History of Computing

William Aspray

Women and Underrepresented Minorities in Computing

A Historical and Social Study

Springer

History of Computing

The History of Computing series publishes high-quality books which address the history of computing, with an emphasis on the 'externalist' view of this history, more accessible to a wider audience. The series examines content and history from four main quadrants: the history of relevant technologies, the history of the core science, the history of relevant business and economic developments, and the history of computing as it pertains to social history and societal developments.

Titles can span a variety of product types, including but not exclusively, themed volumes, biographies, 'profile' books (with brief biographies of a number of key people), expansions of workshop proceedings, general readers, scholarly expositions, titles used as ancillary textbooks, revivals and new editions of previous worthy titles.

These books will appeal, varyingly, to academics and students in computer science, history, mathematics, business and technology studies. Some titles will also directly appeal to professionals and practitioners of different backgrounds.

More information about this series at http://www.springer.com/series/8442

William Aspray

Women and Underrepresented Minorities in Computing

A Historical and Social Study

Springer

William Aspray
Department of Information Science
University of Colorado Boulder
Boulder, CO, USA

ISSN 2190-6831 ISSN 2190-684X (electronic)
History of Computing
ISBN 978-3-319-24809-7 ISBN 978-3-319-24811-0 (eBook)
DOI 10.1007/978-3-319-24811-0

Library of Congress Control Number: 2016941870

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Preface

This book is the second of two books written by this author – and published in the *Springer History of Computing* series – on the history of underrepresentation in the computing disciplines in the United States. These two books can be read entirely independently of one another. The first book, entitled *Participation in Computing*, discusses the role of the National Science Foundation in this effort. This second book presents a more general account of women, African Americans, American Indians, and Hispanics in the computing disciplines in the United States over time.

The writing of these two books was stimulated by a recent grant program of the Alfred P. Sloan Foundation to better understand the underlying causes for the persistent underrepresentation of women in the computing disciplines. African Americans, American Indians, and Hispanics have also been persistently underrepresented in the computing disciplines despite numerous efforts to correct this problem; and thus, this book considers all of the main demographic groups that are underrepresented in computing in the United States.

The author of this book is principally a historian of science and technology, and this work is primarily a history – with particular attention to the formal education that prepares individuals from these underrepresented demographic groups for computing careers. However, one way in which this book differs from the existing historical literature is that it pays considerable attention to the social science literature, which it employs to bolster historical understanding.

Organizational Structure of the Book

This book has two main sections, which can be read entirely separately from one another. The first section presents a digest of relevant literatures, while the second section contains historical case studies.

There are many types of scholars interested in underrepresentation in computing. These include computer scientists, social scientists studying science and technology, education faculty and psychologists studying the learning of science and technology, race and gender scholars, education historians, policy scholars, and historians of computing. The relevant literature on this topic extends across all of these academic literatures. While any interested scholar is probably already familiar with the relevant literature from her own academic discipline, she may have less familiarity with the literatures from the other relevant academic disciplines.

The first section of the book digests these various relevant literatures on behalf of the interested reader. A computer scientist interested in this topic might be willing to read ten pages on the history of women in American science, but he is unlikely to read all of Margaret Rossiter's comprehensive three-volume study of this topic. This first section of the book provides a historical overview, drawing from some of the leading historical and social science sources concerning: college education for women, science and engineering education for women, and higher education as well as STEM (science, technology, engineering, and mathematics) education and careers for African Americans, Hispanics, and American Indians. The value added by this section thus comes from the digesting of a large set of disparate literatures, not from new historical scholarship.

The second section of the book serves a different function. It provides new historical case studies – first about organizations interested in broadening participation in the STEM disciplines generally and in computing in particular and then about college and university departments of computer science and engineering that have had success in attracting, retaining, and advancing women in STEM and computing careers.

Many women and underrepresented minorities who have sought to enter the computing field have received support from various nonprofit organizations. From the 1950s to the 1970s, these organizations were focused on the STEM disciplines broadly, not specifically on computing. While these early organizations continued to operate in the 1980s and beyond, they were joined in the 1980s by organizations specifically focused on computing. Both the early and later organizations are often focused on a single demographic group: women (SWE, AWIS, WEPAN, MentorNet, ABI, CRA-W, ACM-W, NCWIT), African Americans (NSBE, NACME, GEM, BDPA, ADMI, CDC, CMD-IT), Hispanics (SACNAS, MAES, SHPE), or American Indians (AIHEC, AISES).[1] This section of the book provides profiles of each of the organizations listed above – brief ones for the early, STEM-focused organizations, longer ones for the computing-focused organization. Two of these STEM-focused organizations, MentorNet and WEPAN, receive more detailed treatment because of their significant work in the computing community.

These nonprofits are not the only organizations that support the development of human resources for the computing field in the United States. In the author's companion book, *Participation in Computing*, he discusses the Broadening Participation in Computing alliances created with funding from the National Science Foundation,

[1] This statement is a simplification of the target audiences. For example, SACNAS has been interested in American Indians since its founding, although its founders and its target audience were primarily Hispanic. MentorNet began in 1997 focused solely on women, but in 2003 expanded its charter to include diversity more broadly.

such as the Expanding Computing Education Pathways and STARS alliances.[2] The companion book also shows the important role of professional organizations, most notably the ACM, through its Computer Science Teachers Association and its Educational Policy Committee. The National Science Foundation itself is also an important player because of the research and implementation it funds relating to broadening participation in computing.

