (2008)
VLSI Engineers					0.01					NRC (2008)
Japan									**1.0 – 1.5**	
ICT workers in big firms							0.70			METI (2008)
Employment in ICT Sector	4.03	3.82	3.77	3.78	3.78	3.85				MIC (2008a)
Software Engineers								1.00		MIC (2008b)
Singapore									**0.1 - 0.2**	
ICT workforce				0.11	0.11	0.12	0.13			IDA (2007)
South Korea									**0.5 – 1.5**	
ICT workers	1.20	1.30	1.37	1.38	1.39	1.41				KAIT (2006)
Taiwan									**0.3 – 0.7**	
ICT workers								0.72		TIER (2009)

There are no projections for the size of the global NIT workforce available across all countries. Some countries make their own projections but these data usually use varying definitions and cover differing periods of time.

4.1.2 Other Global Workforce Trends

A 2008 report by the Computing Technology Industry Association (CompTIA) explored worldwide trends in the IT workforce. The report found that global IT managers are "bullish" about the growth of the IT workforce, with the majority saying that they expected the number of IT employees on their staff, in their country, and worldwide to increase over the next five years. Many managers expressed that there were not enough qualified IT candidates in the country in which they worked. Managers in Russia, Poland, Japan, and South Africa were more likely to point to shortages while managers in the United States, Italy, and India were more likely to say that there were more than enough qualified IT workers in their country. CompTIA created an index of confidence in the IT job market by country using individual survey responses. This index is shown in Table 4.3.

Table 4.3: CompTIA (2008) Worldwide IT Job Market Confidence Index

Rank	Country	Category
1	India	Emerging
2	China	Emerging
3	Russia	Emerging
4	Poland	Emerging
5	South Africa	Emerging
6	Japan	Established
7	United States	Established
8	Canada	Established
9	Australia	Established
10	Italy	Established
11	United Kingdom	Established
12	Germany	Established
13	Netherlands	Established
14	France	Established

Source: CompTIA (2008)

IT managers in India and China were the most bullish about their IT job markets, followed by Russia, Poland, and South Africa. The United States ranked seventh in this index. These rankings were consistent with a dichotomy created by CompTIA based on common survey responses that labeled India, China, Russia, Poland, and South Africa as emerging NIT countries and the remaining countries as having established IT workforces. IT managers from emerging countries were more optimistic about IT workforce growth than those in established countries.

4.1.3 Students Pursing Degrees Abroad

In 2005, over 2.7 million college and university students worldwide were enrolled in institutions outside of their country of citizenship, a 4.9 percent increase from 2004.[439] About half of these students attended schools located in the United States, France, Germany, and the United Kingdom; 21 percent attended schools in the United States. Earlier sections of this report discussed the fraction of foreign students enrolled in US NIT programs but did not address US students enrolled in NIT programs abroad. Unfortunately, this information is not available. However, the OECD estimates the number of students from each country enrolled abroad in all degree programs. In 2005, 38,672 US citizens were enrolled in tertiary (education following secondary/high school) institutions abroad. US students pursuing degrees abroad tend to attend institutions in English-speaking countries. The largest proportion of US citizens enrolled abroad (37 percent or 14,385 students) were enrolled in schools in the United Kingdom (UK). Other popular destinations for US institutions included Germany (9 percent) and Australia (8 percent). Table 4.4 shows the number of US students studying abroad by destination. Data are not available by destination country for most non-OECD countries.

[439] OECD (2007)

Table 4.4: US Students Pursing Degrees Abroad by Country of Destination (2005)

Destination Country	Number of US Students	Fraction of US Students
United Kingdom	14,385	37%
Germany	3,363	9%
Australia	3,226	8%
France	2,429	6%
Ireland	2,168	6%
New Zealand	2,077	5%
Japan	1,552	4%
Korea	371	1%
China	N/A	N/A
India	N/A	N/A
Singapore	N/A	N/A
Taiwan	N/A	N/A

Source: OECD (2007)

The United States sends fewer students abroad for degrees than many of the other countries studied in this report.[440] China sends the most students to study abroad- more than 404,664 students in 2005; 23 percent of these Chinese students were studying in the United States. Table 4.5 lists the number of students studying abroad and in the United States for each of the countries studied in this report and a selection of EU countries.

Table 4.5: Students Pursuing Degrees Abroad by Country of Origin (2005)

Country of Origin	Students Studying Abroad	Number Studying in US	Fraction Studying in US
China	404,664	92,370	23%
India	139,223	84,044	60%
Korea	96,423	55,731	58%
Germany	66,811	9,024	14%
Japan	62,853	44,092	70%
France	53,868	6,847	13%
United States	38,672	-	-
United Kingdom	21,847	8,602	39%
Singapore	19,162	3,937	20%
Taiwan	N/A	N/A	N/A

Source: OECD (2007)

The data presented above are not available by degree field. However, the OECD tracks degree fields by destination country. Finland is the most attractive destination for foreign students studying for degrees in sciences, agriculture, engineering, manufacturing, and construction; 40 percent of students studying in Finland in 2005 were pursuing degrees in these fields. In the United States, 34 percent of foreign students were studying for science and engineering degrees while 31 percent were studying for degrees in the social sciences, business, and law.[441]

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[440] There is little data on students who study abroad for only part of their degree programs (6-12 months), although it is likely that the US would rank higher in this category.
[441] OECD (2007), p. 311

4.2 Country-Specific Trends and Initiatives

Most international NIT labor force information is available at the country level. The following sections present trends in the NIT workforce and programs and initiatives being undertaken to strengthen the NIT workforce in the countries selected for this study.

4.2.1 European Union

The Information and Communications Technology (ICT) market (analogous to NIT) in the EU grew at a rate of 4.3 percent in 2007, to 763 billion euro, and was expected to grow by about three percent annually in 2008 and 2009.[442] Due to the economic downturn, in late 2008 the European Information Technology Observatory (EITO) decreased projected growth for 2009 from three to two percent. The EU countries with the highest growth rates in 2007 were Spain at 4.6 percent and France at 3.2 percent. The major sectors of ICT growth in the EU are projected to be notebooks (projected 9.9 percent growth in 2008), Internet access and services (10.7 percent projected growth), and mobile data services (11.1 percent projected growth). The main products driving ICT growth across the EU are flat-screen televisions, game consoles, and navigation devices.[443] Due to this sustained growth in the ICT industry, there has been a strong demand for NIT workers in the EU.

The EU uses the term “e-skills” to refer to the knowledge and aptitude needed to use ICT in daily life. Thus, e-skills are seen as a critical issue in the establishment of the future European “Information Society” and in developing the ICT workforce. This is especially important in the context of the European Information Society 2010 (i2010), which links ICT-related activities at the European Commission (EC) with the broad Lisbon Agenda on increasing EU competitiveness.

In 2002, the EC held a European E-Skills Conference in Copenhagen. The conference integrated themes and concerns raised in several independent study groups and initiatives on the future of the European ICT industry. At the conference, the EC initiated the formation of the “E-Skills Forum,” which organized a conference in 2004 to construct a long-term strategy for addressing ICT-related workforce issues. This activity culminated in a September 2007 Communication from the European Commission titled, “E-Skills for the 21st Century: Fostering Competitiveness, Jobs & Growth.”[444]

The 2007 Communication identified five key challenges in meeting the e-skills needs of the EU for the future:

- A lack of recognition of the coming shortage of ICT workers;
- The lack of a cohesive, EU-wide approach to e-skills;

[442] EITO (2008)
[443] EITO (2008)
[444] Commission of the European Communities (2007)

- The image problem of ICT as a profession, and the decline in the supply of highly skilled ICT workers;
- The insufficient coordination and cooperation between formal (university-based) ICT education and industry-based training;
- The general persistence of “digital illiteracy.”

In its analysis of the e-skills situation in Europe, the EC has identified three broad categories of e-skills:

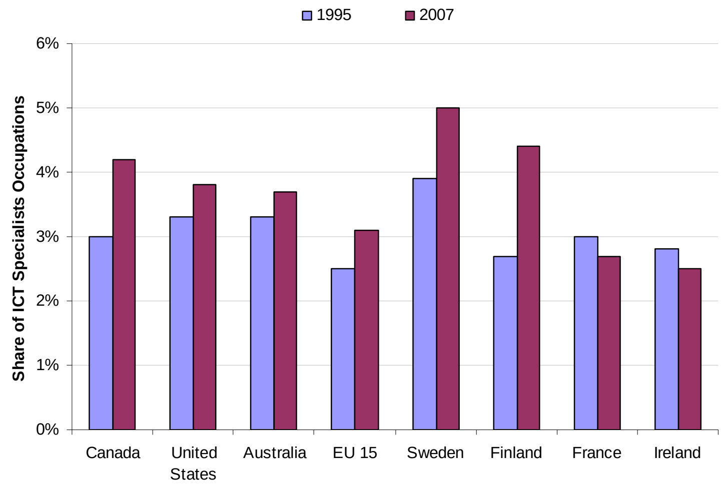
- ICT user skills, referring to skills needed by citizens who do not make a living from ICT work;
- ICT practitioner skills (called “ICT specialists” by the OECD), referring to skills used by professionals in ICT-intensive occupations (skills for IT workers);
- “E-business” skills, referring to the capacity of businesses to use ICT to improve their operations and competitiveness (skills for IT-enabled workers).

This section discusses the perceived crisis in the European ICT workforce, and the steps being taken by the EC and individual European national governments to deal with that crisis.

4.2.1.1 NIT Workforce Trends

The EU compiles very little data on the NIT workforce. While the Eurostat Labor Force Survey provides good information on the EU workforce at an aggregate level, it does not provide much useful information by occupation. The best comparative data on this issue comes from the OECD, which calculates the share of ICT occupations in the economy for the EU countries in the OECD. Figure 4.4 shows these percentages in 1995 and 2007 for each of the OECD countries.

Figure 4.4: Share of ICT Specialists Occupations in the Total Economy, Narrow Definition, 1995 and 2007



Source: OECD (2008)

In 2007, the EU 15[445] had a lower share of NIT workers than Canada, the United States, and Australia. Sweden and Finland have seen the largest increase in the share of NIT professionals from 1995 through 2007, while France and Ireland are the only two OECD countries to have their share decrease over this time period. These data show that the United States ICT workforce comprises about 3.8 percent of the total workforce. Using the CPS data, we calculated this fraction to be about 2.4 percent. Therefore, it appears that the narrow definition of an ICT worker used by the OECD may still be broader than the definition of the category 1 NIT worker used in this report.

We used the fractions above together with the OECD workforce data to estimate the size of the ICT workforce in the EU. We were only able to do this for EU countries that are in the OECD. We calculated the number of ICT workers in EU OECD countries to be about 6.7 million. We also calculated another estimate using total EU employment data provided in the Eurostat database and an estimate by the European Information Technology Observatory (EITO) that the IT sector represented 3.4 percent of all EU employment in 2007.[446] This led to an estimate of NIT employment in the EU of 7.4 million. However, as we discussed earlier, this definition is likely broader than the definition of the category 1 NIT workforce used in this report. Kolding and Kroa projected the size of the EU *networking* labor force in 2008 to be about 1.2 million.[447] Given that the NRC estimated the size of the category 2 NIT labor force to be twice as large as the category 1 labor force,[448] we estimate a wide range for the category 1 NIT labor force in the EU ranging from three to seven million. There are no data available breaking out the EU ICT workforce by sector or by citizenship requirement.

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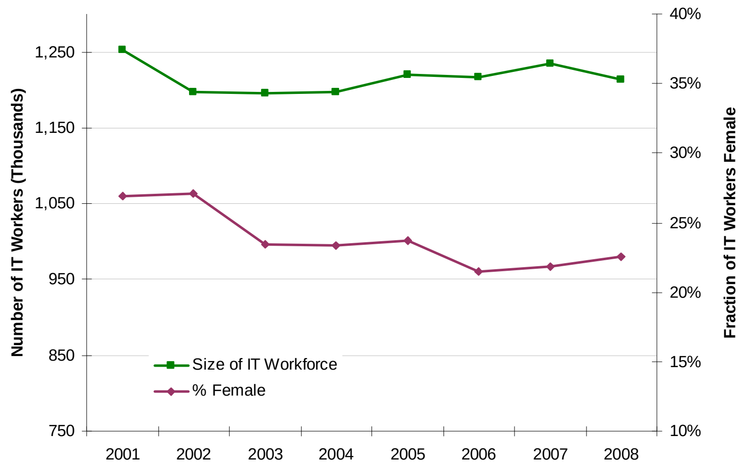
[445] This includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
[446] Tovar-Caro (2009)
[447] Kolding and Kroa (2005), p. 7
[448] NRC (2001)

The UK has one of the largest IT workforces of any EU country. Data on the IT workforce in the UK and the underrepresentation of women are available in a report co-authored by the UK Department for Business Enterprise and Regulatory Reform.[449]
Figure 4.5 shows the size of the UK IT workforce and the percentage of women in the IT workforce from 2001 through 2008. The size of the UK IT workforce declined slightly from 1.25 million in 2001 to 1.2 million in 2008, an average annual rate of decline of 0.4 percent.

Figure 4.5: UK IT Workforce and Female Representation (2001-2008)

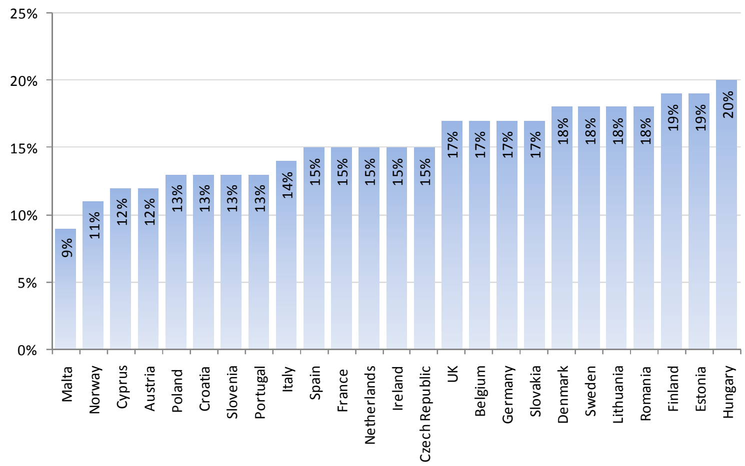


Source: Department for Business Enterprise and Regulatory Reform et al. (2009)

Like in the United States, female representation in the UK IT workforce is low. It decreased from about 27 percent in 2001 to 23 percent in 2008. Women in the UK are underrepresented to an even greater degree among computer engineers (two percent) than in other IT occupations. Colley et al. described some of the prevailing reasons for women's underrepresentation in the UK, which are similar to those for the United States.[450] In 2007, women's representation in ICT occupations across Europe was lower than in the United States, as shown in Figure 4.6.

[449] Department for Business Enterprise and Regulatory Reform et al. (2009)
[450] Colley et al. (1994)

Figure 4.6: Labor Market Representation of Females in ICT Occupations within Selected European Countries (2007)[451]



Source: Department for Business Enterprise and Regulatory Reform et al. (2009)

Many of the reasons for underrepresentation of women in NIT careers in other countries are the same as those discussed for the United States. Two studies published in the early 1990s discussed the role of computer anxiety among women in Spain and Australia.[452] Other concerns raised in Western countries are the underrepresentation of women in the higher levels of IT and overrepresentation in the lower levels.[453]

Many NIT workers in the EU are foreign. While estimates of the number of immigrant NIT workers in the EU do not exist, there is evidence that immigrants are a significant source of high-skilled talent. For example, the fraction of immigrant workers with at least a tertiary education in the EU (25 percent) is close to that in the United States (30 percent).[454] The EU is also undertaking efforts to expand high-skilled migration. A 2004 EU report titled *E-Skills for Europe: 2010 and Beyond* recommended that the EC undertake "efforts to maintain and enhance the attractiveness of the European Union for inward investment and inward migration of high-tech workers" as part of developing a long-term strategic approach to the ICT sector.[455] One of the most significant EU proposals to attract high-skilled workers is a proposal for a "blue card" that would create a single application procedure for high-skilled non-EU workers to reside and work within the EU.[456] The proposal aims to attract up to 20 million highly skilled workers from outside the EU.[457] Currently, EU countries have differing policies towards foreign workers, with most requiring labor market "tests" before issuing work visas. Salt et al.

