Chapter 8
Gender and Computing

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Worldwide, information technology (IT) has exhibited phenomenal growth over the past several decades. This growth underlies the creative and analytical processes for the full range of endeavors ranging from science to business and social interaction, and it powers the burgeoning IT economy. Other benefits include vast career opportunities (OECD 2012), and the implications associated with unparalleled access to information. Finally, a benefit noted in many nations is that women's access to IT and participation in computing can be an important mechanism of economic growth and societal development. Nevertheless, women and men are seldom equal participants in this boom.

Computing occupations differ greatly in the level of education needed for entry, ranging from short-term certifications to advanced research-based doctoral degrees. The gendered patterning of access to education, in general, combined with the relative importance of computing within a nation may, together, affect the representation and status of women in the field. In many nations, computing is a new discipline, arriving at a time when women's educational access has already been secured, while in other nations, computing has grown within an existing sex segregated educational context. This context may not affect women's computing participation in the manner one might expect, however. In this chapter we explore computing education, the relative status of computing within national contexts and the ways in which national policies associated with workforce development impact the level of sex segregation of jobs in computing.

Computing is a broad term that refers to a range of skills obtained in programs of various content and lengths, including those that are short-term certifications to

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advanced research training in computer science[1] doctoral programs. The term "computing" describes an activity as well as an academic discipline, while the term "information technology" (IT) has come to be the term commonly used to modify the word "workforce," and is in general use in the United States. Going one step further, the OECD (2010) and the United Nations (multiple references) use the acronym "ICT[2]" to reference the information and communications technology workforce, segmenting that workforce into three broad categories:

- Basic users of generic tools (e.g., WORD, EXCEL) necessary in the information society
- Advanced users of advanced, sometimes sector-specific tools
- ICT specialists develop, maintain, and operate ICT systems

We focus on the latter category to address gender stratification among creative specialists. ICT specialists can be further disaggregated by their role in developing, maintaining, and operating ICT systems. In this chapter we look at a relatively narrow slice of the overall ICT workforce, specifically those individuals who obtain training in the academic discipline of computer science in preparation for jobs as various types of ICT specialists. While this is likely to be a relatively small slice of the overall ICT workforce, we argue that those who obtain computer science degrees are advantaged in the ICT industry and, as well, are more likely to be those who exercise creative control within this field.

ICT work is foundational in the current global economy. Computers are powerful tools with which workers interact in various ways, ranging from simple input/output to complex design and analytical work. The stratification of computing work and the association of this stratification with gender and other bases of difference can impact the future direction of work, in general, and privilege, in particular. Finally, some elements of computing are not geographically bounded, while other elements are. For example, the brick-and-mortar network infrastructure for telecommunications is spatially specific, like any other construction. The information that flows through that infrastructure, however, is not only unanchored in a spatial sense, but also enables the global diffusion of knowledge. As a result, computing is a critical element of globalization, with its concomitant promises and potential dangers.

This chapter uses data from OECD, international and national reports, along with the current research literature to address three key questions about women's participation in computing compared to that of men:

Q1: What is the gender composition of computing? To what extent does this vary across nations?

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[1] We use "computer science" recognizing that in many cases this term includes "information sciences," "informatics," and similar closely aligned disciplines. We mean it in the broad and inclusive sense for purposes of this chapter. We use gender to refer to the social construction of meanings associated with femininity and masculinity, which includes expectations, norms, attitudes, behaviors, and beliefs that are patterned by sex.

[2] Our use of ICT and IT are fundamentally interchangeable. Generally, though, when we are referencing the United States, we use "IT" and then "ICT" for the rest of the world, as is the custom in international publications.

Q2: What are the factors that encourage women's participation in computing and how do these vary as compared to the factors that draw men to the field?
Q3: To what extent does gender matter in computing?

The broad variations in women's participation in computing cross-nationally shed important light on the role of gender and culture in enabling or thwarting women's participation in this growing labor force. This chapter will not be able to provide a comprehensive answer to these questions; instead, we provide some provisional insights that could form the basis of additional research.

8.1 Gender and Computing

In the United States, up until the mid-1980s, there was a relatively large representation of women in computing, which, like most jobs, has been characterized by occupational segregation by sex. Prior to the boom in use of microprocessor-based desktop computers, computer users generally communicated with the machines using stacks of punch cards. Many equipment room operators, programmers, and data keyers were women, and this work—regardless of its level of actual intellectual complexity—was socially constructed as similar to secretarial labor (Bratteteig 2008). Women's early work in computing was foundational to the field (Abbate 2012; Fritz 1996; Ensmenger 2010), with such notable accomplishments as Rear Admiral Grace Hopper's invention of COBOL, among others. Women performed both routine and complex functions in early computer rooms. The large demand for programming talent and the concurrent professionalization of computing came to be bound up with the masculinization of the field. As with other fields, masculinization processes erected barriers to women's entry as men actively sought to exclude women (Frehill 2004; Oldenziel 1999; Tympas et al. 2010).