The second section of this book concludes with a long, single chapter that profiles colleges and universities that have been successful in opening up computer science or engineering to female students. The chapter opens with a discussion of several social science studies that discuss what characteristics make for a department able to attract, retain, and advance female students. Then five case studies of successful departments are given: University of California Berkeley/Mills College, Carnegie Mellon University, Olin College, Smith College, and Harvey Mudd College. Several other colleges and universities are discussed briefly after these five detailed case studies.

Caveats and Acknowledgments

In order to write this and the companion volume so quickly, certain shortcuts were taken. No trips were made to archives to find source materials. There has been an extensive, if not exhaustive, search of the published literature for source materials. More than 900 sources have been consulted in writing these two books. This book relies not only on published books and articles but also on websites, project reports, white papers by nonprofit organizations, existing oral histories, and other sources. The project also involved the recording of a number of new oral histories, and these interviews provide the largest value added to this work. They are housed at the Charles Babbage Institute at the University of Minnesota–Twin Cities and will eventually be made available to other scholars.

Some 25 computer scientists, historians, and social scientists have kindly volunteered their time to advise on this project. Their names and affiliations appear in Table 1. They have devoted many hours providing guidance, opening doors, and critiquing draft chapters. Thanks also to the two doctoral students in the University of Texas at Austin School of Information, Steve McLaughlin and Rachel Simons, who provided research assistance, and to another doctoral student, Melissa Ocepek, who helped to render the references into a form suitable to the publisher. Everyone interviewed for this book as well as all the principal investigators in the Sloan Foundation program that supported this project, in addition to the Project Advisory Group members listed in Table 1, were given a chance to comment on a complete first draft of the manuscript. Their comments led to many improvements in the text;

[2] The one organization covered in both that book and in this one is the National Center for Women & IT (NCWIT).

Table 1 Project Advisory Group

Rick Adrion (U. Massachusetts)
Atsushi Akera (Rensselaer P.I.)
Lecia Barker (U. Colorado Boulder and NCWIT)
Bruce Barnow (George Washington U.)
Paul Ceruzzi (National Air and Space Museum)
Jan Cuny (NSF)
Nathan Ensmenger (Indiana U.)
Mary Frank Fox (Georgia Tech)
Peter Freeman (Georgia Tech)
Juan Gilbert (U. Florida)
Jonathan Grudin (Microsoft)
Thomas Haigh (U. Wisconsin–Milwaukee)
Evelynn Hammonds (Harvard U.)
Peter Harsha (Computing Research Association)
Mary Jane Irwin (Penn State U.)
Martin Kenney (U. California, Davis)
Ed Lazowska (U. Washington)
Ephraim McLean (Georgia State U.)
Thomas Misa (Charles Babbage Institute)
Andrew Russell (Stevens I.T.)
Lucy Sanders (National Center for Women & IT)
Robert Schnabel (ACM)
Bruce Seely (Michigan Tech U.)
Eugene Spafford (Purdue U.)
Moshe Vardi (Rice U.)
Roli Varma (U. New Mexico)
Stuart Zweben (Ohio State U.)

all factual errors and unreasonable interpretations are the sole responsibility of the author.

This study was enabled in part by a grant from the Alfred P. Sloan Foundation, which helped the author to buy out of his teaching for a year and pay for transcription of interviews. The author is also grateful for support from the School of Information at the University of Texas at Austin, which relieved him of some administrative responsibilities for a year and paid for a part-time research assistant for a semester, and for a grant from the Institute of Museum and Library Services, which supported a doctoral student for a semester to assist with the research. Most of the research and writing was conducted while the author was the Bill and Lewis Suit Professor of Information Technologies at Texas, but the last stages of the work were carried out at his new academic home, the Department of Information Science at the University of Colorado Boulder.

Boulder, CO, USA William Aspray

Contents

Chapter 1
Introduction

Abstract This chapter provides an introduction to the two main sections of this book. The first section of the book provides a summary of the historical and social science literature about the history of higher education – and science, technology, and computing education in particular – for women, African Americans, Hispanics, and American Indians in the United States. The second section provides case studies of organizations interested in broadening participation in the science and technology disciplines in general and in computing in particular; as well as case studies about college and university departments of computer science and engineering that have had success in attracting, retaining, and advancing women in engineering and computing careers. The chapter discusses overarching themes that run through the book: exogenous forces (war, civil rights, reverse discrimination, and IT workforce needs); the conceptualization of the underrepresentation problem in terms of a pipeline instead of a pathway; solutions that involve fixing people contrasted with those that involve fixing the system; the role of nonprofit organizations and individual change agents in broadening participation in computing; and the issues surrounding intersectionality, i.e. cases in which someone belongs to two or more underrepresented groups such as being both female and African American.

> *We felt like anomalies…. The women felt the difference most keenly during breaks, when they couldn't join in the inside jokes and casual conversations into which their male colleagues seemed to fall so easily. In a profession so dependent on teamwork and learning new technology, being part of the community is not just a matter of feeling comfortable. It's essential to being competitive.* (Katherine Jarmul, co-founder of PyLadies, as quoted in Shah 2012)

This book addresses the history of underrepresentation of women and certain groups of minorities in the computing field in the United States.[1] The focus is primarily on the formal education of information workers rather than on the workforce

[1] This book employs the contemporary policy language when it speaks of "underrepresented minorities" instead of the term "race", which is more commonly used by historians. Race is, of course, a social construct. At one time in American history, Jews, the Irish, and Eastern Europeans were segregated from Whites as separate racial groups, but today they are all considered as Whites. African Americans, however, have historically been racially segregated throughout American history and continue to be segregated today. Not all minorities are underrepresented in the computing