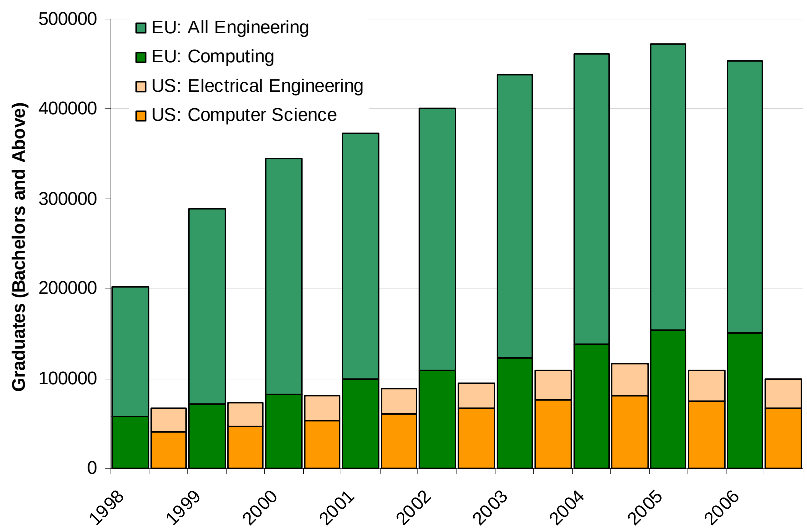
[451] Fraction of Women in ICT occupations in the UK differs from earlier estimate due to use of different datasets for UK and EU-wide comparisons in Department for Business Enterprise and Regulatory Reform et al. (2009)
[452] Farina et al. (1991) and Okebukola et al. (1993)
[453] Panteli et al. (2001), Tijdens (1997)
[454] Lowell (2008)
[455] European E-skills Forum (2004)
[456] Cerna (2008)
[457] http://ec.europa.eu/prelex/detail_dossier_real.cfm?CL=en&DosId=196320

(2004) noted that these tests are often abbreviated or ignored for highly skilled workers, "especially in ICT."[458]

4.2.1.2 Supply of NIT Graduates and Workers

The EC provides estimates of the number of graduates by level of education and degree field going back to 1998 for all countries in the EU. We extracted data covering graduates from levels five and six of the International Standard Classification of Education (ISCED), which covers all tertiary education. Unfortunately, the fields of study in the EU data do not correspond directly to those for the US data. The two NIT-related fields of study in the EU data are computing and engineering. However, engineering includes all types of engineering, not just those areas related to NIT. Figure 4.7 compares the number of computing and engineering degrees awarded at all levels of tertiary education for the EU to those awarded in the United States in CS and EE from 1998 through 2002.

Figure 4.7: Comparison of Computing and Engineering Degrees Awarded in EU and US (1998-2006)



Source: Eurostat and NCES

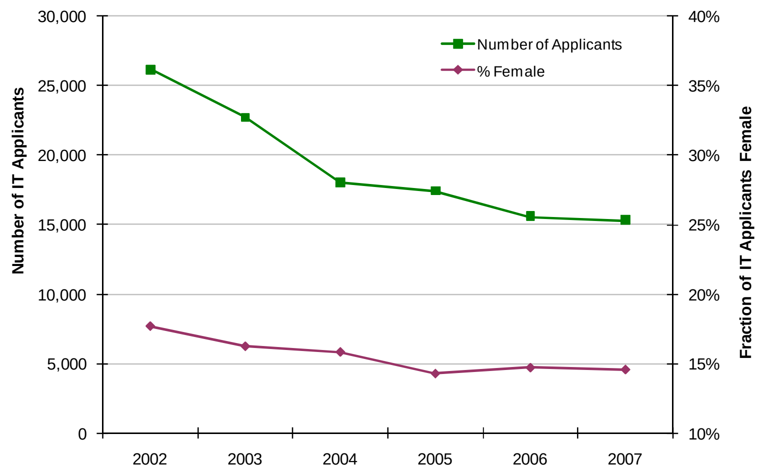
The number of computing graduates in the EU is higher than the number of CS graduates in the United States and has been growing more rapidly since 1998. In 1998, the EU countries graduated about 57,000 computing graduates while the United States graduated about 40,000 computer science graduates, or about 30 percent fewer graduates. By 2006, the EU countries awarded 151,000 computing degrees while the United States awarded 67,000, or about 55 percent fewer. The EU awarded more computing degrees per capita (335 per million inhabitants) than the United States (217 per million inhabitants) in 2006.[459] As would be expected, the number of all EU engineering graduates is much higher than the number of electrical engineering graduates in the United States. We display these data nonetheless to give a sense that no matter what fraction of EU engineering graduates are electrical engineers, the total number of EU NIT graduates is

[458] Salt et al. (2004)
[459] Eurostat, NCES, and CIA World Factbook

likely higher than the number of NIT graduates in the United States. There are no publicly available projections of EU NIT graduates but a 2004 EU study identifies shortages of IT workers in many member states.[460]

As for the workforce, the best available country-level education data comes from the UK. The UK experienced a decline in the annual number of computer science/IT applicants in higher education from about 26,000 in 2002 to about 15,000 in 2007, an annual rate of decline of ten percent, as shown in Figure 4.8. Like the decline in CS majors observed in the United States, this has raised significant concern in the UK.

Figure 4.8: UK Higher Education Applicants for Computer Science / IT related Degrees



Source: Department for Business Enterprise and Regulatory Reform et al. (2009)

Women's representation declined among NIT degree applicants in the UK. The fraction of female NIT degree applicants in the UK fell from 18 percent in 2002 to 15 percent in 2007. In 2004, across Western Europe, the fraction of math and CS degrees awarded to women was higher than the percentage of applicants in the UK, at 30 percent. Some European countries with higher rates of female representation among NIT degree recipients include Portugal (41 percent), Finland (42 percent), Greece (40 percent), and Italy (43 percent).[461]

Although not an EU country, Switzerland provides one of the most dramatic examples of the declining interest in NIT worldwide.[462] Swiss enrollments in NIT degree fields declined by 60 percent over the past five years. In response, the government of Switzerland declared 2008 the "year of IT" and undertook initiatives to promote IT by organizing events, conferences, and meetings.[463]

460 Boswell et al. (2004), p. 3
461 Klawe et al. (2009)
462 Tovar-Caro (2009)
463 Tovar-Caro (2009), p. 46

4.2.1.3 Comparing Supply and Demand

An important question about the condition of the NIT workforce in Europe is whether there is, in fact, a shortage of ICT workers. Looking at present conditions, a few analysts have questioned whether there is an e-skills "crisis" at all. Beginning in 2006, Eurostat, the European statistical agency, has conducted an annual survey of e-skills statistics in households and enterprises, linking data from 13 national statistical offices. As pointed out by the German market research firm Empirica (which has been contracted by the EC to monitor e-skills statistics for the EU), the most recent Eurostat data show that only 7.2 percent of all firms with 10 or more employees tried to hire employees with ICT specialist skills, and that only 3.4 percent of all firms reported any difficulty in hiring ICT specialists.[464] Furthermore, due to the economic downturn starting in 2008, hiring for IT jobs (as for other types of positions) declined precipitously by early 2009, compared with activity from a year earlier.[465]

Other data indicate that there is a shortage of skilled IT workers in the EU. Even if the figures cited by Empirica are accurate, the implication is that nearly 50 percent of firms which are hiring ICT practitioners have difficulty filling those positions. While the current economic downturn may be limiting the demand for ICT practitioners in the short term, the long-term supply and demand conditions may not be favorable to employers.

In November 2007, the Council of European Professional Informatics Societies (CEPIS) published its own analysis of the ICT practitioner labor market, titled *Thinking Ahead on E-Skills*.[466] The report presented five different scenarios for the European economy, based on varying projections, and derived their implications for the need for ICT practitioners in 2010 and 2015. As the following table shows, CEPIS projected a surplus of ICT practitioners in 2010 only in the most unfavorable scenario (decline), and estimated that severe shortages would be seen by 2015 in all scenarios.

Table 4.6: **CEPIS Projection Scenarios on ICT Practitioner Supply and Demand in 2010 and 2015**

	Renaissance	Steady Climb	Global	Fight Back	Dark Days	Decline
2010						
Demand	250,000	205,000	204,000	178,000	139,000	101,000
Supply	180,000	175,000	178,000	178,000	139,000	102,000
Surplus/Shortage	**-70,000**	**-30,000**	**-26,000**	**0**	**0**	**1,000**
2015						
Demand	243,000	188,500	129,800	150,000	111,000	38,000
Supply	192,000	186,000	131,300	120,000	90,000	30,000
Surplus/Shortage	**-51,000**	**-2,500**	**-1,500**	**-30,000**	**-21,000**	**-8,000**

CEPIS (2007)

The EC has concluded that there is a growing shortage of skilled ICT workers, and that this will reduce the global competitiveness of the EU in the future. This is particularly true in areas where the development of new ICT technologies will be critical to

[464] e-Skills Monitor (2009)
[465] Espiner (2009)
[466] CEPIS (2007)

competitiveness. The EC issued a communication on March 13, 2009 titled "A Strategy for ICT R&D and Innovation in Europe: Raising the Game."[467] This communication states that "there is a growing deficit in the EU of qualified skills in ICT R&D," and recommends that the EC take action to counter that situation.

4.2.1.4 Programs and Initiatives

Citing the projected shortfall in the supply of ICT practitioners and the potential harm to EU competitiveness from the situation, the EC's *Communication on E-Skills* proposed a "long-term e-skills agenda" with five action areas for the EC:[468]

- Promoting long-term cooperation and monitoring progress;
- Developing supporting actions and tools;
- Raising awareness;
- Fostering employability and social inclusion;
- Promoting better and greater use of e-learning.

While the *Communication on E-Skills* dealt with all forms of e-skills, including user e-skills, many of the action items outlined by the EC focused on ICT workers. Below are a few activities already underway. These activities can be loosely grouped under the following categories:

- Organization and coordination;
- Standardization of competences and certifications;
- Awareness and talent development.

4.2.1.4.1 Organization: The E-Skills Industry Leadership Board

In 2006, a task force commissioned by the EC and led by private sector IT executives issued a number of recommendations on how to support the global competitiveness of the EU ICT industry.[469] In the section on "Skills and Employment," the report recommended the formation of an "Industry Leadership Group" to facilitate EU-wide coordination on e-skills. In June 2007, the E-Skills Industry Leadership Board (ILB) was founded by a consortium of professional societies, trade associations, and IT and networking firms. The E-Skills ILB works with the Directorate-General Enterprise & Industry within the EC which supports ICT and innovation policy. These organizations, together with the European Centre for the Development of Vocational Training (CEDEDOP), undertake activities such as co-sponsoring a biannual European e-skills conference, held most recently in October 2008, and a series of workshops on various topics in e-skills promotion held in 2007.

[467] Commission of the European Communities (2009)
[468] European Commission's Communication on E-Skills (2007)
[469] EU ICT Task Force (2006)

4.2.1.4.2 Standardization: The E-Competence Framework

The immediate issue in coordinating e-skills policy for Europe is harmonizing the labor market for ICT workers. To enable a unified environment for the education, recruitment, and advancement of ICT talent, the EU desires to have standards for identifying and describing the skill levels of ICT occupations. The flagship effort in this area is the E-Competence Framework, supported by the EC but driven by national organizations focused on the standardization of ICT skill descriptions.[470]

Competence frameworks are used by private firms internally to standardize job descriptions and create an explicit career track for IT professionals. This concept has been elevated to the national level by efforts such as SFIA in the UK and ATTIS in Germany (see the following section for more detail on those initiatives). Over a two-year period, a set of experts supported in part by the European Centre for Standardisation (CEN) developed a comprehensive framework identifying:

- The key competence areas needed to build, manage, and operate ICT in an enterprise environment;
- The specific competences that a worker must possess in each area;
- A rating system to evaluate proficiency in each competence;
- The supporting skills and knowledge within each competence.

The E-Competence Framework (ECF) version 1.0 was approved as a workshop agreement under the CEN and published in October 2008.[471] The expert group responsible for developing the Framework also produced a user guide that explains the uses of the ECF by employers, human resource professionals, ICT practitioners, and other audiences.[472] Some of these uses are listed below.

- Firms can use the ECF to pinpoint the knowledge and skills needed for each type of ICT job in their organizations, and better match internal talent to each position.
- Firms can use the ECF in standardized job descriptions, which aids in recruiting and highlights the requirements for internal candidates to advance into new positions.
- Universities and training schools can use the ECF to design curricula for programs to prepare graduates for specific types of ICT practitioner occupations.
- Governments can use the ECF to quantify their local ICT talent pool and identify gaps which must be filled through education, immigration, or outsourcing.

The E-Competence Framework is also being linked to the European Qualifications Framework, which is used for cross-national talent evaluation and recruiting. It is also

[470] http://www.ecompetences.eu
[471] Comité Européen de Normalisation (2008a)
[472] Comité Européen de Normalisation *(*2008b)

being integrated with the Bologna Initiative to harmonize higher education standards across EU nations, so that graduates of ICT programs in one country will be prepared for jobs across the EU. That effort is being coordinated by the European Quality Assurance Network for Informatics Education (EQUANIE), founded in January 2009.[473]

In a related effort, the E-Skills ILB has formed the Certification Council. This group is examining all of the professional ICT certification programs used in Europe (such as the Microsoft Certified Software Engineer program, or the Certified Information Systems Security Professional rating), and mapping those certifications to the ECF so that national and independent certifications can be compared and matched to a standard set of competences.[474]

4.2.1.4.3 E-Skills Week 2010

A second key area of EU-wide activity is raising awareness about ICT careers among young people and prospective employees. A flagship effort in this area is the planned E-Skills Week, sponsored by the EC. E-Skills Week will be an umbrella label for multiple events in every EU nation, aimed at showcasing the attractiveness and advantages of a career in IT. E-Skills Week will be launched in March 2010 with a major event at the CeBIT trade show in Germany, and will conclude with a high-profile ceremony in Brussels.[475]

In addition, the Directorate-General for Information Society & Media sponsors an independent initiative to encourage women to pursue careers in ICT. The IT Girls website serves as a clearinghouse for information and materials on the shortage of women in IT and possible ways to change the situation.[476] The DG also organized a conference on the topic in March 2009, called "Cyberellas are IT!"[477] Part of the conference was devoted to relaying the successes and lessons learned from a 2008 "shadowing exercise," where firms were encouraged to give young women the chance to come to the workplace and follow IT professionals as they went about their jobs.

4.2.1.4.4 Country-Specific Activities

Although the EC is increasingly active in developing policy on e-skills throughout Europe, it is often following the paths already taken by national governments and attempting to weave together various regional initiatives. Several countries have well-established efforts in areas similar to the EC.

United Kingdom

A number of initiatives have been undertaken in the UK to improve and expand the ICT workforce.

[473] http://www.eqanie.eu/
[474] O'Sullivan (2008)
[475] Richier (2009)
[476] http://ec.europa.eu/information_society/activities/itgirls/index_en.htm
[477] http://ec.europa.eu/information_society/activities/itgirls/conference_0309/index_en.htm

Organization: e-skills UK

E-skills UK is the organization officially licensed by the UK national government as the Sector Skills Council (SSC) for Business & Information Technology.[478] SSCs are employer-led consortia that fund research on future supply and demand for skilled workers in various key industries. The SSCs create strategies and recommend policies to ensure the development and availability of skilled talent for employers in those industries. E-skills UK develops both national and regional strategies on building and maintaining the ICT workforce.