OECD's *Internet Economy Outlook, 2012*
A biennial volume describing recent market dynamics and trends in industries supplying IT goods and services and offers an overview of the globalization of the information and communication technology (ICT) sector and the rise of ICT-enabled international sourcing. It analyses the development and impact of the changing global distribution of services activities and the rise of China and India as significant suppliers of ICT-related goods and services. It also looks at the increasing importance of digital content in selected industries and how it is transforming value chains and business models. The potential of technological developments such as ubiquitous networks, location-based services, natural disaster warning systems, the participative web and the convergence of information technology with nanotechnology and biotechnology is also examined. This book includes StatLinks, URL's linking statistical graphs and tables to spreadsheets containing the underlying data.

Accessible online at
http://www.oecd.org/sti/ieconomy/ieoutlook.htm

In addition to the professionalization and concurrent masculinization, the digital revolution changed the nature of work in computing. Computer programmers and users were increasingly able to directly access computational power on their desks—or in their hands—that rivaled and exceeded the old punch-card and tape-driven systems. Hobbyists, who were predominantly men, too, drove change in the material conditions of computing, as new electronics components became increasingly widely available via retail outlets.

Evidence of this rapid change in the nature of work in ICT is reflected in the workforce publications of the European Union. Since 2000 the biennial report series *OECD Information Technology Outlook* was issued through 2010. In 2012, however, the report became the *Internet Economy Outlook*, reflecting the on-going migration from brick-and-mortar enterprises to the ever-expanding net.

8.2 Caveats: Information and Data Availability

The data about participation in computing greatly varies across the globe. Issues associated with gender and information technology and the ways in which countries are addressing these issues vary. To some extent, the issues described by Seely-Gant (2015) with respect to the UN millennium goals and gender impact these data issues. That is, in nations where the average girl is unlikely to receive much education beyond the primary level, where electricity is not universally reliably available, computing degrees are a less relevant metric to understand gender gaps in computing than is the extent to which girls have access to computers, as compared to boys. Hence, as will be discussed, below, data gaps in degree attainment are not surprising. Physical resources that are taken-for-granted in many OECD member economies shape the general access and outcomes of education and impact the gendered relations of computing (United Nations Economic and Social Council, Statistical Commission 2012, 2013).

Reports of women's participation in science and engineering vary in the level of detail about the constituent fields. When one is interested in computing, in particular, the level of aggregation can be more problematic because of the varied ways in which computing is "counted" in different countries or economic systems. For example, in some places, computing is counted within a larger "engineering and technology" category (e.g., China), while in others it is often (though not always) aggregated along with mathematics (e.g., United States) or with all of the natural sciences (e.g., European Union).

The OECD provides data on economic participation in 34 member nations, almost exclusively in Europe and North America. Degree data from these nations is generally available for the past 10–20 years (depending on the nation) about degrees awarded in computing at the Tertiary A level (generally equivalent to the US bachelor's degree) and doctoral (Advanced Research Programs) level by sex. Workforce data are often not available at the detailed occupational level in published international compendia; workforce information in such volumes typically aggregates workers to a relatively high level of detail (e.g., the "professionals" category includes individuals in computing). Finally, social scientists have completed studies of the ICT workforce in these nations, using more detailed data about workers to complete quantitative studies complemented by qualitative data collected using a plethora of methodologies to provide additional insights into the social forces associated with women's participation in computing and with the meaning of gender for the discipline and its products.

A large gap in data exists, however, since many economies that are in the midst of large-scale technological advancement are not members of the OECD. For example, the so-called "BRIC" economies, Brazil, Russian Federation, India, and China, are not members of OECD (Wilson and Purushothaman 2003). Therefore, OECD data collections do not, uniformly, include data from these economies, each of which is a sizable and growing economy and important in the ICT sector.

Similarly, high-quality data on computing degrees and workforce participation disaggregated by gender are scarce from much of Africa and the rest of Asia (i.e., beyond Russia, India and China). The World Bank Group, the International Labor Organization, and United Nations all collect and distribute some data on workforce and education across the globe, but, again, these data are often reported at a level of detail insufficient to understand the issues for specific fields like computing.

Data for African nations can be especially challenging to obtain. The centrality of the ICT sector in the global economy has led to a high level of interest; therefore, several studies provide some information about ICT in Africa but none provide data on computing degree attainment. As discussed earlier, access to basic education for girls, access to physical resources, in general, and to electricity, in particular, pose significant structural constraints on participation in IT. A 1999 UNESCO study of the scientific, technical, and vocational education of girls in Africa summarized findings from 21 separate country reports (Hoffman-Barthes et al. 1999). Later, infoDev completed a 2007 study with country reports about gender equity and ICT in 53 African countries. Finally the United Nations Economic Commission for Africa (UNECA 2008, 2009a, 2009b) has completed a series of studies that emphasize the connection between gender mainstreaming in ICT, national ICT policy development about standards and human resources, and desired outcomes such as economic development.

8.3 Cross-National Variation in Women's Participation in Computing

Even with the data limitations, just discussed, the cross-national data provide an initial answer to the question:

Q1: What is the gender composition of computing? To what extent does this vary across nations? What do we know about sources of that variation?

Education (degrees) and work (jobs) are two ways in which we can conceptualize participation in computing. A third way, usage, including for leisure purposes such as gaming, is not considered in this chapter, although we acknowledge the importance of this third area in which a potential digital divide exists with which there may be subsequent issues for gendered stratification of computing.