W. Aspray, *Women and Underrepresented Minorities in Computing*,
History of Computing, DOI 10.1007/978-3-319-24811-0_1

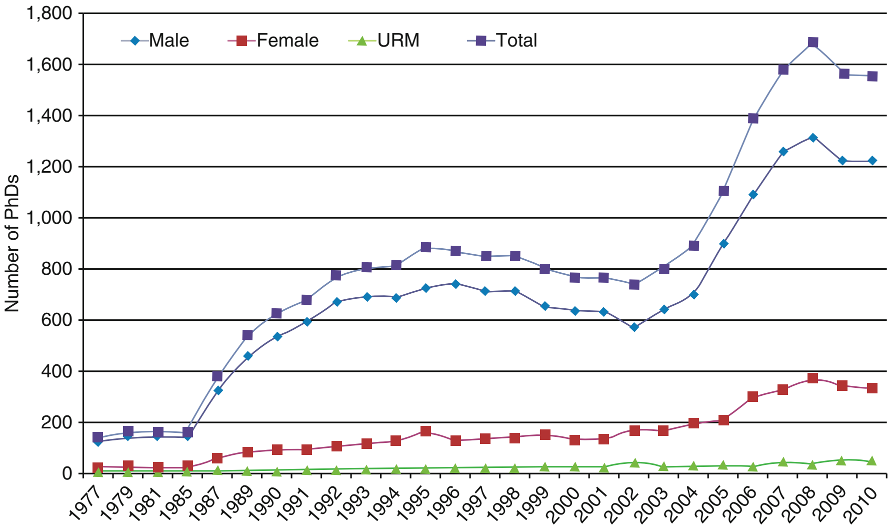

Fig. 1.1 Computer science doctoral degrees granted (Data Source: IPEDS Completion by Race, from https://webcaspar.nsf.gov). This figure is published as Figure 1 in http://cra.org/crn/2013/05/expanding_the_pipeline_diversity_drives_innovation/]. (Source: McKinley and Camp 2013)

itself. As Fig. 1.1 and Table 1.1 show, women, African Americans, Hispanics, and American Indians have been consistently underrepresented in the computing field throughout the entire era of modern computing, i.e. since 1945.[2] Figure 1.1 shows underrepresentation of women and minorities in receiving doctoral degrees in computing from 1977 to 2010. Table 1.1 shows similar underrepresentation at the bachelor's level for 2014.

There are various reasons why this underrepresentation is important. It a *social equity* issue that these high-paying, fulfilling, socially transformative jobs are less available to individuals from other demographic groups than they are to many White and Asian men. Shortages of skilled professionals occur every few years in the computing fields, and many scholars and policymakers believe both that these shortages have been harmful to American competitiveness and that larger participation of these underrepresented groups would go a long way towards meeting this *skilled workforce need*. Other scholars and policymakers (Page 2008; Barker et al. 2014)

field. For example, Asians from India, China, and Korea are over-represented in computing in the United States. Other Asians, such as the Hmong and Vietnamese, are underrepresented.

[2] The numbers about representation of women in traditional scientific and computing occupations may tell only part of the story. For example, the treatment of the ENIAC women at the time – and in many historical treatments since then – has treated these women mostly as assistants in a way that undervalued their scientific contributions. Similarly, occupational classifications over time may not count the large numbers of women in the data processing industry as information workers. See, for example, Light (1999), Grier (2005) and Misa (2010).

Table 1.1 Bachelor's production in the computing fields (2014) – percentages by demographic group

	Computer science	Computer engineering	Information systems/science/ technology	US population
Women	14.1	11.7	20.3	51
African Americans	3.2	3.3	8.2	13
American Indians	0.4	1.0	0.3	2
Hispanics	6.8	8.4	10.7	17

Sources: 2014 CRA Taulbee Survey; US Census
Note: The Taulbee Survey only includes data about Ph.D.-granting institutions, so it does not include data on most of the for-profit universities, which have higher percentages of minority student enrollment than the Taulbee schools

have pointed out that the work products of *diverse work teams* are more innovative and more likely to meet the needs of a wide range of customers than those created by a White male monoculture of technology developers.[3]

There is a small body of historical literature about women in computing in the United States. In addition to a number of articles and books focused on narrowly defined pieces of this history, there are three general books on this history: monographs by Janet Abbate (2012) and Nathan Ensmenger (2012), and an edited volume by Thomas Misa (2010). The literature on the history of underrepresented minorities and computing is much thinner; and in fact there are not yet any book-length general histories of this topic.

The social science literature on underrepresentation in computing is perhaps two orders of magnitude larger than the historical literature mentioned above. Like the historical literature, this social science literature is stronger and more numerous on women than on underrepresented minorities. Unfortunately, none of the major historical studies in this area have been informed in any substantial way by this social science literature, even though it has promise to offer insights into underlying causes.

This book is intended primarily as an historical study, even though it pays considerably more attention to the social science literature than do the other historical works on underrepresentation and computing mentioned above. This book is not a definitive history of underrepresentation and computing in the United States, but it provides useful background material drawn from the historical and social studies of computing, education (especially technical education), and race and gender that should help prepare some future scholar to write a more definitive history.

[3] This paragraph is copied almost verbatim from the introduction to the author's companion book, *Participation in Computing: The National Science Foundation's Expansionary Programs.*

1.1 Overarching Themes

We will close this introduction with a brief discussion of some of the themes that run throughout this book and its companion volume – and, indeed, are likely to be present in any historical study of broadening participation in computing in the United States.