Some of the activities funded and organized by e-skills UK include:

- Diploma in IT**:** Launched in September 2008, the Diploma in IT is a standardized program of instruction for students 14 to 19, designed to prepare them for higher education degree programs in ICT or directly for employment in ICT occupations. Students can choose from a wide range of specialist options.
- IT Professional Development Programme**:** This program is a specialized curriculum of IT course modules developed cooperatively by leading companies and four universities. The program is targeted at professionals who are already in IT careers and is designed to give them the foundation and tools to understand rapidly changing technologies that are shaping the IT industry.

Standardization: The SFIA Foundation

In July 2003, a new organization was founded by e-skills UK along with the British Computer Society, the Institute of Engineering & Technology, the Institute for Management Information Systems, and the IT Services Management Forum.[479] This effort, called the Skills Framework for the Information Age (SFIA) Foundation, was the UK's attempt to create a set of national standards for describing IT skills required for employment in the ICT industry. The SFIA document provides employers with a means to define the roles within its IT organization, develop detailed career advancement and professional development plans, and create standardized evaluations of IT personnel. Version 4 of the SFIA was released in December 2008. The SFIA Foundation certifies training institutes and consultants who are qualified to provide SFIA-based services to employers.

As an illustration of how the SFIA helps employers, the utility company National Grid began using SFIA in its IT human resources strategy in 2004. The British Computer Society conducted a mini-audit of the progress at National Grid in 2006. A BCS survey found that 70 percent of the IT staff felt that the professional development situation in the firm had improved due to the use of SFIA; 83 percent reported that they felt that their personal development plans now focused on important gaps in their skills, and 75 percent were more likely to review their progress with their managers.[480]

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[478] http://www.e-skills.com
[479] http://www.sfia.org.uk/
[480] Perry (2008)

Awareness: CC4G and BigAmbition

E-skills UK is involved in a number of initiatives meant to introduce young people, especially women, to the ICT profession. Two examples are:

- Computer Clubs for Girls (CC4G): A network of after-school clubs sponsored by e-skills UK targeting girls aged 10 to 14. CC4G introduces girls to the use of computers in activities related to their interests, such as music, fashion, celebrity, and design.
- BigAmbition: A website that provides young students with compelling content and information about careers in IT, prospective employers, and educational opportunities. The site is a collaboration among top IT and industrial firms, universities, and e-skills UK.[481]

Germany

Two sets of initiatives focused on the IT workforce have recently been undertaken in Germany, one focused on the vocational education system, the other on older workers.

Standardization: Advanced IT Training System (AITTS)

In 2002, as part of a comprehensive revision of the national vocational education system, the Fraunhofer Institute for Software and Systems Engineering developed a new approach to standardizing job profiles and skill definitions in the ICT sector. Rather than identifying technical skills used on the job, the Fraunhofer team took a work-process view of ICT activities in an organization. This perspective integrates social and behavioral skills, such as management capacity and mentoring, into the framework for ICT competences. The resulting system, called the Advanced IT Training System (AITTS), combines both formal classroom training with informal, on-the-job training as the recommended path to support professional development for IT personnel.

The AITTS defines the actual role of IT in an organization and models how information systems are managed to support the business. It then recommends how personnel should be organized to develop and maintain those systems. The AITTS identifies four types of "trainers" as playing a role in professional development: coaches, technical experts, classroom trainers, and superiors. A final version of AITTS was approved in October 2002, and is now codified in German workplace regulation. AITTS implementation in private firms is conducted by experts who are certified by the German Chambers of Commerce & Industry.[482]

Awareness: Generation 50+ for older workers

The German Industrial Metalworkers Union (IG Metall) has initiated a project to promote the role of older workers in the IT profession. A study by the staff of the vocational training group in IG Metall found that age discrimination is a systemic problem in the German IT industry. For example, many job announcements list 40 as the maximum age

481 http://www.bigambition.co.uk
482 Federal Ministry for Education & Research (2003)

for candidates, and most corporate budgets fund early retirement packages instead of retraining older workers. However, their study also found that IT departments are already aging, with the average IT worker now 40 years old at firms like Software AG. In addition, the unemployment rate for IT workers over 50 stands at 50 percent.[483]

IG Metall is working with BITKOM and the Fraunhofer Institute on a new model for age-based learning within the AITTS framework. This would include increased use of mixed-age teams in IT organizations, utilizing older workers in roles such as coach or technical expert. The proposal, which is part of Germany's "Initiative 50 Plus" to promote the employability of older workers, also uses a knowledge management framework to highlight the importance of older IT professionals to organizations.

Ireland

In 1998, when Ireland was evolving into a major center of IT employment in Europe, a group of six IT firms (Corel, CSC, IBM, Microsoft, Oracle, and Symantec) worked with the Irish national government to examine how to ensure the adequate supply of IT workers in the local economy. The group decided to focus on the long-term unemployed, consisting of residents who lacked the education and resources to qualify for traditional careers. The consortium created the Fastrack to IT, or FIT, Initiative.[484] Due to its focus on people who were viewed as "unemployable," the FIT Initiative has created an integrated set of programs for its recruits that will:

- Create a new type of IT curriculum which combines digital literacy with IT skills;
- Develop a standardized means of defining, evaluating, and certifying skill levels in IT occupations;
- Provide easy access to instruction for people with limited resources;
- Integrate training providers with placement agencies and employers to ensure that graduates meet industry needs.

The FIT Initiative now sponsors a number of projects. For example, the MigrantICT project focuses on newly immigrated entrants into the Irish workforce and develops specialized courses for that population. The eTuition project, being conducted with partners in Italy, seeks to develop new ways to encourage schoolteachers to integrate ICT topics into their everyday instruction.

Netherlands

In 2004, employers in the Netherlands IT industry recognized the need for a broader set of curricula at the university level to train students as ICT practitioners. Working with the University of the Applied Sciences of the Netherlands, a number of firms funded the development of the "Bachelor of ICT" degree programs (HBO-I). These programs cover topics such as Business Information Technology, ICT Management and Security, Game

483 Ewald and Hageni (2007)
484 http://www.fit.ie/homepage.asp

Design and Technology, and similar themes. The foundation of the HBO-I effort is a "competence cube," which standardizes the description of IT-based processes and functions in an organization. The HBO-I cube maps the curriculum to the skills required to support the IT operations of an enterprise.[485]

Currently, the main HBO-I effort creates a bridge between the universities and industry, and coordinates an event where employers can meet with graduates of the Bachelor of ICT programs. In addition, HBO-I is funding various efforts to improve the image of the ICT profession in the Netherlands, with a specific focus on recruiting women into the field. HBO-I members have also formed working groups to address other issues in IT workforce development, such as the teaching of IT topics in secondary schools and using the HBO-I model to enable retraining of workers with non-IT degrees.

Overall, the EU faces a situation comparable to that in the United States regarding its NIT workforce: while the size of the workforce appears to be growing, there is a pervasive and significant fear that the supply of NIT workers will not meet future demand. Networking and information technologies continue to grow even more critical to the performance of most firms. In addition, the ability of EU firms and economies to compete globally will depend on the region's ability to sustain a significant level of innovation in the NIT sector. Thus, the EC recognizes the need to maintain an adequate supply of new NIT talent and to enhance the efficiency of the internal market for NIT labor to ensure that the existing workforce is utilized fully.

The EC has not implemented any particularly innovative approaches to NIT workforce development. Its role is to coordinate national activities across the EU, and to disseminate information and best practices among the member nations. Some of the individual national efforts may serve as useful examples for US programs:

- E-skills curriculum development. In the United States, NIT workforce training is guided largely by vendor-specific certifications. Still, there may be some merit in encouraging the development of vendor-neutral standardized curricula for NIT workers, much like the Diploma in IT developed by e-Skills UK and the HBO-I "Bachelor of ICT" in the Netherlands. Encouraging collaboration between universities, IT user firms, and IT vendors may help to ensure greater consistency in how students are prepared for entry into the NIT workforce.
- Appealing to non-traditional recruits. Just as women and minorities are underrepresented in the NIT workforce, there are other underrepresented populations that could also provide potential labor. The FIT program in Ireland shows how the chronically underemployed can benefit from special programs in IT training. In addition, the Generation 50+ concept in Germany addresses the important issue of age discrimination in IT hiring practices. The aging of the NIT workforce is also an issue in the United States, especially in the federal government.

[485] http://www.hbo-i.nl

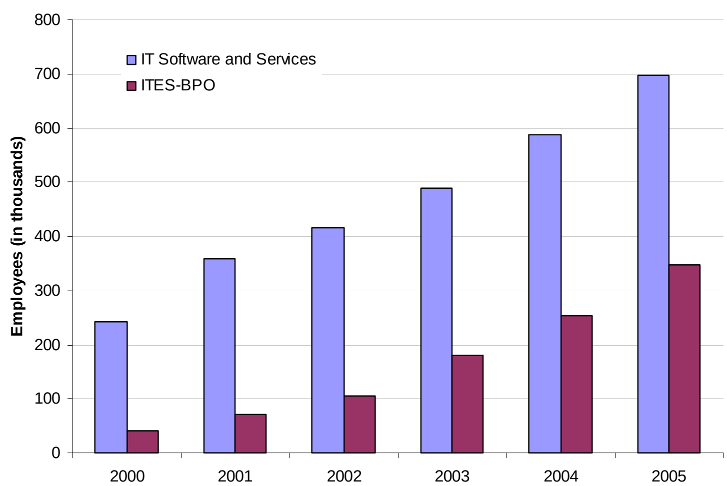
4.2.2 India

Although the IT industry began in India around 1974, it did not witness significant growth until the beginning of the 1990s.[486] At that time, Indian software firms were able to take advantage of a unique set of opportunities. Western companies had to cut costs, but building and maintaining computer systems required a large pool of skilled technical workers. Indian firms were able to meet that demand with a supply of English-speaking engineers who earned a fraction of Western salaries. Fast fiber-optic links also made the exchange of information easier. The Indian IT workforce has been growing rapidly over the last decade and further growth is predicted. India has also undertaken a number of initiatives to sustain this growth.

4.2.2.1 NIT Workforce Trends

The Indian IT industry has been growing at a rate of about 30 percent per year since 2003.[487] This estimate includes both IT and IT-enabled (often referred to as business process outsourcing [BPO]) industries. Estimates for the size of India's NIT workforce also tend to include both IT and IT-enabled workers. Figure 4.9 shows the size of the IT software and services workforce and the size of the IT-enabled software and services (ITES-BPO) workforce in India from 2000 through 2005.

Figure 4.9: Size of the NIT Workforce in India (2000-2005)



Source: ACM (2006)

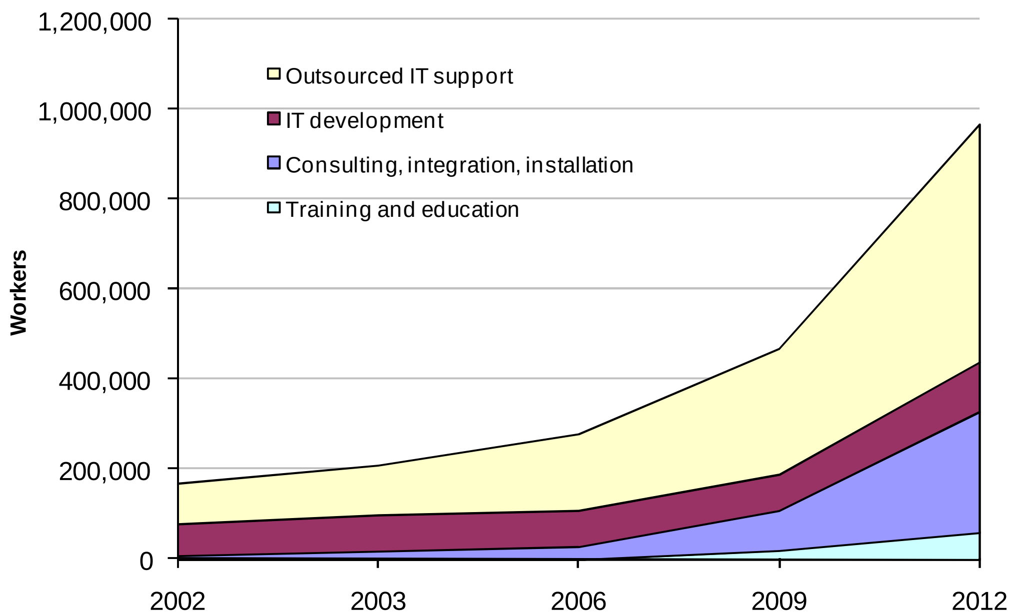
The Indian NIT workforce has grown rapidly over the past decade, growing at an average rate of about 20 percent per year from 2000 to 2005. Much of this growth is in IT export services. The IT industry group NASSCOM projects this sector to grow from about 210,000 workers in 2003 to about 970,000 workers by 2012.[488] A recent article claimed that the Indian IT and ITES workforce surpassed two million workers in 2008.[489] This is

[486] Bajpai and Shastri (1998)
[487] NASSCOM and McKinsey (2005)
[488] Government of India Ministry of Communications and Information Technology (2003)
[489] Kumar (2008)

almost double the size of these sectors combined in 2005. Of these two million, NASSCOM estimates that about 1.2 million are IT workers. NASSCOM estimates that about 25 percent of IT workers are female, among the highest in any industry in the Indian economy. However, comparing these data to the available degree statistics, it appears that the majority of these women are in the ITES workforce and not in the category 1 NIT workforce as we define it in this report.

A 2003 report commissioned for the Indian government projected that much of the increase in the NIT workforce would occur primarily because of outsourced IT support, as shown in Figure 4.10. This figure includes only NIT workers serving export markets. However, this is the majority of Indian NIT workers.

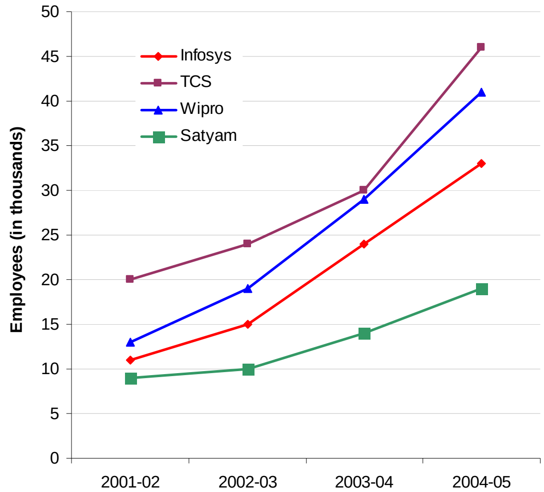
Figure 4.10: Projections of IT Export Services Workforce in India



Source: NASSCOM and KPMG (2003)

India has seen significant growth in both domestic IT firms, such as Infosys and Wipro, and multinational corporations with offices located in India. Figure 4.11 shows the growth in the number of employees in the top four Indian IT companies from 2001 through 2005.

Figure 4.11: Employment Growth in Major Indian IT Firms



Source: ACM (2006)

Almost every large multinational IT company has a presence in India. Table 4.7 lists the major multinational IT firms with significant operations in India.

Table 4.7: Major Multinational IT Firms in India

Company	Nationality	Employment in India	Global Employment	% in India
Oracle	US	6,900	41,658	16.6
Microsoft	US	1,250	57,000	2.2
SAP	Germany	2,000	38,802	5.2
IBM	US	23,000	369,277	6.2
HP	US	15,000	150,000	10
Veritas	US	900	17,250	5.2
Adobe	US	500	3,142	15.9
EDS	US	2,400	117,000	2.1
Cap Gemini	France	2,000	59,324	3.4
Siemens Bus. Sys.	Germany	4,000	36,000	11.1
Atos-Origin	France	750	46,583	1.5
Tietoenator	Finland	120	14,000	0.9

Source: ACM (2006)

It is clear that India's IT workforce is growing rapidly. However, there is a concern that the supply of qualified students will be unable to keep up with demand and that growth may slow by 2010.[490] Additionally, NASSCOM predicts that the recent global economic downturn will reduce annual growth in the industry from 30 percent per year to about 20 percent per year. Experts predict that future growth will be fueled by the rapid expansion of the Indian domestic IT market rather than continued rapid growth in export services. There are no data available on the demand for IT workers in India with Indian citizenship.