We use data from OECD's online database Stat Extracts on degrees in computing at the Tertiary A (U.S. bachelor's degree) and Advanced Research Program (PhD) levels. Data on the research workforce were taken from the U.S. Bureau of Labor Statistics (BLS), the Government of India, and various offices of the United Nations.

8.3.1 Education

Figures 8.1 and 8.2 show data on the number of first tertiary (i.e., bachelor's) degrees and advanced research (i.e., doctoral) degrees in computing in the OECD member countries for 2011, the most recent year for which data were available. We have segmented these charts along the *x*-axis by the overall size of computing degree production in reverse order into four groups and then, within each of these groups ordered the nations by the percentage of women among degree recipients. Our objective is not to explain the differences in degree production between the countries shown but, rather, to provide these data as a way to contextualize the relative percentage of women who earn computing degrees in each nation. The bars

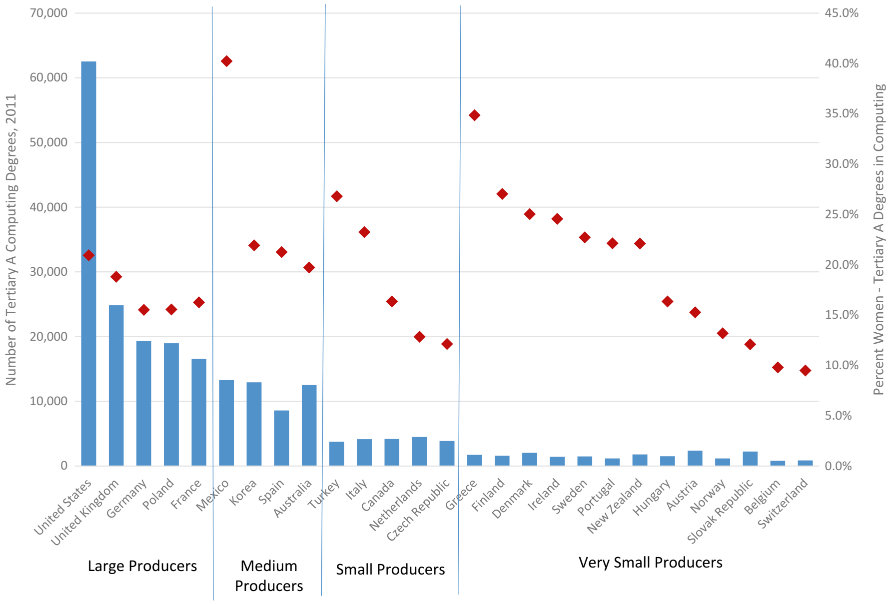

Fig. 8.1 OECD Tertiary A degrees in computing, 2011. *Source*: Frehill, LM. 2013. Analysis of OECD Degree Data. Original data accessed online at OECD Stat Extracts, http://stats.oecd.org/#

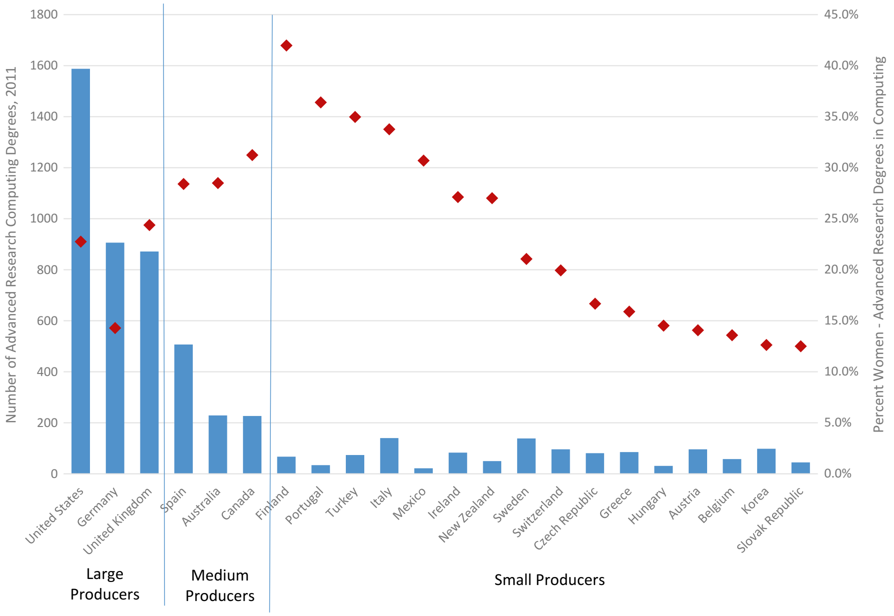

Fig. 8.2 OECD advanced research (doctoral) degrees in computing, 2011. *Source*: Frehill, LM. 2013. Analysis of OECD Degree Data. Original data accessed online at OECD Stat Extracts, http://stats.oecd.org/#

represent the total number of computing degrees at the bachelor's level (Fig. 8.1) and the doctoral level (Fig. 8.2). The diamonds show the percentage of women among degree recipients, associated with the *y*-axis on the right.

Data were not available for all 34 OECD member countries; therefore, Fig. 8.1 includes data on bachelor's degrees for 24 countries, while Fig. 8.2 reports on doctoral degrees awarded in 22 of these nations. Figure 8.3 shows data on the propensity of students, separately by gender, to earn Tertiary A degrees in computing.