1.1.1 Four Exogenous Forces

In this section, we briefly identify four exogenous forces that have shaped efforts to broaden participation in computing in the United States since 1945. The first is the return after the Second World War of male veterans who displaced a number of women from science and engineering jobs. There were many fewer women working in jobs during the war as scientists or engineers than there were women working in manual manufacturing positions, but those who were displaced from scientific occupations were often unhappy about this change. One outcome of this dissatisfaction was the creation of the Society of Women Engineers in 1950. It was the first of a number of organizations formed from the 1950s to the 1970s with the purpose of helping to broaden participation in the STEM disciplines. This story is told in passing in Chaps. 2 and 6, and will not be discussed further here.

The second exogenous force shaping broadening participation in computing in the United States were the civil rights and women's rights movements. For example, the women's rights movement led directly to the establishment in 1980 of the Committee on Equal Opportunities in Science and Technology with the purpose of advising the Director of the National Science Foundation on matters of broadening participation across the STEM disciplines.[4] The role of the women's rights movement in these broadening participation activities is told in passing in Chaps. 2 and 6 and in another publication by this author (Aspray 2016), and so will not be discussed further here.

The impact of the civil rights movement is less well known, so we will take some extra space to discuss one important episode related to this particular exogenous force. The second half of the 1960s was punctuated by race riots in Rochester, NY, Harlem, and Philadelphia in 1964; in the Watts section of Los Angeles in 1965; in Cleveland and Omaha in 1966; in Newark and Plainfield, New Jersey as well as in Detroit and Minneapolis in 1967; in Chicago, Washington DC, Baltimore, and again in Cleveland in 1968; and again in Omaha in 1969. In response to the wanton destruction and lack of opportunities for minorities, in 1973 the National Academy of Engineering, together with the Commission on Education, convened a Symposium

[4] There were other important pieces of federal legislation as well, e.g. the Civil Rights Act of 1964, which was used as a tool to open university admission to African Americans and other racial minorities, and the Title IX Education Amendments of 1972, which had the effect of enabling much higher female admission in higher education programs in the STEM and medical fields.

Table 1.2 Major recommendations from the 1974 Sloan Report

(1) Reaching the parity number of 18 % in minority participation in engineering;
(2) Forming a new national organization to raise and distribute financial aid to cover 5 years of financial aid for minority college engineering students;
(3) Having industry channel its funding through this new organization and having foundations assist this organization, especially during its first 5 years;
(4) Having the National Academy of Engineering coordinate efforts of many organizations and many programs to increase minority participation in engineering;
(5) Supporting the six historically Black universities that operated engineering programs (Howard, North Carolina A&T, Prairie View A&M, Southern, Tennessee State, and Tuskegee) with special funding so that they could double their enrollments over 5 years;
(6) Identifying colleges with large concentrations of Chicanos, Puerto Ricans, and American Indians to provide them with additional funds so that they would become strong providers of minority engineers;
(7) Improving articulation between 2-year and 4-year colleges concerning engineering education;
(8) Enhanceing counseling and cooperative engineering programs with industry at these colleges;
(9) Improving Ph.D. production of minority students in engineering so as to have adequate minority representation among faculty and academic administrators;
(10) Collaborating with the educational programs of the armed services to increase the number of minority veterans who enter into the engineering professions;
(11) Increasing the number of elementary and high school teachers in bilingual and bicultural schools teaching science and mathematics;
(12) Initiating school-year and summer programs for minority students to increase their interest in science and mathematics; and
(13) Encouraging the U.S. Department of Education to establish programs that support these goals

Source: *Minorities in Engineering: A Blueprint for Action* (Sloan 1974)

on Increasing Minority Participation in Engineering. The more than 250 attendees included government officials, industrial representatives, minority leaders, and students. The major outcome of this meeting was a call for "equitable participation" of minorities within a decade.

To understand the dimensions of the problem and operationalize the call for action at the symposium, the Alfred P. Sloan Foundation sponsored a 7-month study carried out in late 1973 and early 1974 at Stanford University. The study provides today's historian with a good snapshot of the situation in the early 1970s. For the contemporary reader of the 1970s, the study intended to identify numerical targets for minority representation in engineering; ascertain the feasibility, steps, and costs to achieve these goals; and identify organizations that could carry out various aspects of the work. The report appeared in 1974 under the title *Minorities in Engineering: A Blueprint for Action* (Sloan 1974).

The report focused on four underrepresented minority groups in engineering: Black, Chicano, Puerto Rican, and American Indian (using the terms that appeared in the report). These four minorities represented 14.4 % of the population in 1970 but only 2.8 % of the engineers. Of these four minorities, Blacks had the poorest representation, with 11.1 % of the U.S. population but only 1.2 % of the engineering profession. Table 1.2 lists the report's 13 major recommendations.

The report found that Black students take longer to complete a high school degree and have a higher dropout rate than White students. While Black enrollment in college had at least doubled in every decade of the twentieth century, and while there had been a particularly significant growth in Black freshmen enrollment in college between 1970 and 1973, there was still a significant gap between college entry for Blacks and Whites. A greater percentage of Blacks dropped out of college than Whites. The community colleges were a particularly important educational feeder for Blacks, with more than 40 % of full-time Black students enrolled in community colleges; but there were concerns that a two-tiered higher educational system would emerge with the community colleges becoming "dumping grounds" for minorities, where career opportunities would be limited. Until 1960, approximately two-thirds of Blacks enrolled in college were enrolled at historically Black colleges and universities, but there was concern about the financial soundness of these institutions.