Foreign workers are an important component of the NIT workforce in India. While India used to be concerned with outflows of IT talent due to high-skilled migration, the loss of

[490] Blinder (2007), p. 8

IT workers, a “brain drain,” is no longer a concern. Prior to the 1990s, a brain drain occurred because of growing demand abroad and a lack of opportunities for IT workers in India.[491] As shown above, there is now a significant presence of both multinational and homegrown IT firms in India. This has not only led to increased retention of recent graduates but also to the return of expatriate IT workers creating a “reverse brain drain.” It was estimated in 2006 that 30,000-40,000 expatriate IT workers had returned to Bangalore over the previous decade.[492] It was also estimated that between five and twelve percent of IT job applicants for positions in India were non-resident Indians who wished to return. Lowell noted that this fraction is expected to grow. India appears to welcome the experience and knowledge that its expatriates bring but there do not appear to be any significant measures taken to attract them.[493] The opportunities available within the rapidly growing IT industry in India appear to be enough of an incentive.

4.2.2.2 Supply of NIT Graduates

There are very little data publicly available on the supply of NIT graduates in India. A 2005 study by Gereffi and Wadhwa attempted to estimate the relative number of bachelor’s-level NIT graduates produced in India and China each year and to compare it to the number in the United States.[494] Gereffi and Wadhwa collected information from NCES, the Chinese Ministry of Education, and NASSCOM. They attempted to estimate the number of four-year bachelor’s recipients in each country as officially reported numbers are often inflated to include three-year degrees. They attempted to break out CS, EE, and IT degrees from all engineering degrees but were only able to do so for India and the United States. They found that, in 2004, India produced about 95,000 bachelor’s-level NIT graduates compared to 85,000 produced in the United States. Based on this data, the US produced more NIT bachelor’s degrees per capita (277 per million inhabitants) than India (81 per million inhabitants) in 2004.[495] In addition, there is a significant concern about the skill level of Indian NIT graduates, as many must be retrained in full-time four-month courses by the firms that hire them.

Lack of qualified NIT faculty is considered to be a major problem in India. Most qualified IT workers are drawn into industry. This creates many vacancies and leads to many underqualified IT faculty teaching the next generation of IT workers. This was also a problem in the United States during the IT boom and is commonly referred to as the “seed-corn” problem.

Women’s representation in technical fields is low but growing in India. The percentage of female engineers graduating from ITT Bombay grew from two percent in 1972 to eight percent in 2005. In Asia (including the Middle East), women earned 43 percent of first university degrees in math and CS in 2004.[496]

[491] Lowell (2008)
[492] Lowell (2008)
[493] Lowell (2008)
[494] Gereffi and Wadhwa (2005)
[495] Gereffi and Wadhwa (2005) and CIA World Factbook
[496] Klawe et al. (2009)

4.2.2.3 Programs and Initiatives

The Indian government has been making a concerted effort starting in the mid-1980s to develop the NIT industry. However, as is emblematic of India's economic success, most of the initiatives regarding workforce development have been undertaken by private enterprises. Multinational corporations and local companies have undertaken many initiatives to ensure the continuing development of the NIT workforce. Through partnerships with Indian and foreign universities, they have brought interns and expatriates to work in Bangalore or Hyderabad. A recent example of this trend is a program that helps American students participate in a two-month internship at a variety of different IT companies such as Infosys and Satyam.[497] They have also set up online education opportunities for employees interested in learning a new technology, and offer a growing number of classes aimed at providing on-the-job skills to entry-level engineers. Many complain that there is underinvestment in this type of training by firms in the United States.

The Indian IT industry and its workforce face many barriers to continued growth including lack of infrastructure, a talent shortage, and rising salaries. In response to these concerns, the government (at both of the federal and the state levels) feels the need to act quickly to ensure the sustainability of the industry, and with it, India's economic success. Deficiencies in the higher educational system are often singled out as the critical issues facing the IT workforce in India. In the 2005 survey, NASSCOM identified a list of crucial considerations focused on education that the Indian government needs to address to maintain the strength of its IT workforce. These included allowing the setting-up of Focused-Education-Zones that are exempt from controls on key operating parameters (e.g., fees, admissions, etc.) for colleges and universities, and deregulating higher education through a phased decentralization over the next five to seven years, and moving to a demand-based funding system for colleges and universities.

Other studies have also focused on the importance of reforming the education system in India. A World Bank study commissioned in 2001 highlighted the shortcomings in the Indian system, blaming the rigidity of its curriculum and evaluation methods for India's impending talent shortage. Further, the study noted that the current system lacks specific policy guidelines and goals to help it fit the requirements for the NIT industry. The study claimed that the system lacks continuous monitoring, which would help ensure that students going through a rigorous curriculum are on track to meet the demands of industry. Other problems identified include the lack of adequate infrastructure, which is a commonly cited problem facing all industries in India.

A prominent report focusing on the life cycle of the NIT worker was co-authored by NASSCOM and the American accounting firm KPMG in 2003. This report suggested that the whole system needed to be examined critically. The report recommended that the cycle be continuous: attracting, educating, certifying, deploying, and then ultimately re-training workers to remain familiar with new technologies. The report also stated that graduates of the Indian system often have a strong theoretical or conceptual background,

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[497] Prayag (2005)

but lack communication skills and the capacity to be creative. The report proposed integrating specific modules starting at the primary or secondary school level. These modules would encourage computer literacy so that students could familiarize themselves with the workings of a computer at a young age. At a later age, students could be offered classes in customer service that would include teamwork and time-management skills. The report also recommended certification through a common exam that test skills in computer proficiency, analytical abilities, and language. The results of this exam could then be used to place candidates across sectors.

India has undertaken a number of efforts focused on underrepresented groups. The majority of these efforts have been targeted at women and the rural Indian population. Facing a shortage of workers from traditional institutions, Indian corporations have been trying to attract workers that heretofore had been ignored. Gender and caste play important roles in everyday life in India; consequently, women and scheduled (oppressed) castes have not benefited significantly from the country's economic growth. Corporations are now learning to recognize the importance of maximizing the workforce by employing women. Therefore, they are offering them high salaries and flexible hours, and are providing support for young mothers by paying a family member to move in or by subsidizing the cost of daycare. Some of them have even begun offering existing employees an additional 25 percent on their referral bonus if they refer a woman for an open position with the firm.[498]

Rural India has not benefited significantly from the country's IT-driven economic growth. However, both industry and government in India are undertaking efforts to improve the availability and quality of workers from these areas. Companies are reaching out to rural India by setting up training centers in less developed regions in order to recruit potential engineers. The government has invested in infrastructure projects aimed to increase connectivity to rural areas: asphalt roads, streetlights, power generators, and Internet connections. Many states have started focusing on promoting e-literacy by installing computer systems in village schools to help students familiarize themselves with computers.[499] The government also recently passed laws reserving seats for members of historically oppressed castes, called the "scheduled castes." These quotas are as high as 15 percent in institutions of higher learning, and empower a population that previously had very little support.

Overall, there are a significant number of issues facing the NIT workforce in India. While its size and rapid growth makes India a significant current and future competitor to the United States, there are many issues that need to be resolved if it is to continue to grow. These issues include matching educational skills and industry needs, providing adequate infrastructure, and empowering segments of the population that have thus far been ignored. However, both government and industry are undertaking a number of efforts to address these issues. From reforming higher education to providing flexible schedules for underrepresented groups, India is working to address the major concerns facing its NIT workforce.

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[498] Economic Times (2008)
[499] Dossani et al. (2005)

4.2.3 China

There is very little publicly available information about the NIT workforce in China. The majority of the information available comes from a 2007 World Bank report by Christine Zhen-Wei Qiang titled *China's Information Revolution: Managing the Economic and Social Transformation*. This report shows that the software market in China grew rapidly between 1999 and 2004.[500] The report also shows that the share of total employment in the services sector in China grew from 10 percent in 1978 to more than 20 percent in 2003. However, there are few other publicly available indicators that can help depict trends in the NIT workforce in China. Of all the countries studied in this report, there China has the least information available about its NIT workforce. The available information is summarized in the following sections.

4.2.3.1 NIT Workforce Trends

There are few available estimates of the current or future size of the NIT workforce in China. A recent World Bank report noted: "Due to different concepts, sources, and definitions, statistics about the number of ICT workers in China conflict, making it difficult to analyze trends and forecasts in the market for ICT employment."[501] This report estimated that there were about four million workers employed in China's information industry in 2003. This was 11 percent higher than in 2002. Of these workers, 3.5 million were in the manufacturing industry and 0.6 million were in the software industry.[502] A recent report from the NRC estimated that China employed about 750,000 workers in the export software services industry in 2005.[503] The NIT workforce in China is likely larger than the export software service industry (one million) but less than the number employed in the information industry (four million). However, this includes both category 1 and category 2 NIT workers. A lack of data combined with varying definitions makes estimating trends in China's NIT workforce difficult. Nonetheless, it is clear that the NIT workforce in China is large and growing rapidly. There are no estimates of the NIT workforce available by citizenship requirement in China.

While there are no data available on the number of foreign NIT workers in China, foreign workers play a significant role in the Chinese workforce overall. Similar to India, China used to be concerned about a "brain drain."[504] However, these concerns have lessened recently due to China's rapid economic growth and the opportunities that this has created for workers in China. In 2004, *China Daily* reported that the number of foreign workers in Shanghai was expected to grow at an annual rate of 20 percent for the following three years. It is unclear how many of these workers were NIT or high-skilled workers, although the majority of these workers were from Japan, the United States, Singapore, Malaysia, and Germany.[505] While there are little data available on the number of foreign NIT workers in China, the Chinese government has been trying to attract foreign workers

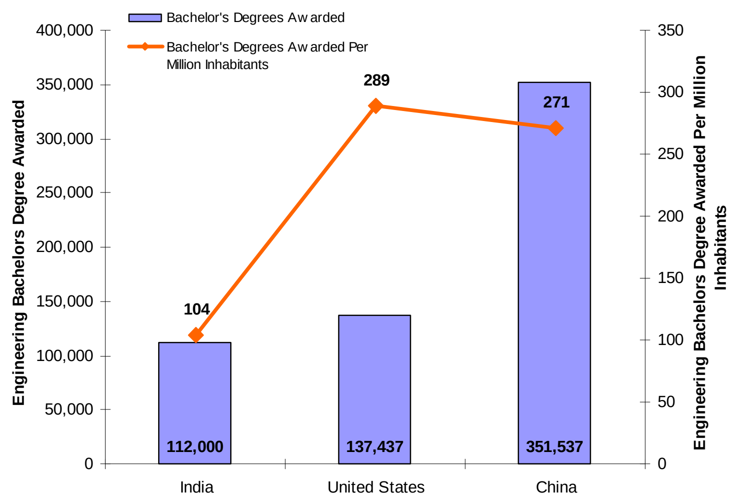
[500] Qiang (2007)
[501] Qiang (2007), p. 82
[502] Qiang (2007), p. 82
[503] NRC (2008)
[504] Meng (2008)
[505] Huilin (2004)

by improving living conditions and protecting intellectual property rights.[506] In 2004, Huilin stated that the city of Shanghai was "looking for foreign skilled professionals, especially in the services sector."[507]

4.2.3.2 Supply of Engineering Graduates

There are no data available directly estimating the number of NIT graduates in China. However, Gereffi and Wadhwa were able to estimate the supply of engineering graduates in China.[508] They found that China produced about 352,000 bachelor's-level engineers in 2004, which in per capita terms equates to 271 engineers per million inhabitants. They generated similar estimates for the United States and India for comparison and found that the United States graduated 289 engineers per million inhabitants and India graduated 103 per million inhabitants. The results for the number of engineering graduates from all three countries on an aggregate and per capita scale are shown in Figure 4.12.

Figure 4.12: Engineering Degrees in China, India, and the United States (2004)



Source: Gereffi and Wadhwa (2005)

China generated almost three times as many bachelor's level engineering graduates as the United States and India. However, it is unclear how many of these were in NIT fields. Additionally, although China produced slightly fewer engineering graduates on a per capita basis than the United States, anecdotal evidence suggests that the number is growing rapidly.

4.2.3.3 Programs and Initiatives

In 2004, the International Statistical Information Center and the National Bureau of Statistics of China measured ICT development in China using a number of indicators. One of the conclusions of this study was that China should aim to boost its national economy through ICT development.[509] The focus of efforts on ICT under the 11th Five-

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506 http://migration.ucdavis.edu/mn/more.php?id=1438_0_3_0
507 Huilin (2004)
508 Gereffi and Wadhwa (2005)
509 Jingying and Qiang (2004)

Year Plan has moved from enabling and promoting ICT to strengthening industry integration and indigenous innovations. In response to these high-level policy statements, the government has produced ICT policies and initiatives that target students, teachers, government workers, industries, and those living in both rural and urban communities. The focus on rural workers is similar to that seen in India.

Like in India, one of the major foci of ICT initiatives in China is education. To help integrate ICT in schools, the Chinese government developed the China Education and Research Network (CERNET), the country's backbone infrastructure for education. It is an online education and scientific research network, claiming to be among the top three academic networks in the world and enabling 70 percent of Chinese universities to provide distance learning. CERNET reaches more than 200 cities, including 36 provincial capitals. About 1,300 organizations, 800 universities, and 15 million users access the Internet through CERNET.[510]

In order to train students in ICT skills, China recognized that teachers also required ICT literacy. In 2000, the Teacher Education Department of the Ministry of Education published a "Training Guidance for Teacher Training about Information School," which requested that all teachers in primary and secondary schools learn how to use information technology by engaging in professional development activities. China also aimed to have over 10 million schoolteachers and several hundred thousand headmasters trained through continuing education by 2003.[511]

In order to encourage industry involvement in educating students in ICT, the Ministry of Education organized events such as the ICT Education Applications Exhibition in Beijing. Over 40 universities and ICT companies took part in the event. This not only provided an opportunity for the Ministry of Education to assess the latest ICT progress, but it was an opportunity for participants to network, review, and exchange ideas.[512]

The government has also aimed to increase human capital in ICT by providing incentives for foreign firms to locate in China. The government uses tax rebates and other financial incentives to lure foreign companies to China. This allows Chinese ICT laborers to acquire ICT knowledge, especially tacit knowledge that cannot be captured in textbooks. The government is also encouraging domestic firms to invest overseas to acquire human capital. This "go-out" strategy can be seen in China's TCL television business merger with France-based Thomson in 2004 and Lenovo's acquisition of IBM's China PC business in 2005.[513]

Like in India, initiatives targeted at underrepresented groups in China often target the rural population. The Chinese government has acknowledged that there is a "digital divide" in the country. In order to support basic ICT skills, utilization of ICT, and overcoming this digital divide, China is looking to build a strong ICT infrastructure in

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[510] Qiang (2007), p. 84-85
[511] UNESCO (2006)
[512] Gu (2003)
[513] OECD (2006)

rural communities. For example, the Chinese government aimed to provide 6000 distance education centers in Western China by 2003 and to equip 90 percent of elementary and secondary schools with Internet access. These schools are expected to offer at least one ICT course for all students by 2010.[514] Overall, the Chinese government has undertaken efforts to reform ICT in education in three areas: promoting the use of educational technology in schools with multi-media computer technologies, promoting the popularization and application of networks, and developing modern distance education.[515]

Industry ICT initiatives in China have been mostly funded by foreign companies and have specifically targeted the rural population. For example, Coca-Cola created an e-learning for life initiative in 2001. Its goal was to help bring digital resources and e-learning opportunities to teachers, less advantaged young people, and rural communities. The project also involved providing ICT skills training for schoolteachers who use the centers and software to teach subjects such as math, Chinese, English, and history. It is claimed that since 2001, 20 Coca-Cola e-learning centers have been established in rural areas of the country, and over 10,000 Chinese students and their communities have benefited from the project.[516] In addition, Microsoft donated $46,000 to the Project Hope Cyberschools to create five computer labs (Cyberschools) in rural China that will teach computer skills to disadvantaged youth. Each lab will have 15 computers, network and audio-visual equipment, computer-assisted educational software, and access to the Internet, thereby allowing access to the highest quality teachers and curricula in China.