Second, the order of magnitude for the number of degrees awarded in the United States (population 313.8 million) is substantially greater than for any other OECD member nation at both the bachelor's and doctoral levels.[3] The United States produced more than 60,000 bachelor's degrees and almost 1,600 doctoral degrees in computing in 2011.[4] The next largest OECD bachelor's degree producer was the

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[3] We have not normalized the number of degrees (total) by population for each nation, as was suggested by one reviewer. We do not seek to explain differences in the number of degrees across countries but, instead, to provide these as a framework for viewing the relative levels of women's participation in computing. We have added Fig. 8.3 as an alternative way to contextualize the place of computing within all fields at the bachelor's degree level for each nation.

[4] Due to the inclusion of computing with engineering for education data from China, we were unable to determine the relative number of computing degrees awarded in China at either the bachelor's or doctoral level. We acknowledge that this number may be large, growing, and that, as with

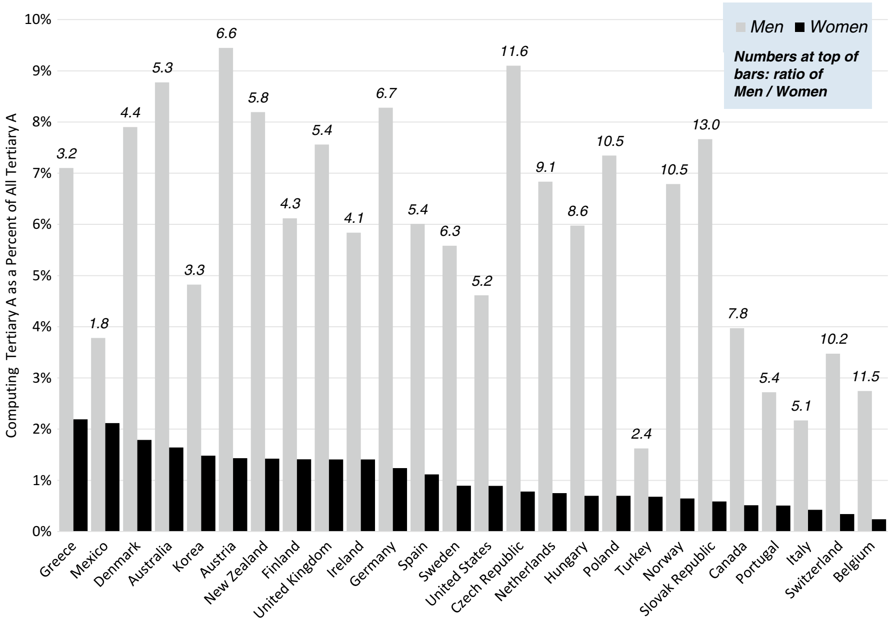

Fig. 8.3 Percentage of computer science majors among men and women Tertiary A recipients, 2011. *Source*: Frehill, LM. 2014. Analysis of data from OECD degree data extracted from OECD Stat Extracts, http://stats.oecd.org/

United Kingdom (population 63.2 million), with just over a third as many computing bachelor's degrees as the number awarded in the United States. Germany (population 81.9 million) and Poland, with just under 20,000 bachelor's degrees, and France (population 65.7 million) with ~15,000, were the next largest producers. Women's representation in computing in these four nations ranged from 15% (Germany, Poland, and France) to 21% for the United States and just under 20% for the United Kingdom.

Four nations are categorized as medium producers: Mexico (population 120.8 million), Korea (population 50.0 million), Spain (population 47.27 million), and Australia (population 22.68 million) all produced about 8,000–10,000 computing bachelor's degrees in 2011. Women's participation in computing in three of these nations was on par with that in the United States with women earning 21–22% of degrees in Korea, Spain, and Australia. Mexico was an outlier with women earning 42% of computing bachelor's degrees in Mexico, the largest representation of women among the OECD economies, with Greece (a "very small producer") the second largest at 37%.

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engineering, degree quality could greatly vary across the institutions awarding such degrees. In 2011, according to the *China Statistical Yearbook 2012*, there were 15,804 engineering and 7,019 science doctoral degrees awarded in China.

The great variability in women's representation in computing at the bachelor's level is most evidenced among the "small" and "very small" degree producers—nations that produced ~4,000 ("small") or ~2,000 or fewer Tertiary A degrees in computing in 2011. Some of these nations had very low representations of women—for example, Belgium and Switzerland at just 10%—and others had much higher representation of women—for example, Turkey (27%), Italy (23%), Greece (35%), Finland (27%), Denmark, and Ireland (both ~25%). All of these nations are noteworthy for their policies that emphasize the central role for ICT in economic development as a means to national economic prosperity (OECD 2012).

Figure 8.2 shows data on doctoral degree production at 22 OECD member nations. As at the bachelor's level, the United States, Germany, and the United Kingdom were the largest producers of computing doctorates. The most recent year for which data were available for France was 2009, with 642 doctoral degrees in computing, not shown in Fig. 8.2.

Women's representation at the doctoral level for the top three nations mirrors that at the bachelor's level, with women earning about one-in-five computing doctoral degrees in the United States and the UK and just under 15% in Germany. Women's representation was higher in the "medium producers"—at around 25%—in Spain, Australia, and Canada, nations that produced between 200 and 500 computing doctorates in 2011.