The report found that Chicanos were less likely than Blacks to be successful at the elementary school, high school, and college levels. Unlike Blacks, who were widely dispersed across the nation, Chicanos were primarily concentrated in five states in the American southwest. For every 100 Chicano children entering first grade, only 60 graduated from high school, only 22 entered college, and only 6 graduated from college. This indicated that programs intended to increase Chicanos in engineering would have to focus on precollege as well as college education. The study found that precollege Chicano students are held back by language, both reading skills in English and the low number of Chicano and bilingual teachers. Family expectations that females are less likely than males to continue their education was also cited as a factor.[5]

Puerto Ricans were concentrated mostly in the states of New York and New Jersey. The report found that high school and college completion rates for Puerto Ricans were lower than for Chicanos. English illiteracy was higher for Puerto Ricans than Chicanos. Puerto Ricans were channeled more than White or other minorities into vocational rather than college preparatory public education programs.

The report concurred with a Presidential message to Congress that American Indians are "the most deprived and most isolated minority group" in the nation. (Sloan 1974, p. 53) Many American Indians received their public school education through special Bureau of Indian Affairs-run schools or Church-run mission schools. American Indians experienced elevated high-school dropout rates, and of those who did graduate from high school, they were half as likely as White high-school graduates to matriculate in college. Once matriculated in college, American Indian students had attrition rates not much different from other underrepresented minorities. The report argued that close ties to family and tribe, as well as differences between American Indians and Whites regarding cultural values about individual

[5] Another barrier for Hispanic women in 1970 was that most engineering schools did not admit women (of any race) or only admitted a very few, typically representing well under 10 % of the student population.

versus collaborative action, placed stress on American Indian students. There were even more acute problems in finding bilingual and bicultural teachers for American Indian children than there were for Spanish-speaking children.

Responding to this situation described in the 1974 Sloan report, a number of new organizations were formed to support the advancement of ethnic and racial minorities in the science and engineering disciplines. These included the American Indian Higher Education Consortium (AIHEC) in 1972, Society for Advancement of Chicanos and Native Americans in Science (SACNAS) in 1973, the National Action Council for Minorities in Engineering (NACME) and the Society of Hispanic Professional Engineers (SHPE) in 1974, the National Society of Black Engineers (NSBE) in 1975, and the American Indian Science and Engineering Society (AISES) in 1977. Background material on this exogenous force is covered in passing in Chaps. 3, 4, and 5, and the stories of these support organizations are told in Chap. 7.[6]

The third important exogenous force shaping the efforts to broaden participation in computing is the reverse discrimination environment that developed in the United States in the 1990s and that is still in force to some degree today. It was a conservative reaction to civil rights legislation passed between the 1960s and the 1980s; and it tried to undo preferential policies that had been given on the basis of race or gender through affirmative action programs, e.g. relating to employment or admission to higher education institutions. This issue is discussed in connection with access to higher education for African Americans and Hispanics in Chaps. 3 and 4 and in connection to computer science re-entry programs for women in Chap. 10. This author has also discussed the impact the reverse discrimination environment of the 1990s had on the programs of the National Science Foundation to broaden participation in the STEM disciplines in Aspray (2016).

The fourth exogenous force that we mention here as shaping efforts to broaden participation in computing is IT workforce needs. The demand of employers for IT workers has inexorably increased in the United States over the past 75 years as information and communication technologies have become embedded in ever more aspects of work. However, the demand has not increased at a steady or predictable rate; instead, IT workforce demand is characterized by cycles of demand and glut, of uneven duration and ferocity. A good example is the late 1990s and early 2000s, when there was an insatiable demand for workers to resolve Y2K problems of legacy computer systems and fuel the dot-com boom – only to be followed in 2002 with a dot-com bust that led to numerous IT worker layoffs. One might think that a demand for IT workers would be a good situation for women and minorities who were underrepresented in the workforce. However, employers generally preferred to fill open IT positions with foreign workers rather than with Americans from underrepresented groups. This was the story of the fierce battles around H-1B visas

[6] We make no claim to have been exhaustive in the list of STEM broadening participation organization. We list in the main body of the text only those that we profile later in the book. For example, the National Society of Black Physicists was created in 1977 and is not discussed here. There may well have been additional organizations of this type.

around 2000 and over outsourcing of IT work 5 years later. A second way in which this exogenous force played out is that higher education enrollments in computer science increased rapidly when industry increased demand for IT workers. The higher education system is not very flexible in its ability to meet rapidly changing enrollments. In the face of too many students, many computer science departments introduced weed-out courses that had the impact of weeding out many students with weak high school education or low self-confidence. These courses had the inadvertent effect of disproportionately weeding out women and underrepresented minorities. They sometimes also introduced higher entrance standards that also often affected women and underrepresented minorities in a disproportionate manner. This exogenous force is discussed in passing in Chaps. 8 and 9.

1.1.2 Pipeline Versus Pathway

Many analyses of the issues related to broadening participation in computing use the metaphor of a pipeline: if you do not take the right preparatory courses in middle school and high school, you cannot be admitted into an undergraduate major in one of the computing disciplines; if you do not have receive an undergraduate degree in a computing discipline, you cannot be admitted into a graduate program in a computing discipline; if you do not receive a graduate degree in a computing discipline, you cannot obtain a position in a high-level computing occupation, such as professor or senior researcher in industry. The iconic embodiment of this argument is a paper that appeared in *Communications of the ACM* in 1997, written by the computer science professor Tracy Camp and entitled "The Incredible Shrinking Pipeline." (Camp 1997) Camp's paper described a pipeline that leads from high school to a good computing career, but one that is leaky in many places, losing people from the pipeline at each of these transitions; so that only a few – too few – individuals were able to achieve the desired job at the end of the pipeline.