Overall, China faces many of the same issues as India except with a less developed IT industry and fewer highly educated English-speaking workers who can participate in the global economy. Sustaining growth in China's IT industry requires educational reforms and attracting individuals, such as rural workers, who typically have not participated in the NIT workforce. Initiatives have been undertaken to address these issues by both government and industry. However, compared to other countries we studied, there is a lack of publicly available information that describes the key issues and the initiatives being undertaken in China.

4.2.4 Singapore

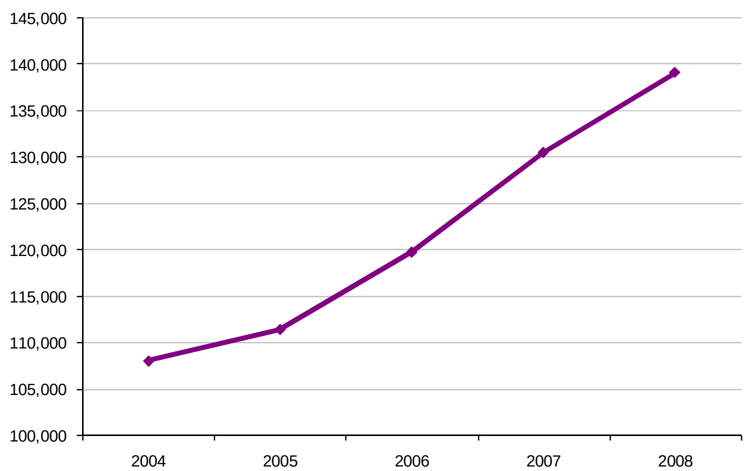
The NIT industry in Singapore is growing rapidly. According to the Singapore Ministry of Trade and Industry (MTI), the information and communications sector in Singapore grew at an annual rate of 7.2 percent in 2008, up from 6.5 percent in 2007.[517] However, MTI expects growth to slow in 2009 due to the global economic downturn. Nonetheless, the high growth in the NIT industry has led to significant growth in the NIT workforce in Singapore. Singapore publishes some of the best available NIT workforce data of any of the countries we studied. This section summarizes these data and discusses the efforts undertaken by Singapore to further develop its NIT workforce.

[514] Qiang (2007)
[515] UNESCO (2008)
[516] UNESCO (2006)
[517] http://app.mti.gov.sg

4.2.4.1 NIT Workforce Trends

Singapore publishes high quality NIT workforce information through its Infocomm Development Authority (IDA). The IDA has conducted an "Annual Survey on Infocomm Manpower" for many years. The most recent survey took place in 2008, with its results published in 2009. This survey defines Infocomm manpower as "a person engaged primarily in Infocomm related work either in an IT or telecommunication equipment and/or services provider, or user organization."[518] Figure 4.13 shows the IDA's estimates for the size of the Infocomm workforce for 2004 through 2008.

Figure 4.13: Size of the Infocomm Workforce in Singapore



Source: IDA (2009)

The Infocomm workforce in Singapore has grown significantly between 2004 and 2008, growing at three percent in 2004 and 2005, eight percent in 2006 and 2007, and seven percent in 2008. The Infocomm workforce included about 139,000 workers in 2008. About 59 percent of these workers had a bachelor's degree. Adjusting the size of the workforce to fit the definition of the category 1 NIT workforce used in this report decreases the size of the category 1 NIT workforce to about 82,000 workers in 2008. In 2008, about 57 percent of Infocomm workers in Singapore worked in Infocomm organizations. Within these organizations, 33 percent worked in IT services, 21 percent in software, and 27 percent in hardware. About 30 percent of the Infocomm workforce was female, a figure that has remained relatively stable over time. The IDA expects growth in the Infocomm workforce to slow to 4.3 percent in 2009 due to the global economic downturn and to rebound to 6.7 percent in 2010.[519] The IDA does not estimate the number of Infocomm workers who are citizens of Singapore.

In 2008, foreign workers comprised a significant portion (17 percent) of the NIT workforce in Singapore.[520] The government of Singapore has an open policy for high-skilled foreign workers that allows any high-skilled worker to immigrate if offered a

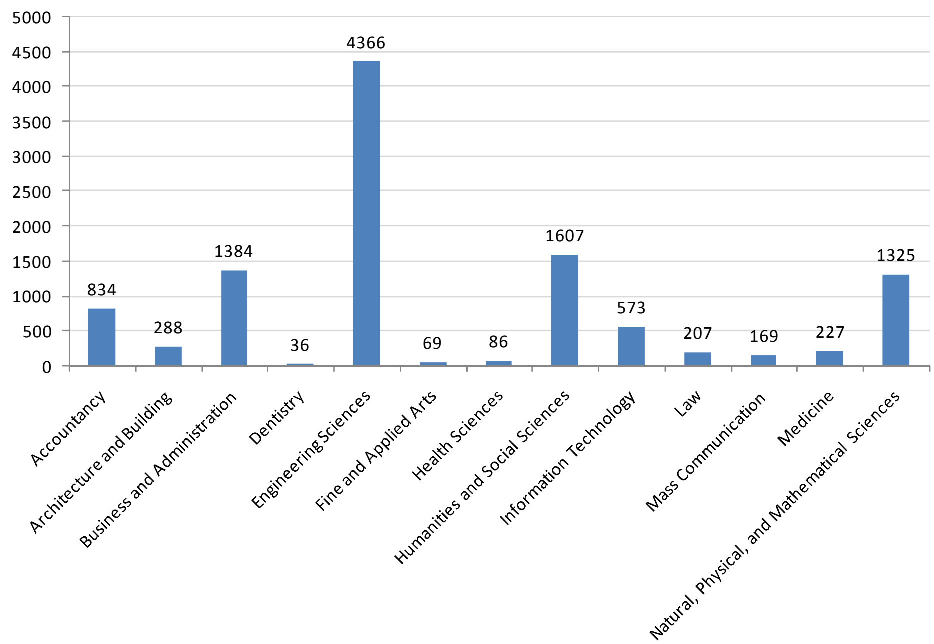
[518] IDA (2009), p. 4
[519] IDA (2009)
[520] IDA (2009), p. 8

job.[521] Even during the recent economic downturn, Singapore continues to seek IT experts from abroad.[522] Initiatives to attract highly skilled workers to Singapore include making it easier for workers to obtain permanent residency, providing grants to companies to reduce the cost of employing foreign workers, and creating urban development strategies aimed at branding Singapore as a "Renaissance City."[523] Many of these initiatives are contentious as some feel that Singapore depends too much on foreign talent. However, others argue that demographic trends require Singapore to recruit additional foreign talent over the next decade.[524]

4.2.4.2 Supply of NIT Graduates

The only available information on the supply of NIT workers in Singapore relates to the supply of new graduates from institutions of higher education and the recruitment of foreign workers. There is no breakout of NIT degrees in the data provided by the Ministry of Education. NIT degrees are included in two categories: information technology and engineering sciences. Engineering sciences includes all types of engineers, not just electrical engineers. Therefore, we cannot directly estimate the number of NIT graduates in each year. Figure 4.14 shows the number of graduates from universities in Singapore in 2007 by degree field.

Figure 4.14: Graduates of Singapore Universities by Field (2007)



Source: Singapore Ministry of Education (2008a)

521 Expert interview
522 http://www.australian-immigration-lawyer.com/visa/living-in-australia/wanted-ict-skills/
523 Yeoh (2007)
524 Yeoh (2007)

There were 573 information technology graduates and 4,366 engineering sciences graduates in 2007. Given these data, the number of NIT graduates in Singapore is likely in the thousands, much lower than in the United States. According to interviewees, a large portion of the IT workforce in Singapore comes from non-CS/EE degree programs but most IT workers have some experience with the basic principles of these disciplines. There is no published evidence of this trend, however. It is also worth noting that, in 2007-2008, Singapore ranked first internationally in both the quality of its math and science education and the quality of its educational system as a whole.[525]

The fraction of women graduating with degrees in NIT disciplines in Singapore is the lowest among all disciplines. In 2007, 36 percent of information technology degrees and 29 percent of engineering sciences degrees were awarded to women. This compares to an average of about 50 percent across all fields and 66 percent in the natural, physical, and mathematical sciences.

4.2.4.3 Programs and Initiatives

Most NIT-related programs and initiatives undertaken in Singapore focus on education. The Singapore Ministry of Education (MoE) has produced two blueprints outlining their plans to reform ICT education in schools. The First ICT Masterplan (MP1), lasted from 1997-2002, and laid the foundation for integrating ICT into education. It focused on setting up the essential infrastructure for schools and the basic training of teachers on the integration of ICT into the curriculum. The goal was to harness ICT for instructional purposes and to provide directions to schools for integrating up-to-date technologies into the educational process.[526] By the end of MP1, Singapore succeeded in laying a foundation that enabled all the schools to integrate ICT into the curriculum. All schools were provided with the necessary physical and ICT infrastructure for ICT-based teaching and learning. Singapore teachers acquired basic competencies in integrating ICT into the curriculum. More importantly, teachers accepted ICT as a pedagogical tool in the classroom, and there were models of excellence in the use of ICT in some schools.[527]

The Second ICT Masterplan (MP2), from 2002-2008, built on the achievements of MP1. It focused on bringing about more effective use of ICT to engage students in learning. MP2 aimed for schools to assume greater ownership and accountability with respect to technology implementation. Therefore, MP2 adopted a systemic approach in which curricula, assessment, instruction, professional development, and the culture of the school were addressed.[528] The plan focused on the interactions among these components and how technology can be leveraged to enhance learning. The MoE worked with school leaders to provide the necessary conditions for classroom teachers to innovate in using ICT in the curriculum.[529] The MoE also created a sustainable mechanism and framework for the sharing of innovative pedagogical practices/models and teacher-created digital educational resources among schools and teachers.

[525] Dutta and Mia (2008)
[526] Singapore Ministry of Education (2008b)
[527] Singapore Ministry of Education (2008b)
[528] Singapore Ministry of Education (2006)
[529] Singapore Ministry of Education (2008b)

While the MP1 and MP2 were being executed, Singapore announced its 10-year master plan called Intelligent Nation 2015 (iN2015) to "realize the potential of infocomm" to benefit the people of Singapore.[530] Led by the IDA of Singapore, iN2015 is a multi-agency effort that is the result of private, public, and people sector cooperation.[531] The goals of this plan are to accomplish the following by 2015:

- to be number one in the world in harnessing infocomm to add value to the economy and society;
- to realize a two-fold increase in the value-add of the infocomm industry;
- to realize a three-fold increase in infocomm export revenue;
- to create 80,000 additional jobs;
- to achieve 90 percent home broadband usage;
- to achieve 100 percent computer ownership in homes with school-going children.

Given the workforce data shown earlier, Singapore appears on track to meet its goal of creating 80,000 infocomm jobs by 2015.

The Singaporean government also provides training incentives, such as Critical Infocomm Technology Resource Program (CITREP) and Strategic Manpower Conversion Program (SMCP). These training programs offer up to 70 percent rebates to corporations on training costs. CITREP aims to provide infocomm professionals in Singapore with specialized skills needed to increase their organization's competitive advantage and to enhance their employability. The SMCP incentive scheme aims to convert non-infocomm professionals and re-skill them as infocomm professionals. The availability of these rebates has created an influx of commercial IT training centers throughout the country.[532]

Many infocomm initiatives in Singapore are collaborations between government and industry. The National Infocomm Scholarships (NIS) provides support for highly talented individuals to pursue infocomm careers. These Scholarships are offered through a collaborative effort of the Singapore IDA and various public and private sector organizations.[533] The NIS presents scholars with the opportunity to gain valuable work experience, industry-relevant mentorship, and employment at any of the 27 supporting organizations. These leading multinational corporations, local companies, and government agencies provide students with early industry exposure.

The MoE and higher educational institutions in Singapore have also collaborated with industry to test and build new infocomm technologies in the classroom. One such collaborative effort, the Industry Collaboration on Future Schools Singapore, selects four

[530] http://www.ida.gov.sg/About%20us/20070903145526.aspx
[531] Singapore Infocomm Development Authority
[532] Loh (2003), p. 34
[533] Infocomm Talent Portal: http://talent.singaporeinfocomm.sg/infocommscholarships.aspx#0

consortia to design and deploy next generation infocomm-enabled solutions for five FutureSchools, which without “having to visit the Singapore Zoo, Science students can, for example, immerse themselves in a 4-Dimensional (4D) environment and observe a lion’s behavior, record it and share the information with fellow students.”[534]

Another example of an innovative program in Singapore involves the use of Tablet PCs (TPC) at Crescent Girls School to create a school-wide wireless network.[535] This allowed for a self-paced and personalized learning as well as for collaboration. For this initiative, innovative applications were co-developed by Heuristix Lab and used in subjects such as Mathematics and Geography. Such applications included, “Fun with Construction,” “Mindbook,” and “Virtual Classroom” which enabled teachers and students to participate in tests and quizzes anywhere within the school or from home. Teachers are co-developing new applications for the sciences, languages, and digital games. In addition, CrezSphere was introduced to the Crescent Girls School in 2005 as a virtual learning platform that runs on Microsoft Learning Gateway. With this virtual learning platform, all staff and students can access the latest news about school, friends, and coursework. CrezSphere includes discussion forums for each subject, as well as practice papers, online lessons, and advice and learning resources, thereby building a virtual community within the school.[536]

Most of the NIT workforce initiatives being undertaken in Singapore focus on integrating IT into education. These range from collaborative efforts to design and build learning technologies to providing training to teachers on the use of IT. Some programs focused on closer academic-industry cooperation stand out as examples for the United States, such as the National Infocomm Scholarships. While there is no literature evaluating these programs, the continued rapid growth of the infocomm workforce in Singapore shows that these efforts were likely not wasted.

4.2.5 Taiwan

Taiwan is one of the global leaders in ICT hardware manufacturing. In 2008, Taiwan had the world’s largest market share in the production of netbook PCs (99 percent), motherboards (93 percent), notebook PCs (93 percent), and cable modems (90 percent).[537] Between 2005 and 2007, the output of the ICT industry in Taiwan grew at an average annual rate of 14 percent.[538] To sustain industry growth, the ICT workforce in Taiwan has been growing rapidly and there have been a number of initiatives undertaken to ensure that this growth continues. These are discussed in the following sections.

4.2.5.1 NIT Workforce Trends

There is little publicly available data on the size and composition of the ICT workforce in Taiwan. The Taiwan Institute of Economic Research (TIER) estimates that the ICT sector employed about 715,000 workers in 2008, or about 13 percent of the workforce.

[534] IDA (2008)
[535] IDA (2007)
[536] IDA (2007)
[537] Institute for Information Industry (2008)
[538] Taiwan Department of Investment Services (2007)

Employment in the ICT sector grew at about five percent in 2008.[539] The category 1 NIT workforce is likely smaller than the 715,000 estimated by TIER since that includes some non-ICT jobs in ICT firms. However, because much of Taiwan's ICT industry is comprised of original equipment manufacturer (OEM) firms with few marketing or other non-technical roles, a significant portion of the jobs in the ICT sector are likely in ICT occupations. TIER estimates that, in 2008, there was a demand in Taiwan for 40,000 new ICT workers, of which 15,000 were in fields of information services and digital content. TIER estimates that this demand will shrink to 30,000 in 2009, as there is a decreasing demand for hardware engineers and only a slight increase in demand for workers in information services and digital content. Tristan Liu, an economist at TIER, commented, "for the last five years, the ICT sector has been the top industry in terms of R&D and job creation … If you don't count the service sector, it is still the fastest-growing sector in Taiwan."[540] While there is no exact estimate of the size of the Taiwanese NIT workforce consistent with the category 1 definition used in this report, we can say with some certainty that it is in the hundreds of thousands and that it is growing relatively rapidly. There is no available breakdown of the Taiwanese NIT workforce by sector or citizenship.