The remaining OECD countries for which data on doctoral degree production were available for 2011 each produced under 200 computing doctorates in 2011. Italy and Sweden were the largest of these producers at 140 and 139, respectively. The wide range in women's representation is clear among these small producers. Women earned 37% of doctoral degrees in computing in Finland but just under 15% in Hungary, Austria, Belgium, Korea, and the Slovak Republic in 2011.

Figure 8.3 shows the percentage of all Tertiary A degrees awarded in computing to women and men, separately by gender. The dark bars show that 2.2% of Greek women but only 0.2% of Belgian women who earned Tertiary A degrees in 2011 did so in computing. The relative importance of computing as a Tertiary A field for men varied substantially more than for women, with a low of 1.6% of men in Turkey and a high of 9.4% of men in Austria earning Tertiary A degrees in computing in 2011.

The numbers on the top of the light bars indicate the ratio of men's to women's percentage of degrees in computing for each nation. A complicated picture emerges suggesting a need for greater case-by-case analysis to better understand the underlying labor market forces shaping the gendered patterning of degrees in computing in each nation. For example, as shown in Fig. 8.1, women in Mexico earned 40% of computing Tertiary A degrees in Mexico. Figure 8.3 shows that about 2% of Mexican women who earned Tertiary A degrees in 2011 did so in engineering. Men in Mexico, though, had one of the lower rates of participation among the OECD nations shown in these three figures: only 3.8% of Mexican men who earned a Tertiary A degree in 2011 did so in computing. At the other end of the spectrum, only computing accounted for just 0.6% of women's but 7.7% of men's Tertiary A degrees in 2011 in the Slovak Republic, which had the most pronounced gender gap. Additional detail about the nature of computing work, the structure of the national labor markets, the extent to which the computing jobs necessitate university training,

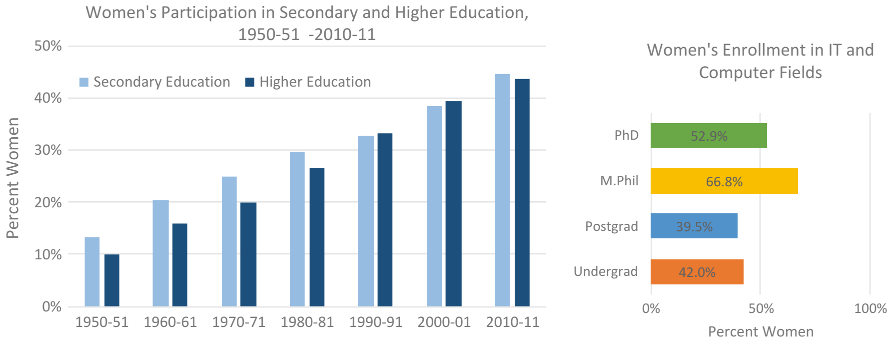

Fig. 8.4 Women's participation in education 1950–2010 and CS/IT in India 2011. *Source*: Frehill, LM. 2014. Analysis of data from: Government of India 2013a, 2031b, 2013c

and the way that gender is patterned in each of these areas suggests a need for more detailed case study analysis.

As discussed earlier, data comparable to that provided for OECD nations were not available for India, which reports on enrollments and not degree attainment. India has become a significant force in the global IT marketplace for both products and labor. Women's participation in education has been a focus of much policy work in India (Government of India 2010; Nayar 2011; Kumar 2008). Figure 8.4 shows the trend since the 1950–1951 academic year in women's participation in education in India. In that year, women accounted for just about 10% of all students in higher education but in 2011, the most recent year for which there are data, women accounted for 44% of students enrolled in higher education. For much of the time since 1950–1951, women's participation in higher education lagged that of their participation in secondary education, but the size of that gap has narrowed. In 2011–2012, 45% of students enrolled in higher education were women.

The second chart in Fig. 8.4 shows women's participation in IT and computer fields in higher education. Compared to the rates discussed, above, for OECD nations, women's participation in computing in India was relatively high in terms of the enrollment data shown here. The undergraduate and postgraduate levels include data from a heterogeneous set of institutions, representing various quality levels and areas of academic preparation (World Education Services 2007; Natarajan 2005). For example, the Indian Institutes of Technology (IITs) are considered the highest-quality institutions for engineering-related disciplines in the country, with some boasting programs that are on par with the best programs at institutions in other countries. Admission to the IITs is based on the results of a rigorous examination: in 2007–2008 only 3% of men and 1% of women who took the examination were admitted (Nayar 2011). In 2012, women accounted for one-third of candidates with marks on the examination high enough for entry; providing optimistic news that the historically low representation of women at the IITs of 10–12% will be increasing (Srivastava 2012).

8.3.2 *Workforce*

Women's participation in the computing workforce—just like their representation among those who complete academic credentials in the field—varies greatly across nations. To a large extent, the economic laws of supply and demand impact the labor market for computing in significant ways. That is, in the United States, for example, the demand for labor in computing has been and will continue to grow over the next decade (U.S. Bureau of Labor Statistics 2012a). Worldwide, too, the ICT workforce is growing, suggesting that gender equity in computing may be critical to the health of the world economy (OECD 2012).