Camp is by no means the only person to use this metaphor; indeed it is commonly found in discussions of broadening participation in computing and also in efforts to craft solutions: for example, how do we make the pipeline less leaky so that more people can make the transition from high school to the undergraduate computer science major? The metaphor perhaps makes the most sense in the case of the computing occupation that is of primary interest to Camp, becoming a professor of computer science in a research-intensive university. It is not a perfect metaphor even in this occupational setting, however, because there are people who take a different pathway to their computing professorship, for example through the reentry program discussed in Chap. 9 that operated at Berkeley (to enable people who majored in a non-computing subject as an undergraduate to prepare for graduate student in computer science) or by training in a traditional way for the professoriate in a different, computing-intensive field, such as physics or economics, and then being hired into a computer science faculty position.

In point of fact, there are many different computing occupations; and these occupations have widely varying educational requirements.[7] It is hard to count the numbers accurately, but perhaps only a quarter of the people who hold positions in computing occupations have any formal education in computing. (See Freeman and Aspray 1999.) In 2004, the Committee on Equal Opportunity in Science and Engineering, the esteemed advisory body created by the U.S. Congress in 1980 to advise the Director of the National Science Foundation on issues of broadening participation in the various science and engineering disciplines, specifically renounced the pipeline metaphor and advocated replacing it with a pathways metaphor that emphasizes the many different possible pathways to a computing career.[8]

The 2004 CEOSE report to Congress included a review of NSF's broadening participation efforts. Analyzing NSF programs since 1980, the Executive Summary of this report highlighted the need for a changing framework for understanding the nature of the process by which one prepared for and entered a STEM occupation. This is where they discussed moving from the pipeline metaphor to the pathway metaphor[9]:

> Early efforts to broaden participation focused primarily on encouraging individuals from underrepresented segments of the population to enter STEM disciplines. This "pipeline" metaphor is a way of looking at the persistence of women, minorities, and persons with disabilities in STEM statistically. It emphasizes attracting students into the STEM "pipeline" when they are young, and spotlights the points at which "leaks" occur, differentially draining away individuals from underrepresented groups. Today, many efforts to make science and engineering more inclusive are paying attention instead to the multiplicity of "pathways" by which persons from underrepresented groups can enter and progress through STEM careers. Creating viable pathways requires addressing the tough issues related to what invites children to learn science (attraction), what causes young people to choose to keep learning mathematics and science (retention), and what then leads students to graduate (persistence) and continue into STEM careers (attachment). (CEOSE 2004)

This emphasis on pathways rather than pipeline is probably even more appropriate today, given the many informal pathways to a computing education through online courses, computing boot camps, and hackathons.[10]

---

[7] See, for example, the analysis in Freeman and Aspray (1999) or the federal occupational categories related to computing at http://www.bls.gov/ooh/computer-and-information-technology/home.htm

[8] Two years earlier, Carol Muller (the founder of MentorNet) and Susan Metz (a co-founder of WEPAN) had written an editorial calling for an abandonment of the pipeline metaphor and renewed focus on multiple entry points into STEM careers. (Muller and Metz 2002)

[9] Evelynn Hammonds has also pointed out another problem of the pipeline metaphor: it led policymakers for a number of years to the mistaken belief that "the factors leading to the production of white male scientists were the same ones that lead to the production of women and minority scientists." (Personal communication to the author, 18 March 2016)

[10] It is an unexplored question which computing occupations are open to people who take these informal pathways, and which kinds of employers are willing to hire people with an informal computing education; but it is clear that this informal education opens up some computing occupations with some employers.

Several scholars studying broadening participation in computing have criticized the pipeline metaphor. Jolene Jesse, a program officer at NSF who studies issues of women in science, is one. (Jesse 2006) An earlier study in which she participated, jointly conducted by the American Association for the Advancement of Science and the Committee on Professionals in Science and Technology, examined nontraditional pathways into the computing workforce.

> A 'nontraditional pathway' is defined as the path taken by a nontraditional student, i.e., someone who: delays enrollment at least three years after graduating from high school or earning a GED; attends college mostly part-time; takes longer than six years to complete a degree; is employed full-time during most of their studies; or has dependents while attending college. (MIT Press, Scholarship Online, http://mitpress.universitypressscholarship.com/view/10.7551/mitpress/9780262033459.001.0001/upso-9780262033459-chapter-8)

These pathways are completely missed by the pipeline metaphor.

Mark Guzdial, a computer scientist at Georgia Tech who is a leading scholar in computer science education, writes in his computer education blog:

> By using the "leaky pipeline" metaphor, we stigmatize and discount the achievements of people (women, in particular in this article) who take their technical knowledge and apply it in non-computing domains. Sure, we want more women in computing, but we ought not to blame the women who leave for the low numbers. … [N]ew research of which I am the coauthor shows this pervasive leaky pipeline metaphor is wrong for nearly all postsecondary pathways in science and engineering. It also devalues students who want to use their technical training to make important societal contributions elsewhere. (Guzdial 2015)

Lecia Barker, a professor in Department of Information Science at the University of Colorado Boulder and a senior research scientist at NCWIT, has noted that the pipeline metaphor can be counterproductive when trying to broaden participation in computing because it accepts as lost those individuals who leaked out of the pipeline at an earlier stage rather than finding a way to prepare them for a computing career. (Private communication to author, November 2015)

Historian of computing Thomas Haigh has also criticized the pipeline metaphor, but his criticism is that the pipeline metaphor focuses too much on the formal educational system instead of on the workplace. Haigh (2010) writes:

> History broadens our perspectives. The literature on women in computing is dominated by discussion of computer science education. Fixing computer science is equated with fixing computing. This is justified by the metaphor of the pipeline carrying women from specialist education into IT work. Yet we saw that the gender dynamics of data processing were well formed by the 1960s, before undergraduate computer science education was an appreciable factor. Gender dynamics were shaped instead by the specific historical legacy of data processing work and the broader gender politics of corporate society. So to understand gender segmentation in the workforce, we must study the workplace as well as the classroom.