While there are little data available on the number of foreign NIT workers in Taiwan, foreign workers play a significant role in the overall Taiwanese workforce. Like other countries with developing economies, Taiwan experienced a brain drain in the 1970s and 1980s that began to reverse in the 1990s.[541] The reverse is often attributed to decades of investment in education and infrastructure in Taiwan. The most striking example is the Hinschu Science-based Industrial Park, an attempt to create a center of investment and technology like Silicon Valley. This attracted foreign workers including both expatriates and those born abroad. These efforts were very successful, with the park employing 102,000 people in 2000.[542] Officially, Taiwan has relatively strict requirements for foreign workers, including being a university graduate with at least two years of work experience. These rules are often relaxed in occupations where there are shortages.[543] More recently, efforts have been undertaken to expand the number of high-skilled foreign workers in Taiwan. In 2007, Taiwan created the National Immigration Agency (NIA) to "facilitate the migration of highly skilled people into Taiwan by streamlining the entry procedure and helping immigrants adapt themselves to Taiwanese society."[544] Taiwan sees highly skilled foreign workers as an important part of its workforce.

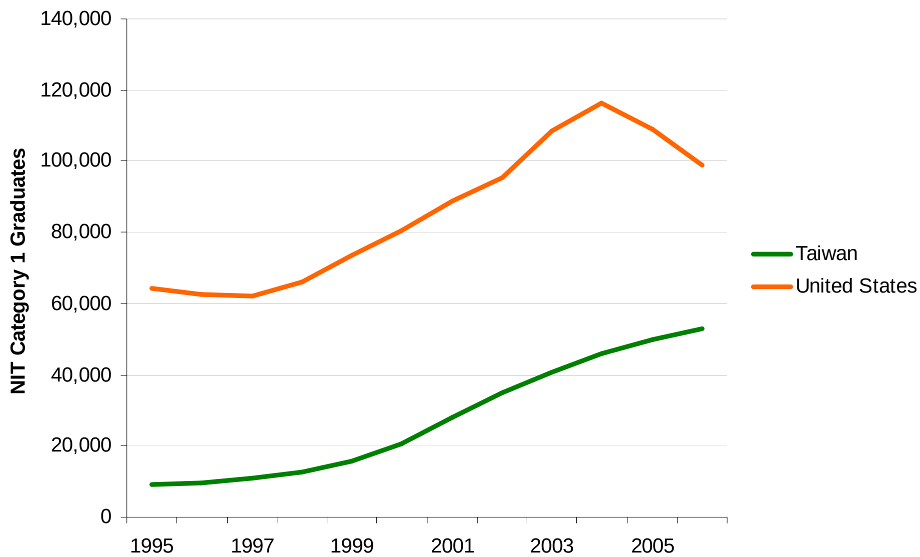
4.2.5.2 Supply of NIT Graduates

The Ministry of Education of Taiwan provides a good set of historical data describing the enrollments and graduates in NIT degree fields. Figure 4.15 compares the number of NIT degrees awarded at all levels in Taiwan between 1995 and 2006 to the number in the United States. While the number of NIT degrees awarded in Taiwan is significantly lower

[539] Rickards (2009)
[540] Rickards (2009)
[541] O'Neil (2003)
[542] O'Neil (2003)
[543] Her (2007)
[544] Her (2007)

than in the United States, it has been growing rapidly. Taiwan produced about half the number of NIT degrees awarded in the United States in 2006.

Figure 4.15: NIT Degree Comparison: Taiwan and United States (1995-2006)



Source: Republic of China (Taiwan) Ministry of Education and NCES

Compared to the relative number of engineering graduates in the United States, China, and India, ranging from 100 to 300 per million citizens, Taiwan awards many more degrees per capita, about 3,000 NIT degrees per million citizens.

4.2.5.3 Programs and Initiatives

To support the growth of its ICT industry, Taiwan has prioritized foundational ICT education policies and promotion of ICT through the education of teachers and students. The Computer Center of the Ministry of Education (MOECC) has taken the leading role in developing National ICT Education Plans. The Ministry of Education (MoE) has begun several initiatives to develop the ICT workforce including setting up competitions on how to stimulate IT usage in primary and secondary schools and developing interactive learning tools. For example, the MoE created the History and Culture Learning Net, an application to nurture active, creative, and cooperative learning of historical facts and figures.[545] Another example is the Educities initiative. Under the auspices of the National Science Council and the MoE, Educities was created in 2000 to help facilitate knowledge diffusion. Educities is an "open online educational platform" that allows the participants, such as the scholars, teachers, parents, and students to come together and create and share online instructional and educational resources.[546] To further facilitate teaching and research activities for schools, the Ministry of Education, National Science Council, and Academia Sinica established the Taiwan Network (TANet). Currently, TANet provides students, teachers, and employees of schools at all levels with

[545] Taiwan Ministry of Education (2007a)
[546] Educities (2006)

network services and encourages the sharing of resources. As of 2006, TANet's network services are available to an estimated 3.99 million people.[547] Besides general online education platforms like EduCities and TANet, the MoE also established "network teaching platforms." In 2006, the Network Application & Service Center at the National Chi Nan University was created with support from the MoE. This was specifically targeted at remote areas and students from financially disadvantaged families in Taiwan.[548]

The MoE has also revised its educational policies to include ICT skills. In 2006, ICT courses were included in the guidelines for primary and secondary education. This included a policy that information courses will become electives in senior high schools starting in 2009. The MoE also recognized that in order to raise the quality of ICT education for students, it was necessary to do the same for teachers. The Ministry of Education established standards for various kinds of infrastructures in order to obtain funding to turn primary and secondary schools into comprehensive e-schools, which allows teachers and students to access e-learning services easily.[549] Over the years, more than one million teachers have participated in training courses on ICT. The MoE has established websites such as a "learning gas station," the Education to E-learning (Etoe) learning resources net, and Six Major Learning Nets to be used by teachers, students, and parents across the nation.[550] The learning gas station focuses on providing content and teaching materials, whereas the Etoe learning resources net emphasizes the sharing of teaching resources and the Six Major Learning Nets is an e-learning tool. The MoE aims to expand the sharing of learning resources in both the public and private sectors. Therefore, the MoE also plans to standardize course materials to allow the digital sharing of information to teachers in different cities, counties, and areas.[551]

As in other countries, there is a perceived disconnect between ICT skills taught in school and those desired by Taiwanese industry. The Taiwan government acknowledged these concerns and has undertaken initiatives to improve course materials in schools. The MoE created a pilot project in 2006 called the Project for Information Technology Teaching and Training. Its main objective is to meet industry needs for high-quality ICT workers by reforming curricula within several universities.[552] The new curricula include software engineering, program design, and embedded system-related courses to help promote fundamental problem-solving skills.

The Taiwanese government has undertaken a number of efforts to include underrepresented groups in the ICT workforce, especially individuals from rural areas. For example, the MoE established Digital Opportunity Centers (DOC) to bridge the digital gap between rural and urban cities. With 200 million USD in aid from industry, rural cities were provided information software, hardware, books, and network installations. From the combined efforts of the industry, government, and academia, 61

[547] Taiwan Ministry of Education (2006c)
[548] Taiwan Ministry of Education (2007b)
[549] Taiwan Ministry of Education (2006a)
[550] Taiwan Ministry of Education (2006a)
[551] Taiwan Ministry of Education (2008)
[552] Taiwan Ministry of Education (2006d)

DOCs in 168 remote areas across Taiwan have been completed. In 2006, 14,000 students were able to enroll in various programs offered by DOCs, while 71,800 used the PCs at DOCs. Furthermore, 2,900 volunteers worked at the DOCs with 13,000 students attending after-school assistance.[553]

Most of the NIT workforce initiatives undertaken in Taiwan focus on integrating ICT into primary and secondary education. These are also important concerns in the United States. Many of the Taiwanese knowledge-sharing initiatives among teachers and students could serve as useful examples for those desiring to improve the use of ICT education in US schools. In addition, like many other countries, Taiwan recognizes that there is a disconnect between ICT education and the skills demanded by industry. Initiatives in this area could also be informative to efforts in the United States.

4.2.6 Japan

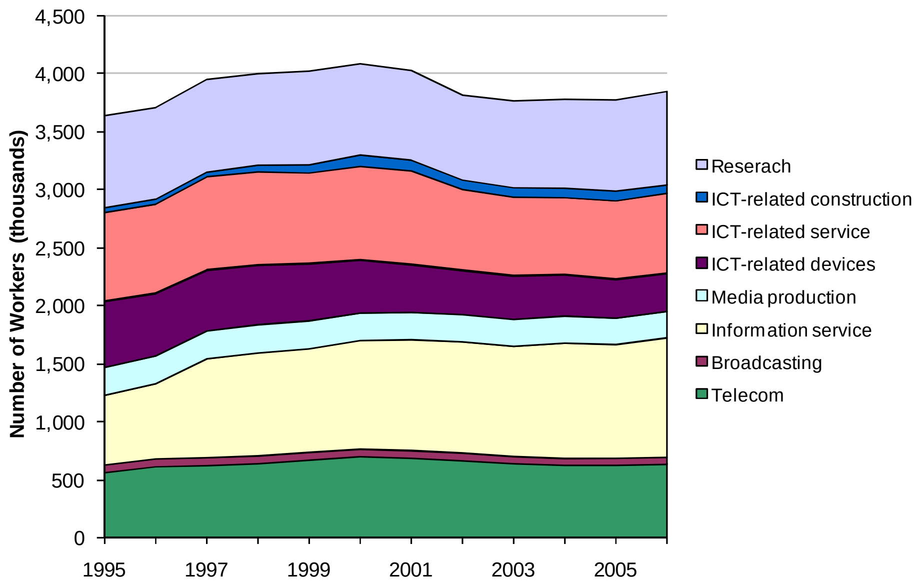
ICT is a significant component of Japan's economy. The Japanese Ministry of Internal Affairs and Communications (MIC) estimates that the ICT industry was responsible for 40 percent of the economic growth of Japan in 2004.[554] Japan's ICT industry is strong in the areas of optics and imaging, components for mobile telephones, and TV and advanced visual content. It has a significant market share in DVD recorders at 69 percent, plasma display TVs at 54 percent, and digital cameras at 74 percent.[555] Japan has also focused a lot of effort on studying and improving its NIT workforce, as discussed below.

4.2.6.1 NIT Workforce Trends

While Japan generates a lot of data on the NIT workforce, there are very few estimates that are consistent with the definition of the category 1 NIT workforce used in this report. The MIC collects data on employment in the ICT sector in Japan. These data capture employment in the ICT sector and not the number of ICT workers. Many workers in ICT firms are not ICT workers and many ICT workers work in non-ICT firms. Nonetheless, this serves as an indicator of the relative size of the ICT workforce. Figure 4.16 shows employment in the ICT sector in Japan between 1995 and 2006.

[553] Taiwan Ministry of Education (2006b)
[554] MIC (2007)
[555] Myoken (2008)

Figure 4.16: Employment in the ICT Sector in Japan (1995-2006)

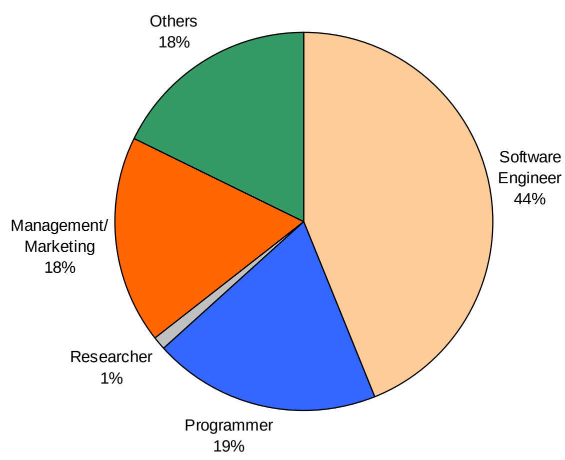


Source: Japan Ministry of Internal Affairs and Communications (2008a)

According to the figure above, the ICT industry in Japan employed about 3.8 million people in 2006, down from a peak of about 4 million in 2001. Employment in the ICT-related devices sector declined by almost 50 percent from 1995 to 2006, while employment in other sectors remained relatively stable.

There are also data available on the type of ICT workers in Japan. The Japanese Ministry of Economy, Trade, and Industry (METI) conducts a survey of large ICT firms in Japan. This survey estimated that there were about 700,000 workers in the large ICT firms in Japan in 2007. Figure 4.17 shows the breakdown of these workers by occupation.

Figure 4.17: Japan ICT Workforce by Occupation (2007)



Source: Japan Ministry of Economy, Trade, and Industry (2008)

The majority of ICT workers in large firms are software engineers (44 percent) followed by programmers (19 percent). There are no available data breaking out the demand for IT workers who are Japanese citizens.

There is little information available on the representation of women in the Japanese IT workforce. However, one indicator available at the R&D level is the fraction of IT patents awarded to women. From 1980 to 2005, the National Center for Women and Information Technology calculated that 6.5 percent of Japanese IT patents had at least one female inventor. This was lower than in the United States, where nine percent of IT patents were awarded to women over the same time period.[556]

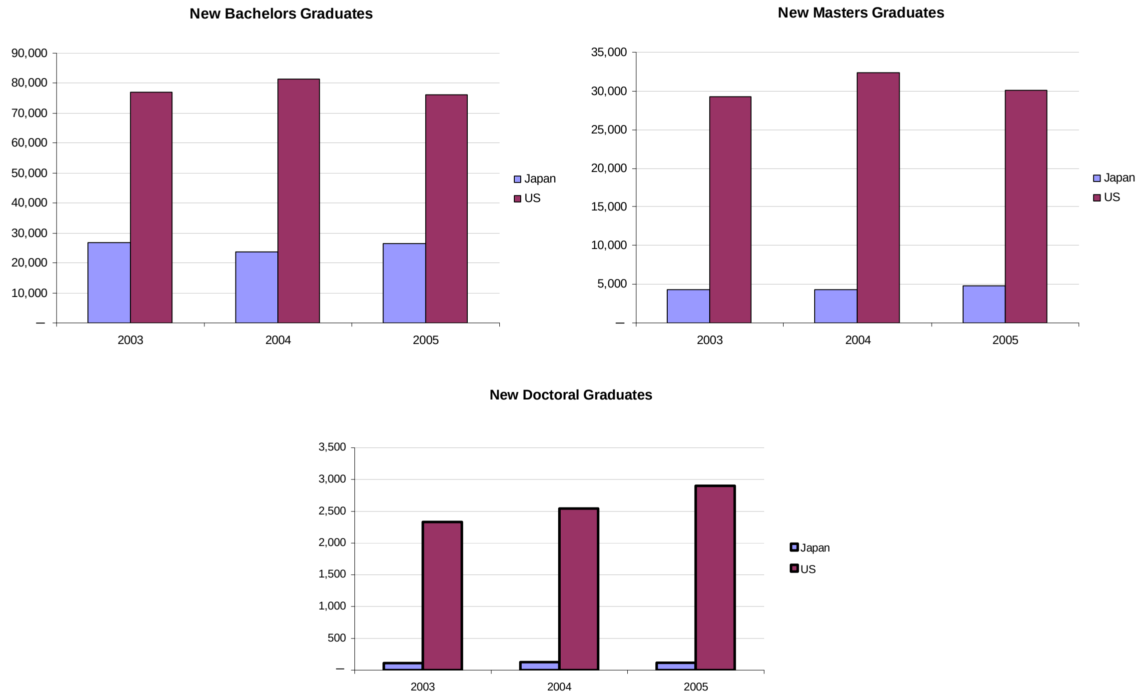
While there are little data on the policies of Japan with respect to foreign IT workers, Japan's foreign worker policies are strict compared to other countries.[557] In the 1990s, the government of Japan loosened its policies to make it easier for foreign workers to immigrate to Japan. This led to an increase in inflows of high-skilled foreign workers.[558] In 2004, there were an estimated two million foreign workers in Japan.[559] A significant portion of these were likely high-skilled workers. The number of visas granted by Japan to high-skilled workers increased 75 percent from about 140,000 in 1992 to almost 250,000 in 1999.[560] In ICT fields, the OECD reported that Japan has become increasingly reliant on workers from China due to domestic skill shortages.[561] In 2000, 36 percent of foreign workers in Japan were from China, second only to The Philippines at 46 percent.[562]

4.2.6.2 Supply of NIT Graduates

Japan's Ministry of Education, Culture, Sports, Science, and Technology (MEXT) publishes statistics on the number of new graduates entering employment each year by degree level and field. Figure 4.18 shows the number of graduates entering information and communications fields for each degree level in Japan compared to the United States.