The finer level of detail for US labor force data provides a useful illustration in Fig. 8.5 of sex segregation within computing. Figure 8.5 shows the relative size of subfields within IT in the United States and women's representation in each. Overall, women account for about 25% of workers in US computing occupations (hence, the red line as a point of reference) but women's representation in detailed computing occupations varies from 8% of computer network architects, to ~37% of database administrators. Referenced along the left axis, the bars show the number (in 1,000 s) of people employed in each subfield. The red diamonds, referenced on the right axis, show the percentage of women within each subfield, with the horizontal line at 25% showing the overall representation of women across all fields of computing occupations. The yellow bars indicate subfields in which the U.S. BLS reports that the customary educational credential is less than a 4-year college degree, while the

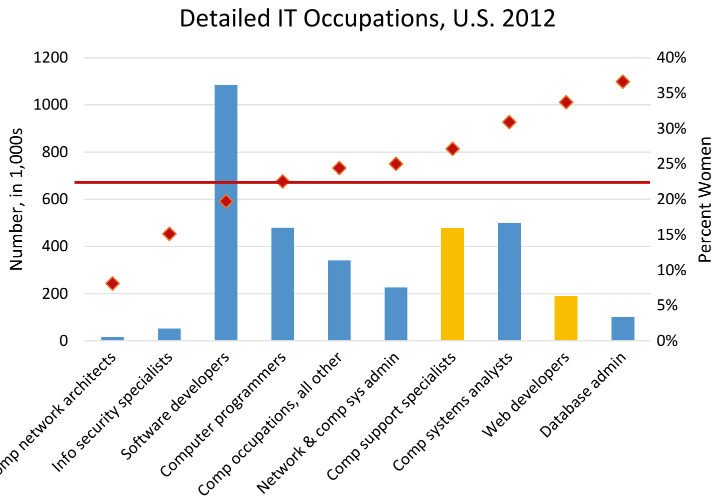

Fig. 8.5 Women's participation in U.S. computing occupations, 2012. *Note*: *yellow bars* indicate the customary education requirement is less than a bachelor's degree, the *blue bars* are those for which a bachelor's degree is the entry credential according to the U.S. Department of Labor Statistics. *Source*: Frehill, L. M. 2014. Analysis of BLS 2012c

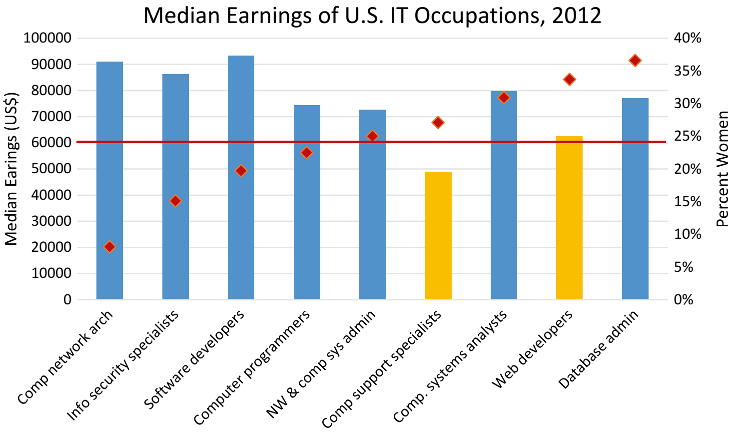

Fig. 8.6 Median earnings of U.S. IT occupations, 2012. *Note*: *yellow bars* indicate the customary education requirement is less than a bachelor's degree, the *blue bars* are those for which a bachelor's degree is the entry credential according to the U.S. Department of Labor Statistics. *Source*: Frehill, L. M. 2014. Analysis of BLS 2012b

blue bars indicate those fields for which a bachelor's degree or higher is typical. Women's representation is below the average of 25% in the following fields: software developers, applications, and systems software, the latter of which is the largest computing subfield. Women account for proportionately more than 25% of computer systems analysts and computer support specialists.

Figure 8.6 plots the median earnings of the same US IT occupations shown in Fig. 8.5, again, showing yellow bars for subfields for which U.S. BLS indicates that less than a bachelor's degree is a sufficient level of education and blue bars for those for which a bachelor's degree is the expected entry credential. Women's *representation* is *lowest* in the three *highest paid* occupations, which include two of the smaller occupations—computer network architects and information security specialists—as well as the largest one, software developers. Women's representation is higher than the 25% average in the two lowest-paid subfields—computer support specialists and web developers—the same subfields that, according to the U.S. BLS, are the only fields in IT that require less than a bachelor's degree.

Not shown in either Figs. 8.5 or 8.6 is "Computer and information research scientists," for which the customary credential is a PhD according to the U.S. BLS. With just 29,000 occupants, details about the gender and racial/ethnic composition of this subcategory were not provided by the BLS. Median earnings for these highly skilled professionals were the highest among US IT occupations at $102,190, which is more than twice the median for all US occupations of $45,790, to put this figure into a larger wage context.