Some of the more recent social science research on underrepresentation is beginning to adopt a pathway metaphor. See, for example, Fox and Kline (2016), which discusses women faculty in computing from a pathways perspective.

1.1.3 Fixing the People Versus Fixing the System

Many of the interventions employed in broadening participation in computing principally address what is sometimes called "fixing the women". These interventions include, for example, women's support groups, special summer-before-college bridging programs for minority students, special sections of introductory computer science for people with limited computing experience, special financial aid programs for minorities, special mentoring opportunities for underrepresented groups, and conferences such as the Grace Hopper and Tapia celebrations, which target women and minority populations, respectively. These interventions can help to rectify shortcomings an individual has experienced, such as coming from a poor family or having a poor public school education – and some of these activities, such as the Grace Hopper conference – have fiercely loyal supporters.

However, there is also a negative side to these interventions: they can stigmatize underrepresented groups and reinforce stereotypes and unconscious bias about who should be doing computer science. Moreover, some social scientists believe that the track record of such interventions show that they are not effective at making the wholesale change of broadening participation in computing sought at the national level. Some organizations such as the National Center for Women & IT, and some individual researchers such as Mary Frank Fox and Gerhard Sonnert, believe that substantial change comes only through fixing the system rather than fixing the individuals. Systemic change is difficult, and it is unsettling to those who have existed in the established system. It is not surprising that, for many years, technology companies were more engaged in recruiting new women and minority hires rather than changing the practices and environments within their organizations so as to improve retention and advancement of women and underrepresented minorities. Chapter 10 discusses some of the issues associated with broadening participation in computer science departments; and Chaps. 8 and 9 discuss this issue in passing as various organizations, including NCWIT, are discussed.

1.1.4 Nonprofit Organizations and Individual Change Agents

Much of this book (Chaps. 6, 7, 8 and 9) focuses on nonprofit organizations. Many of these organizations had their origins in the concerns of a few scientists, engineers, and computer scientists who wanted the STEM disciplines in general or the computing discipline in particular to be equally open to all people, regardless of race or gender. These organizations can achieve what the concerned individuals – who often want to devote their main efforts to their scientific or engineering career – cannot do alone. Organizations have staff members who can handle the management of programs and events, provide effective communication to multiple stakeholders, and conduct business with safeguards that enable these organizations to act professionally and ethically. All of these organizations have strong advisory committees populated by members of the scientific professional community – many of whom volunteer large amounts of time and have strong identification with the organization. As nonprofit organizations, the most common funding model is project grants from either government (especially the National Science Foundation) or corporate entities. The most successful of these broadening-participation organizations focused on computing at this time are the CRA Committee on Women in Computing Research (CRA-W) and the National Center for Women & IT (NCWIT).

Equally important in this story of broadening participation in computing are individuals who serve as change agents – people who have served to transform their organizations or their profession through their individual actions to make them more effective at carrying out this broadening participation mission. Some of them are known for their roles in specific organizations, e.g. Jan Cuny's work in creating the Broadening Participation in Computing and the CS10K programs at the National Science Foundation; Anita Borg's work in creating Systers, the Grace Hopper conference, and what is now called the Anita Borg Institute; Lucy Sanders in creating NCWIT; and Richard Tapia in his inspirational work at Rice University. Others, such as the ethnographer Jane Margolis who studied both Carnegie Mellon University and the Los Angeles School District, have had a reach that has had more importance for its national dissemination of ideas than its contributions to a single institution.[11]

1.1.5 Intersectionality

This book is organized with chapters specifically about women or about a particular racial group (African Americans, Hispanics, and American Indians). The world is not nearly so tidy a place as this chapter organization suggests. There are many variations across these individual racial categories, e.g. tribal differences among American Indians, or to take another example the geographical, racial, language, and cultural differences between Chicanos living in the western and southwestern United States and Puerto Ricans living in the eastern United States. Many individuals are of more than one race. In addition, there are many other groups that are underrepresented that are not discussed in detail in this book, e.g. as organized by age, various sexual orientations, or various disabilities. People who are underrepresented in computing by belonging to more than one of these underrepresented groups often have multiple and simultaneous issues at play. This is an important topic, but it is not addressed except briefly in passing several times in this book.[12]

---

[11] There are, of course, many more individual change agents than I can mention here. It has been a highlight of this author's career to get to know many of these people and watch them in action.

[12] Some examples of recent literature on intersectionality and STEM include Bruning et al. (2012), Herrera et al. (2013), Ko et al. (2013), Charleston et al. (2014) and O'Brien et al. (2015).

References

Abbate, Janet. 2012. *Recoding gender: Women's changing participation in computing*. Cambridge, MA: MIT Press.

Aspray, William. 2016. *Participation in computing: The national science foundation's expansionary programs*. Cham: Springer.

Barker, Lecia, Cynthia Mancha, and Catherine Ashcraft. 2014. *What is the impact of gender diversity on technology business performance?* NCWIT Research summary. http://www.ncwit.org/sites/default/files/resources/impactgenderdiversitytechbusinessperformance_print.pdf. Accessed 9 Sept 2015.

Bruning, Monica, Jill Bystydzienski, and Margaret Eisenhart. 2012. *Intersectionality as a framework for understanding diverse young women's interest in engineering*. Getting to the Heart of it All: Connecting Gender Research, WIE Programs, Faculty & Corporate Partners, WEPAN National Conference. June 25–27. Columbus, OH. 14.