[556] NCWIT (2007b)
[557] Fuess (2003)
[558] Fuess (2003)
[559] Takeda (2006)
[560] NSB (2004b)
[561] OECD (2006), p. 146
[562] Chalamwong (2004)

Figure 4.18: Number of New Graduates Entering Employment in Information and Communications (2003-2006)



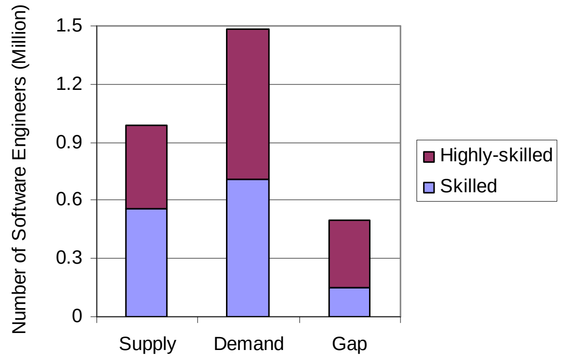
Source: MEXT and NCES

Japan awarded on average 25,000 bachelor's degrees, 5,000 master's degrees, and 100 doctoral degrees in ICT each year for the past three years. This is significantly fewer than the number awarded in the United States and is likely to remain that way given the smaller size of Japan's population. On a per capita basis, Japan produced fewer degrees at the bachelor's, master's, and doctoral level (208, 38, and 0.9 degrees per million inhabitants respectively) than the United States (248, 98, and 9 degrees per million inhabitants respectively) in 2005.[563]

In order to determine whether a shortage of ICT workers existed, Japan conducted a study on ICT workforce development in 2007. This study estimated the supply of software engineers in Japan to be about 900,000 and demand for these engineers to be about 1.5 million. This results in a gap of over 500,000 software engineers, as shown in Figure 4.19.

[563] MEXT, NCES, and CIA World Factbook

Figure 4.19: Software Engineer Supply/Demand in Japan (2007)



Source: Japan Ministry of Internal Affairs and Communications (2008b)

The overall size of the NIT workforce in Japan is likely to be somewhere between the estimated supply of one million software engineers and the estimated four million workers employed in the ICT sector.

4.2.6.3 Programs and Initiatives

The IT Strategic Headquarters is the main body that provides high-level guidance for NIT policy in Japan. In 2006, the IT Strategic Headquarters developed the *New IT Reform Strategy*, which set high-level priorities in Japanese NIT policy through 2010. This strategy marked a turning point from a hardware-oriented policy (where the Japanese government has aggressively invested in building infrastructure) to a software-oriented policy. In order to implement the strategy, the IT Strategic Headquarters requested that the government address the shortage of skilled software engineers by 2010.

A number of Japanese government ministries – including MIC, MEXT, and METI – have funded programs to develop and strengthen the NIT workforce in Japan. These programs are summarized below.

<u>Ministry of Internal Affairs and Communications (MIC) Programs</u>

Between 2005 and 2007, the MIC funded a program for developing Project Based Learning (PBL) materials. The target users of the PBL materials were program managers in 2005, information technology architects in 2006, and ICT managers in 2007. In response to the *New IT Reform Strategy* released by the IT Strategic Headquarters in 2006, the MIC organized the Commission for ICT Global Competitiveness and requested the commission set a short-term goal to increase Japan's competitive edge in the global software market. The commission was comprised of key figures from Japanese industry, government, and academia. The commission's report requested the MIC to increase investment in software R&D (Research and Development), software standardization, software workforce development, and public relations to increase the international visibility of Japanese software enterprise business. The report listed seven goals, one of which focused on the NIT workforce, including:

- Reviewing workforce development programs of other counties that export skilled software engineers, such as China and India, and developing a plan for establishing a national center for software workforce development;
- Developing pilot curricula and PBL materials for higher education institutions to foster skilled software engineers;
- Providing an opportunity for young software engineers to participate in large-scale software development projects implemented in national R&D institutions, such as the Japanese National Institute of Information and Communications Technology.

The workforce development goals required considerable time to be implemented, and the Director-General for Information and Communication Policy Planning organized a study group in 2007 to create an actionable plan to achieve these goals. The workforce study group consisted of key figures from industry and academia. The group discussed the key barriers to developing a skilled software workforce and explored ways to address these issues. The workforce study group released a report in 2008, which included the following findings and recommendations.[564]

- Software services are a relatively new business and still evolving. The highly skilled personnel who are capable of utilizing state-of-the-art software technology to solve problems in their corporate activities and increase labor productivity have a crucial role in their companies. However, the corporate culture has not matured enough to reward such personnel. A career path for such personnel has not been created in many companies, and very few companies have systematic programs for developing such personnel.
- Software engineering also has a relatively short history as an academic discipline and is evolving. Both companies and universities have been too busy in keeping up with the latest changes to cooperate in developing the workforce from a long-term perspective. As a result, a large discrepancy exists between the skills taught to students in universities and the skills expected by companies. For example, academic programs emphasize programming practice and basic theory of computer science, while companies place a high value on design and modeling, project management, and communication skills. Furthermore, the academic community puts too much emphasis on publishing articles, while companies desire practical application.
- Many Japanese software vendors have trained their entry-level software engineers by themselves. However, competition in the global software market is increasing, and they expect universities to reduce their training burden or hire skilled engineers from China, India, etc.
- The Japanese government, industry, and academia have worked hard to solve the problems listed above, but their efforts have been fragmented. The workforce

[564] MIC (2008b)

study group recommended the establishment of the national center to coordinate these efforts and to link the Japanese efforts with international ones.

Based on the findings and recommendations of the workforce study group, the MIC revised the ICT Global Competitiveness Program in 2008 and reorganized the seven measures under three new missions: (1) build a national platform for increasing the global competitiveness of Japanese software services, (2) promote R&D projects to enhance Japan's hardware advantage, and (3) implement the strategy for increasing Japan's competitive edge in the global software market.

Ministry of Education, Science, and Technology (MEXT) Programs

The MEXT implements the Program for Development of Leading IT Specialists. This is a four-year program running from 2006 through 2009, for which the MEXT has provided funding of about 8 million USD annually. The purpose of this program is to provide university students with a variety of professional courses to develop their software skills. Both software vendors and high-tech companies that use software to increase the value of their products have provided professional training courses through this program. These courses include lectures on project management, corporate operations, social issues, export control, and trade issues.

Ministry of Economy, Trade, and Industry (METI) Programs

From 2004 through 2006, the METI funded the Industry-University Partnership Program for Practical IT Training. Through this program, the METI funded universities and vocational schools to incorporate practical training courses from software vendors and companies into their curricula. Approximately 2,500 students took these training courses. Considering that the number of computer science graduates in Japan is around 20,000 annually, more than one tenth of the graduates took these training courses. In 2008, the METI also started a program to honor company employees annually for their contributions to standardizing IT skills and helping other employees develop these skills.

Industry-Driven Initiatives

The shortage of the skilled software engineers has been a serious problem for Japanese companies. The Japan Federation of Economic Organizations (JFEO) conducted a survey with its member companies to understand their workforce problems. Findings of the survey included:

- Computer science programs of Japanese universities were too academic to give their students practical skills, and less than ten percent of graduates in computer science were ready to work;
- Most of the JFEO's member companies provided their entry-level software engineers with own training, but 20 percent of them were not ready to work even after taking this training;
- Japanese companies expected universities to produce a steady stream of 1,500 graduates annually in the specialized field of software engineering.

In 2005, the JFEO recommended that Japanese companies, government agencies, and universities work together to meet the target of producing 1,500 graduates in software engineering by 2010 and doubling that number over the long run. In 2006, the JFEO organized the Working Group for Highly Skilled NIT Workforce Development under its Information and Communications Committee and requested that the Working Group examine approaches to achieve these goals.

The various Japanese government agencies took the JFEO recommendation seriously and cooperated with the Working Group for software workforce development. For example, members of the Working Group joined the MIC study group as observers, and assisted the study group in making the actionable plan for workforce development. The Working Group also assisted the MEXT in designing the Program for Development of Leading IT Specialists and in reviewing proposals for the program from universities. The Working Group also assists in the following ways:

- Members assist universities in setting project goals and developing curricula for their professional courses.
- The companies of the Working Group members volunteer their employees as lecturers. This includes four full-time lectures (two for each university) and around one hundred part-time lectures.
- The companies of the Working Group members offer students taking the professional courses financial aid (up to 2000 USD monthly per student).
- Members give speeches to motivate current and potential students taking the professional courses to pursue a career as a software engineer.
- Twenty companies of the working group members offer about fifty summer intern positions for students.

Although companies, government agencies, and universities have cooperated to impart practical skills to students, their efforts are still fragmented and they are far from meeting the target of 1,500 graduates annually. In 2007, the JFEO called for establishing a national center to organize these endeavors. Programs funded by the government have fixed periods and the universities find it hard to offer their training courses continuously after the government funding runs out. The national center would consolidate the resources accumulated through these programs. It would also serve as a hub for the software workforce development initiatives. As mentioned in the previous section, the MIC's ICT Global Competitiveness Program also endorsed the establishment of the national center. The MEXT Program for Development of Leading IT Specialists currently encompasses some of the functions that would be assigned to a national center. The MEXT program will end in 2009, and the JEFO called for establishing the national center in early 2009 to transition seamlessly from the MEXT program.

Many of the Japanese initiatives relating to the NIT workforce have focused on improving the connection between NIT employer needs and NIT curricula. This is also an issue in the United States, and some of the Japanese programs, such as the Program for

Development of Leading IT Specialists, could serve as examples for those wishing to address this problem in the United States. Japan is also hoping to centralize NIT workforce efforts, something that is rarely discussed though may be worth considering in the United States.

4.2.7 Republic of Korea

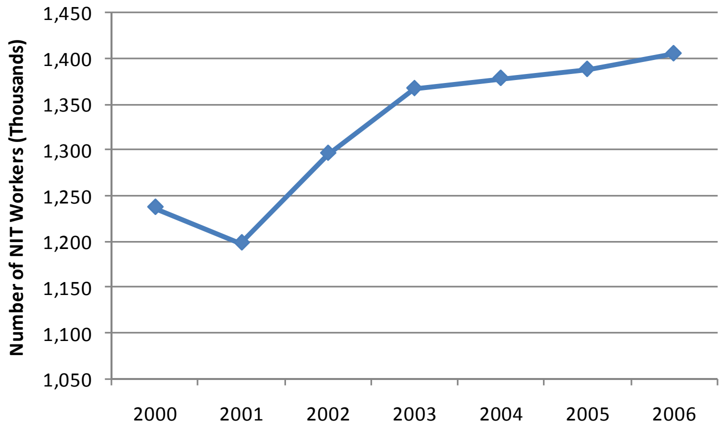
South Korea is among the world leaders in information technology hardware production. Korea accounts for almost six percent of the world production and export volume in the NIT industry.[565] In 2008, the Korean Ministry of Knowledge Economy released a plan to guide the development of the Korea IT industry over the next five years.[566] Currently, Korea has a strong competitive advantage in semiconductors, display panels, memory chips, and wireless communication devices.[567] The new plan attempts to build upon these capabilities with a focus on applications in automobiles, radio frequency identification (RFID) devices, and Internet protocol TV (IPTV).[568] Korea's NIT workforce is well studied and there are a number of initiatives underway to address the perceived shortfall of workers discussed in the following sections.

4.2.7.1 NIT Workforce Trends

The Korea Association of Information & Tele-communication (KAIT) estimates that the size of the NIT workforce in Korea was about 1.4 million in 2006. This includes both category 1 and category 2 NIT workers. Figure 4.20 shows the size of the Korean NIT workforce between 2000 and 2006. The NIT workforce in Korea grew at an average rate of about 2.3 percent per year between 2000 and 2006. Data from the Korea Employment Information Center show that about 50 percent of the NIT workforce have bachelor's degrees or higher.[569] Therefore, the size of the category 1 NIT workforce in 2006 was likely around 700,000.

[565] Research and Markets (2005)
[566] Tong-hyung (2008)
[567] Tong-hyung (2008)
[568] Tong-hyung (2008), EE Times Asia (2008)
[569] Korea Employment Information Center (2006)

Figure 4.20: Korean Category 1 and 2 NIT Workforce in Thousands (2000-2006)



Source: KAIT (2006)

In 2005, women comprised 42 percent of the Korean workforce but only 26 percent of NIT occupations. Their representation is lower in service IT jobs (18 percent) than in manufacturing IT jobs (41 percent). Outside of the IT sector, this trend is reversed with a greater fraction of women in non-IT service jobs (49 percent) than non-IT manufacturing jobs (31 percent).[570]

The Korean Employment Information Center conducts an occupational employment structure survey each year. Table 4.8 shows trends in NIT occupations from 2001 to 2005 in Korea. Over this time period, there has been a decrease in the fraction of NIT workers in software/system development and digital contents occupations while there has been an increase in the fraction of workers in hardware maintenance occupations.

Table 4.8: Percentage of Korean NIT Workforce by Occupation

	2001	2002	2003	2004	2005
Software/System development, design occupation group	19%	17%	16%	16%	15%
Digital contents occupation group	9%	9%	5%	5%	6%
System operation/administration occupation group	11%	13%	13%	14%	14%
Hardware development, design occupation group	11%	14%	17%	13%	11%
IT education occupation group	11%	12%	14%	12%	12%
IT technology sales occupation group	7%	5%	4%	6%	7%
Hardware maintenance, communication and media service occupation group	32%	30%	31%	34%	35%

Source: Korea Employment Information Center

There are little data available on the fraction of NIT jobs that require Korean citizenship. However, looking at the policies on high-skilled foreign labor can provide some insights. Since 1991, the Korean government's policy toward foreign workers has been "to accept workers as technical trainees to solve the country's labor shortage problem."[571] From 1994 to 2000, the number of foreign workers in Korea grew rapidly from 30,500 to 122,500. As for Japan, China has been the largest source of foreign workers in Korea

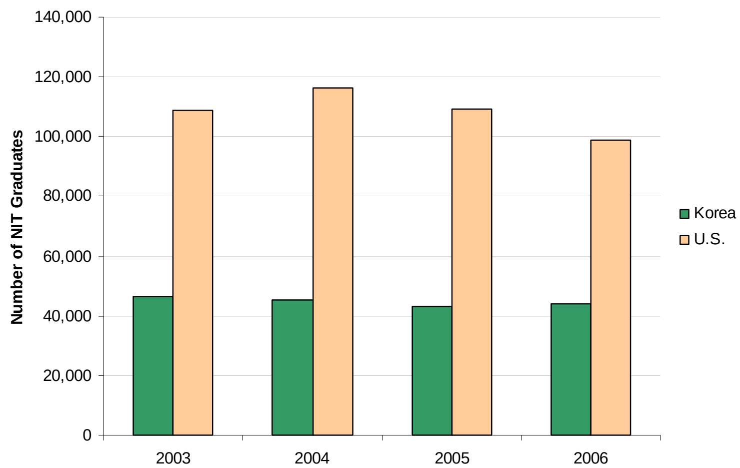
[570] Korea Employment Information Center (2006)
[571] Chalamwong (2004)

comprising 35 percent of the total foreign labor force in Korea in 2000.[572] The majority of these workers are high-skilled workers. As the OECD reported in 2004: "Japan and Korea share a determination to confine immigration to highly-skilled workers."[573] Given the importance of ICT to the Korean economy, many of these workers are likely in ICT fields.