The OECD completed a comprehensive report of women's participation in the ICT workforce in 2007. Fig. 8.7 is taken from the 2007 OECD report. Here, a

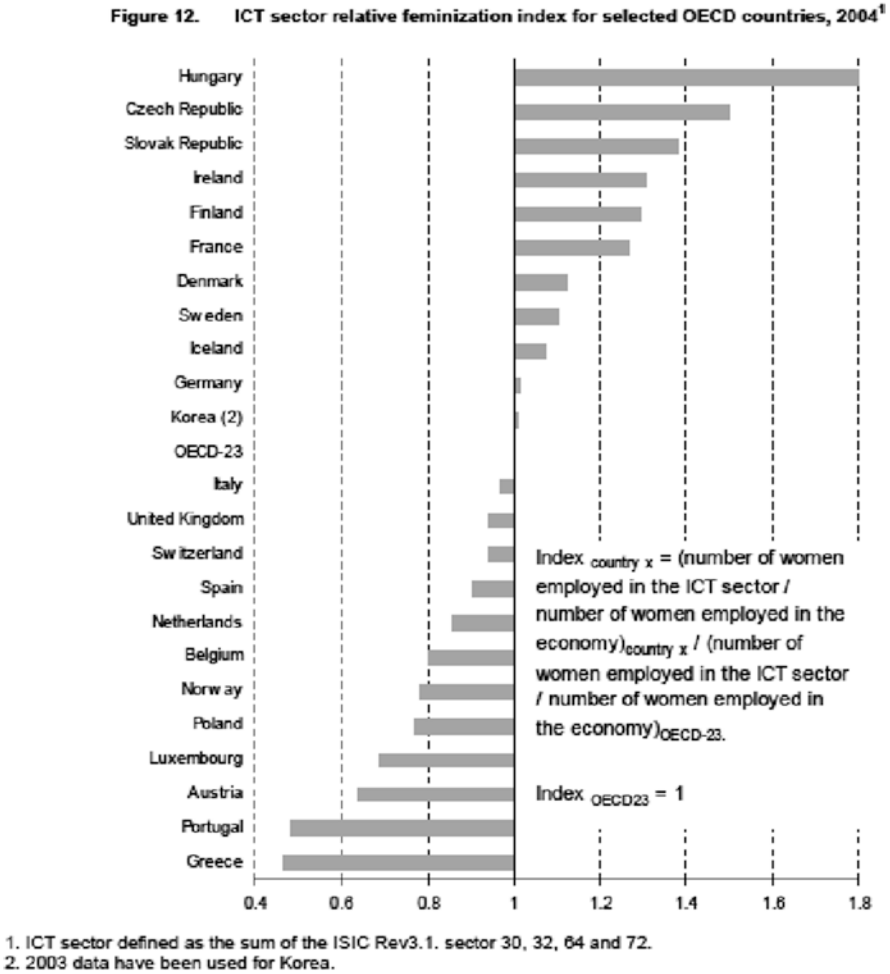

Fig. 8.7 Women's workforce participation in ICT as reported by OECD 2007. (1) ICT sector defined as the sum of the ISIC REV3.1. sector 30, 32, 64 and 72. (2) 2003 data have been used for Korea. *Source*: OECD, based on EULFS, and Korean Work Information Center, Human Resource Development Service

feminization index was used to normalize women's participation in the ICT sector in each country relative to the OECD participation rate. The index is computed as follows:

$$\text{Index}_c = \frac{\left[\dfrac{\#\,\text{Women}}{\text{Total}}\right]_c}{\left[\dfrac{\#\,\text{Women}}{\text{Total}}\right]_{\text{OECD}-23}}$$

Where: c = country
#Women = number of women in the ICT sector
Total = total ICT sector employment

As shown in the chart, Hungary, Czech Republic, Slovak Republic, and Finland are the OECD nations with a higher relative representation of women in the ICT workforce, while in Austria, Portugal, and Greece, women's ICT participation is lower than the average for the OECD. Recall, however, that the data on degree attainment shown in Figs. 8.1 and 8.3 for Tertiary A degrees suggests a need to better understand how educational credentials are mapped into the labor market. That is, the Slovak republic, for example, was a "very small" producer of computing degrees, with women accounting for just 12% of recipients of Tertiary A degrees. Men had a relatively high (7.7% of men's Tertiary A degrees) but women had a low (0.6% of women's tertiary degrees) in computing, suggesting that this credential may not be the critical entry point for the Slovak IT labor market, given the higher level of women's participation in IT work compared to other OECD nations.

In summary, women's representation in computing varies greatly across national contexts and, as illustrated with data for the US labor market, may differ within a nation based on the particular area of computing. These data underscore the importance of disaggregation: while women represented 25% of those in all US computing occupations, women's representation in detailed computing jobs ranged from a low of 8 to a high of 37%. The data from OECD illustrate the significant cross-national differences—in both computing higher education and labor force participation—in women's representation. Detailed data on subfield representation and the relative size of subfields across nations would provide useful additional data to understand the underlying dynamics of these cross-national differences.

8.4 Explanations for the Gender Gap in Participation in Computing

The previous section demonstrated the variability in women's cross-national representation in computing. Here we turn our attention to the question:

> Q2: What are the factors that encourage women's participation in computing and how do these vary as compared to the factors that draw men to the field?

A host of historical and psychological factors have been posited as potential explanations for the gender imbalance among ICT creators. In nations with high standards of living, history and social-psychological reasons are often cited. In the so-called developing nations, the literature has framed poor ICT, educational, and career access as either some of the negative impacts of societal devaluation of women and girls, or potentially like mathematics, the result of specific restricted agency of women in certain countries (Else-Quest et al. 2010).