Camp, Tracy. 1997. The incredible shrinking pipeline. *Communications of the ACM* 40(10): 103–110.

Charleston, LaVar J., Ryan P. Adserias, Nicole M. Lang, and Jerlando F.L. Jackson. 2014. Intersectionality and STEM: The role of race and gender in the academic pursuits of African American women in STEM. *Journal of Progressive Policy and Practice* 2(3): 273–293.

Ensmenger, Nathan. 2012. *The computer boys take over: Computers, programmers, and the politics of technical expertise*. Cambridge, MA: MIT Press.

Fox, Mary Frank, and Kathryn Kline. 2016. Women faculty in computing: A key case of women in science. Chapter 3. In *Pathways, potholes, and the persistence of women in science: Reconsidering the pipeline*, ed. Enobong Hannah Branch. Lexington Books. Lanham, Maryland

Freeman, Peter, and William Aspray. 1999. *The supply of information technology workers in the United States*. Washington, DC: Computing Research Association.

Grier, David Alan. 2005. *When computers were human*. Princeton: Princeton University Press.

Guzdial, Mark. 2015. End the 'leaky pipeline' metaphor when discussing women in science: Technical knowledge can be used in many domains. *Computing Education Blog*, April 27. https://computinged.wordpress.com/2015/04/27/end-the-leaky-pipeline-metaphor-when-discussing-women-in-science-technical-knowledge-can-be-used-in-many-domains/. Accessed 31 Dec 2015.

Haigh, Thomas. 2010. Masculinity and the machine man: Gender in the history of data processing. In *Gender codes: Why women are leaving computing*, ed. Thomas J. Misa, 51–72. Hoboken: IEEE Computer Society Press.

Jesse, Jolene. 2006. The poverty of the pipeline metaphor: The AAAS/CPST study of nontraditional pathways into IT/CS education and the workforce. In *Women and information technology: Research on underrepresentation*, ed. Cohoon Joanne and Aspray William, 239–278. Cambridge, MA: MIT Press.

Ko, Lily T., Rachel R. Kachchaf, Maria Ong, and Apriel K. Hodari. 2013. Narratives of the double bind: Intersectionality in life stories of women of color in physics, astrophysics and astronomy. *Physics Education Research Conference, AIP Conference Proceedings* 1513: 222–225.

Light, Jennifer. 1999. When computers were women. *Technology and Culture* 40(3): 455–483.

Misa, Thomas. 2010. *Gender codes: Why women are leaving computing*. Hoboken: IEEE Computer Society.

Muller, Carol B., and Susan Staffin Metz. 2002. Burying the pipeline and opening avenues to engineering. *ASEE Prism* 12(4). http://www.prism-magazine.org/dec02/lastword.cfm. Accessed 26 Feb 2016.

National Science Foundation Committee on Equal Opportunities in Science and Engineering (CEOSE). 2004. *Broadening participation in America's science and engineering workforce*. The 1994–2003 decennial & 2004 biennial reports to Congress. http://www.nsf.gov/od/iia/activities/ceose/reports/ceose2004report.pdf. Accessed 26 Nov 2014.

O'Brien, Laurie T., Alison Blodorn, Glenn Adams, Donna M. Garcia, and Elliott Hammer. 2015. Ethnic variation in gender-STEM stereotypes and STEM participation: An intersectional approach. *Cultural Diversity and Ethnic Minority Psychology* 21(2): 169–180.

Page, Scott E. 2008. *The difference*. Princeton: Princeton University Press.

Shah, Angilee. 2012. Geek chicks, PyLadies, a gang of female computer programmers. *LA Weekly*, February 16. http://www.laweekly.com/publicspectacle/2012/02/16/geek-chicks-pyladies-a-gang-of-female-computer-programmers?showFullText=true. Accessed 27 Oct 2015.

Sloan Foundation. 1974. *Minorities in engineering: A blueprint for action. Report*. New York: Sloan Foundation.

Part I
Digest of Relevant Literatures

Chapter 2
Opening STEM Careers to Women

Abstract This chapter examines the history of higher education for women, as well as the history of careers for women in science and engineering, in the United States. The first section discusses women's matriculation in college generally from 1900 to the present day. The next section presents a statistical overview of women in science and engineering from the early twentieth century to the present. The third section provides a qualitative analysis of the history of women in science since 1820. The final section provides a qualitative analysis of the history of women in engineering since 1918.

This chapter examines the history of higher education for women, as well as the history of careers for women in science and engineering, in the United States. The chapter relies heavily on a few sources, principally Margaret Rossiter's three-volume history of women in science and Amy Sue Bix's book on the history of engineering education for women. (Rossiter 1982, 1995, 2012; Bix 2013) Those readers who are familiar with the history of higher education for women or the history of science and engineering careers for women in America might not find much new in this chapter. However, many of the computer scientists, education specialists, and other social scientists who study women and the STEM disciplines, including computing, are not familiar with this material. The selection, slant, and augmentation of these two major authors have been designed to appeal to these readers who are carrying out research or interventions related to women and STEM (including computing).

2.1 College Matriculation of Women – A Brief History

In this section, we discuss women's matriculation in college generally. For many of the higher-level professional positions in the STEM and computing disciplines, a baccalaureate degree is necessary, typically with a significant amount of course instruction in the STEM or computing disciplines. A study by three Harvard

W. Aspray, *Women and Underrepresented Minorities in Computing*,
History of Computing, DOI 10.1007/978-3-319-24811-0_2