4.2.7.2 Supply of NIT Graduates

From 2003 to 2006, Korea awarded about 46,000 category 1 NIT degrees each year. This is about 40 percent of the number awarded in the United States, as shown in Figure 4.21. However, Korea awarded more NIT degrees on a per capita basis (917 per million inhabitants) than the United States (323 per million inhabitants) in 2006.[574]

Figure 4.21: Korea vs. US Annual NIT Graduates (2003-2006)



Source: KISDI (2007) and NCES

Unlike many other countries we have examined, the number of IT graduates in Korea has not been growing rapidly, as shown in Table 4.9. While the number of IT graduates increased between 2003 and 2005, the number declined between 2005 and 2006 at both the undergraduate and graduate level. At the same time, the growth in the number of total degrees awarded slowed from about six percent between 2003 and 2004 to less than one percent between 2005 and 2006.

Table 4.9: Number and Percentage of Korean NIT Graduate, by Degree Level (2003-2006)

Level of Degree	2003	2004	2005	2006
Undergraduate IT Degrees	30,431	32,114	32,766	32,346
Graduate IT Degrees	6,387	7,071	6,924	6,194
Total IT graduates (Undergrad + Grad)	36,818	39,185	39,690	38,540

Source: KISDI (2007)

[572] Chalamwong (2004)
[573] OECD (2004)
[574] KISDI (2007), NCES, and CIA World Factbook

Projections for IT degree production in Korea at the bachelor's level and beyond show only a slight increase for 2011 compared to 2007 (0.4 percent increase at the bachelor's level and 3 percent at the master's and doctoral levels).[575]

Korea is one of the few countries outside of the United States that projects the supply and demand for its NIT labor force. In 2007, a team of researchers at Korea Information Society Development Institute (KISDI) published a report titled *Labor Market Forecasts for IT Professions*.[576] The methodology used by the KISDI researchers to project future workforce demand was based on the BLS methodology. Table 4.10 shows the KISDI's estimates for supply and demand over the period 2007-2001 for IT workers. The KISDI estimates a shortage of about 10,000 category 1 NIT workers between 2007 and 2011.

Table 4.10: Korea IT Workforce Supply and Demand Forecast (2007-2011)

	Graduate degree	Undergraduate	All Degree Types
IT workforce supply (A)	33,594	136,009	169,603
IT workforce demand (B)	43,341	137,127	180,468
Gap (A-B)	-7,747	-2,882	-10,629

Source: KISDI (2007)

The shortage of workers in Korea is projected only in software fields, while hardware and other fields are projected to have surpluses of workers between 2007 and 2011 as shown in Table 4.11.

Table 4.11: Gap (A-B) in Supply and Demand by Field and Degree Type (2007-2011)

	Graduate degrees	Undergraduate degrees	All Degree Types
Software	-19,402	-32,110	-51,512
Hardware	2,922	2,453	5,375
Others	8,732	32,540	41,272
Subtotal	-7,747	-2,882	-10,629

Source: KISDI (2007)

Korea appears to face the same problem as the United States, with increasing demand for category 1 NIT workers coupled with a declining or constant supply of NIT graduates. In both countries, this issue is more of a concern in software-related fields than it is in hardware fields.

4.2.7.3 Programs and Initiatives

From 1994 to 2008, the Ministry of Information and Communication (MIC) in Korea was the leading force in designing ICT policy. The MIC was closed down in 2008 and its main function of supporting the ICT industry was assigned to the Ministry of Knowledge Economy (MKE). In part, this change was motivated by the political philosophy of the new administration in Korea, which aims to reduce the size of the government. A major reason for merging the two ministries was that the technologies were merging (referred to in Korea as fusion technology). The government believes that to create a national system

[575] Korea Division of Human Resource Development (2008)
[576] KISDI (2007)

of innovation that can encourage development of fusion technology, the ministries in charge of different technology areas should be merged.

Under the MIC and now the MKE, the Korean government has paid considerable attention to and committed significant resources to building the IT workforce. However, in 2008, the total amount allocated for IT workforce development was decreased by 8 percent to KRW 97.8 billion ($73 million US dollars).[577]

Korean initiatives for encouraging interest and engagement in ICT careers are largely focused on the higher education sector and the retraining of the existing IT workforce. In terms of quantity, Korea now produces more college graduates than the market can absorb, and the lack of jobs for the younger generation has become a critical issue. However, Korean industry continues to express dissatisfaction with the quality of training students receive at universities, and there is concern about the high cost of company training of new hires. There are also concerns about retraining the existing workforce to stay competitive in the fast changing fields of ICT.

Korea can compete globally in ICT hardware and manufacturing, such as manufacturing memory chips, LCD displays, and mobile phones. However, the software sector in Korea is relatively weak and plagued by many problems. The profit margins are thin in the software market, which translates into small sizes of software companies, low wages, and lack of job security.

The lack of interest in majoring in science and engineering fields among high school students has also been a serious concern for the Korean government. So far, the IT sector has been less affected by this trend because the job market is still strong and IT manufacturing companies such as Samsung and LG are leading companies with high prestige.

Korea’s master plan for ICT workforce development focuses on three areas: training highly skilled ICT researchers, retraining the existing workforce, and upgrading university education. Representative policy initiatives in each of these areas are described below.

4.2.7.4 HANIUM Cyber-infrastructure Program

HANIUM is the Korean word for "link to one," and its mission is to provide a service that links enterprise and educational institutions. The Institute for Information Technology Advancement (IITA) developed the HANIUM site in 2004 to train an IT workforce that can meet industry’s demand.[578] This site was designed to allow online communication for industry-university collaboration. HANIUM supports a program that enlists IT professionals in industry to mentor students. As of 2008, 1,400 IT professionals were registered as IT mentors. HANIUM is also a place to find internship opportunities that can lead to permanent positions. A limitation of the HANIUM program is that, even

[577] $1 = KRW 1338.40 as of April 24, 2009
[578] http://www.hanium.or.kr/engl/ScmAdminServlet?cmd=main

with government support, top universities and companies do not actively participate. They do not have as strong a need to participate as second-tier universities and small/medium-sized companies. Unfortunately, their lack of participation diminishes the prestige of the HANIUM program.

4.2.7.5 Strengthening Research Capabilities of Universities: Information Technology Research Centers (ITRCs)

To train high-level researchers and strengthen research capabilities at universities, the MKE supports centers of excellence programs in universities called Information Technology Research Centers (ITRCs). The annual budget for the ITRCs is USD 23 million, which supports about 45 centers each year.[579] The ITRCs are encouraged to work closely with industry partners. There are many other centers of excellence programs supported by other ministries (such as Engineering Research Centers and Science Research Centers supported by the Ministry of Education, Science, and Technology), but the ITRCs focus on IT fields and has been successful in developing close cooperation between universities and the IT industry sector. Other programs designed to strengthen university research capabilities include a fellowship program for international students and support for bringing international scholars to Korean universities.

4.2.7.6 IT Curriculum Improvement – NEXT Program

The NEXT (Nurturing EXcellent engineers in information Technology) program is designed to encourage improved quality of IT education in Korean universities. Once awarded, a university IT department receives USD 150,000 per year for four years. The department curriculum must be certified by the ABEEK (Accreditation Board for Engineering Education of Korea) to ensure that the curriculum meets certain standards and industry needs. The ABEEK is modeled closely after the Accreditation Board for Engineering and Technology (ABET) in the United States. It is a joint effort between engineering societies, the Korean National Academy of Engineering, industry, and government. The ABEEK is the only body in Korea that certifies engineering education.

One of the goals of the ABEEK is to provide curricula that will help university graduates be effective employees immediately after they are hired, without the need for retraining by companies. Samsung is most enthusiastic in supporting ABEEK certification. For example, Samsung declared that it will give job applicants 10 percent extra credit if they have completed a curriculum certified by the ABEEK. This is significant enough to make a difference in the hiring process. Other companies are not yet following Samsung's lead, but Samsung's new policy is having a major impact on Korean universities. Since Samsung's announcement, many engineering departments have started the ABEEK certification process. With the help of the NEXT program, ICT departments are actively seeking ABEEK certification.

[579] Korea Division of Human Resource Development (2008)

4.2.7.7 Retraining Program for IT Workforce

After the economic crisis in 1997, the Korean government provided a major retraining program for employees who were laid off. A stigma was attached to those who went through the retraining program, with the result of weakening support for government retraining. Recently though, the need for providing retraining for the ICT industry has been recognized and the budget for retraining has increased.

There are several different retraining programs. The Short Term Retraining Program for the IT Industry aims to provide customized programs (training schedule, location, and contents) for specific companies. Other programs target specific subfields of ICT, such as software and the digital contents industry. The total amount of funding in 2008 for all of these programs was USD 12.6 million.[580]

4.2.7.8 Summary

Overall, Korea is devoting a significant amount of effort to address its ICT workforce issues. To align industry needs with IT curricula, Korea created the ABEEK. Due to the significant political power of IT firms in Korea, it appears as though these efforts are affecting higher education in Korea to a greater degree than similar efforts are in the United States. Korea also has a better system than in the United States to track the career paths of its graduates and to collect data that are more detailed on the state of its workforce. This is due in part to the fact that Korea is a smaller country than the United States and that it is generally easier for the Korean government to implement data collection requirements. Korea faces many problems that are similar to those facing the United States, including the declining interest in ICT majors among college students and the underrepresentation of women. While there are efforts underway to address these issues, they are not very different from those underway in the United States.

4.3 Gaps in International Information

As noted in the previous sections, there are a number of gaps in the information available on the international NIT workforce. On the demand side, most of the countries we studied provide data on the current size of the NIT workforce and some provide short-term projections. Few countries, with the exception of the EU and Korea, provide long-term projections like those provided by the BLS for the US workforce. For the international data that are available, varying definitions make comparisons difficult. Some countries, such as Korea and Singapore, report data of quality similar to data provided in the United States, but this is not the case more generally. While the International Labor Organisation attempts to provide consistent labor force measures at a high level of aggregation, these data do not have enough detail to analyze the global NIT workforce.

China is the most striking example of a lack of data encountered in this report. China provides the least amount of data on both its workforce and educational system. On the demand side, we were only able to find rough, dated estimates for the size of the NIT workforce in China. In regards to supply, after much effort trying to estimate the number

[580] Korea Division of Human Resource Development (2008)

of NIT graduates in China, Gereffi and Wadhwa could only estimate the number of engineering graduates. Considering the perceived importance of the Chinese workforce to the future of the US NIT workforce, this represents a glaring need. The inability to estimate the number of NIT graduates is also an issue for other countries we studied, including the EU and Singapore. These countries do not provide sufficient detail in their educational data to estimate the number of NIT graduates. This is often because NIT-related engineering degrees are not broken out separately from other engineering degrees. Lastly, while workforce data provided by India are better than for most countries, there is a lack of high-quality trade data needed to estimate the magnitude of outsourcing in the services sector. Given India's position as the most popular location for offshoring IT functions, this trade relationship is important to understand. Chinese workforce data and US-India trade data are two key deficiencies in the information needed to address the major issues facing the US NIT workforce.

In regards to programs to support the NIT workforce, there was sufficient information available for all of the countries studied. However, while we conducted searches in many languages to identify key programs, the results of our searches may be biased towards programs funded through international cooperatives and by governments. Programs organized at the local level like those funded through small non-governmental organizations (NGOs) are less likely to have web pages or to publish other media materials, and are also less likely to be indexed highly in search engines. Nonetheless, our searches led to a number of programs in each country funded by both industry and government. For comparing best practices and finding innovative ideas in the future, it may be valuable to maintain an up-to-date listing of NIT-related programs undertaken around the world.[581]

4.4 Lessons from Other Fields

In the United States, we found that occupational image problems facing NIT also face the field of nursing. There have been significant shortages of workers in healthcare-related fields in other countries as well. Based on our review of the literature, shortages in healthcare occupations have received the majority of international press and scholarly attention outside of the NIT workforce. As noted, in the United States nursing is regarded as a profession dominated by females. It is also viewed as a profession that lacks the prestige of a physician. The shortage of nurses in the United States is attributable partly to its public image and partly to the lack of nurses with advanced degrees to educate subsequent generations. Other countries are facing similar problems but have the added problem that their well-trained nurses leave to seek opportunities abroad. Most of these countries discussed in this section on lessons from other fields are not the countries that are the focus of the study. We found a lack of literature relating to issues in other occupational fields for the countries studied in this report that are relevant to the NIT workforce.

[581] See Scheer (2008) for an example of utilizing Mind Mapping tools to keep an inventory of workforce programs and initiatives.

Internationally, the global nursing shortage provides an analogous problem to the shortage of NIT workers in the United States. However, the global nursing shortage affects wealthy and poor countries differently. In wealthy nations, the need for nurses is critical as the populations are aging and the number of nurses to provide care is decreasing. In poorer nations, increasing populations are taxing the capacity of healthcare services. In addition, the critical shortage of physicians leads to nurses being the source of primary care for significant segments of the population.

In nursing, as in NIT fields, the workforce strategies of all countries, rich and poor, are dynamically linked. The strategies to increase the number of nurses in wealthier countries fall into four primary categories:[582]

- Improve retention in the education and professional pipeline;
- Broaden the recruitment base (include men, mature entrants, ethnic minorities, less qualified entrants with vocational qualifications and work-based experience);
- Attract former nurses back to the profession;
- Import nurses from other countries.

The last of these strategies, importing nurses from other countries, affects the labor markets in both rich and poor countries. It ultimately shifts the problems associated with the nursing shortage to poorer countries. According to a study on the migration of Indian nurses, approximately 50 percent of new registered nurses in the United Kingdom were from India in 2001. In an extreme example of professional importation, approximately 90 percent of the nurses in Saudi Arabia are from abroad.[583]

These broad strategies, particularly importing talent from foreign countries, raise the issue of a brain drain that is relevant to potential strategies for addressing the shortage of NIT workers in the United States. Advocates for increasing the number of H-1B visas issued for the recruitment of foreign-trained NIT workers often overlook the consequences of the possible brain drain on the home countries of those workers. Undoubtedly, in countries with an imbalance between educational training and employment opportunities, stemming the exodus of skilled workers is a continuous challenge. A 2006 World Health Organization (WHO) fact sheet on the migration of health workers[584] recommended that countries on the exporting side of the divide must focus their strategies on increasing the incentives for nurses and health workers to remain in their home country. The WHO then recommended longer-term strategies such as improving the working conditions for nurses and tailoring their education to suit the specific needs of the country.

Efforts to retain talented workers are afoot in many countries and in many fields. One strategy is to connect educational funding to service. The Gretta Foundation,[585] for

[582] http://www.bmj.com/cgi/content/full/324/7340/751
[583] http://www.human-resources-health.com/content/7/1/5
[584] http://www.who.int/mediacentre/factsheets/fs301/en/index.html
[585] http://www.grettafoundation.org

example, offers scholarships to nursing students in nations with severe health crises. Students are required to serve as nurses in their home country for a period of time that is determined by the years of funding they receive. Other countries, such as Thailand[586] and countries in the Caribbean[587] offer scholarships like the Barbados Island Scholarship and the Royal Thai Scholars Program, which require its recipients to seek educational training in specific fields that contribute to national needs. Upon completion of their education, scholars are required to serve in their home countries and contribute their specialized skills. These attempts by nations facing critical development needs offer potential lessons for the United States' efforts to increase the NIT workforce. One such lesson is to develop funding structures attached to promotional campaigns that contractually connect NIT education to a sense of national service and commitment.

The WHO's recommendations for the importing countries also provide potential lessons for NIT workforce strategies in the United States. The first recommendation is that importing can be reduced through efforts to improve the education of domestic students in NIT-related fields. Such efforts are already underway in the United States. The second recommendation is to develop bilateral agreements with the exporting countries. The strength of the NIT educational structure in India, for example, offers a potential opportunity for such partnerships. Many of the US exchange and study abroad programs for students emphasize cultural exchange.[588,589,590] Finding ways to incorporate global cultural fluency into computing education is a potential lesson that could be taken from international strategies focusing on healthcare occupations.

586 http://www.ts47.org/download/TSProgramDescription.pdf
587 http://www.mes.gov.bb/pageselect.cfm?page=78
588 http://www.isep.org
589 http://www.asse.com
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