Looking cross-nationally, researchers have noted that cultural beliefs about gender and gender appropriate labor combine with economic conditions, educational systems, and the characteristics of computing occupations to influence the gender composition of ICT (Charles and Bradley 2006; Charles et al. 2014). These national features are mutually reinforcing. Culture is transmitted through language and media (see Tympas et al. 2010 for an analysis of how Greek media portrays home computing), through the physical environment (Cheryan et al. 2011), through education and through our socialization of children, which makes them difficult to change.

Historical developments shaped computing fields' gender composition. ICT has academic, corporate, and hobbyist roots, each of which had its own gender compositions at the time ICT was forming in the OECD nations (Bratteteig 2008). Its academic roots in science, mathematics, engineering, and business disciplines have different patterns of gender representation as well at the university level. In nations where these fields were male dominated, the disciplinary roots grew into male majorities among computing leaders in academia.

In the corporate world, as ICT professionalized and boundaries were defined, women's computing work was devalued and deskilled (Ensmenger 2010). For example, this process was evident in the early feminization and later deliberate masculinization of computer work in the British civil service (Hicks 2010). When tinkerers and hobbyists led the shift to personal computers, women were further disidentified with ICT, because they were rarely members of these communities. Finally, as occupational gender segregation generally declined in industrialized nations, women had alternative professional opportunities and often chose careers in fields more closely aligned with longstanding feminine stereotyped abilities and interests (Sikora and Pokropek 2012).

Overall, women are attracted to ICT mostly by the same factors that draw men (Tillberg and Cohoon 2005; Cerinsek et al. 2013). According to Tillberg and Cohoon, those factors were: encouragement, perceived alignment with personal abilities and interests, positive initial experiences with computing, and expectations of a rewarding career. The attraction factors align well with an extensive body of knowledge about how people choose their occupations (Eccles 1994; Frehill 1996) and how those factors come into play in computing (Alexander et al. 2011).

Factors that drew women more than men to computing were perception of computing as a route to a helping career (Tillberg and Cohoon 2005; Cerinsek et al. 2013). For example, women but not men tended to mention they liked ICT as a form of communication, being recruited by friends, and defiance of gender-based expectations (Tillberg and Cohoon 2005). The first of these fits with a common gendered behavior in the United States—women's expression of interest in "helping" occupations (Eccles 1994). The second perception: computing as a form of communication fits with an observable gendered pattern in study of languages (Jacobs 1995). The third female-specific factor noted by Tillberg and Cohoon (2005)—defiance of gender-based expectations—exposes the social pressure steering most women away from computing occupations. These women, who were explicitly told that their gender prevented them from succeeding in computing, set out to prove that stereotype wrong.

Another example of common draws to ICT comes from a South African study that found women and men in ICT particularly enjoyed the intellectual stimulation, good salaries, flexible time and work environments, job security and satisfaction in ICT workplaces (Pretorius and de Villiers 2010). Again, there was tremendous overlap in the attractive features of ICT, although flexibility was emphasized by women more than men. This difference likely relates to the typically gendered expectations for balancing work and other aspects of life.

Gendered expectations about who has the ability to be an ICT professional predict the gender composition of the field. These stereotypes are often not even conscious, but affect preferences, confidence, and performance. In a cross-national study, Nosek et al. (2009) reported correlations between gender-science stereotypes and achievement differences by gender. They used the Implicit Associations Test,[5] which is grounded in experimental cognitive psychology, to measure test takers' facility or difficulty connecting science and masculinity versus science and femininity. Nosek and his colleagues examined data from 34 countries and more than a half million people, to find a strong relationship between an implicit connection of science and masculinity and the male advantage over women on the Test of International Mathematics and Science Study (TIMSS). These findings indicate that in nations where science is strongly associated with males, females perform poorly on tests of science, creating a self-fulfilling prophecy.

Another recent cross-national investigation reveals how the construction of gender impacts participation in computing. Charles et al. (2014) document that gendered interest and engagement in mathematics-related disciplines affect participation in computing. They found correlations among economic conditions and cultural beliefs about gender with attitudes and interest in math-based occupations as early as middle school. Their results show that, in countries where students have an economic means to choose careers based on self-expression, career choice is more likely to follow gender stereotypes.

If cultural beliefs and stereotypes affect the gender composition in computing, questions still remain about how those beliefs are formed and maintained, and how they might be overcome. In the United States, the National Center for Women in Information Technology (NCWIT) supports a Social Science staff and a Social Science Advisory Board, both of which work to accumulate and evaluate evidence about disparate participation in computing. Their goal is to motivate and inform other organizations' approaches to increasing women's participation in computing. The organization has compiled a body of literature on factors that create and maintain gender differences in ICT in the United States.

Others echo NCWIT's US findings for other nations, especially the European Commission (2012) and in the 2007 OECD publication on gender and ICT. The box on the "Latin American Women in Computing Congress" suggests that these same factors are hypothesized to be important outside those nations included in US and OECD analyses of gender and computing (Bonder 2003; United Nations Economic Commission for Latin American and Caribbean 2013). As a brief summary, these factors include:

- Cultural beliefs that link technology with masculinity (Frehill 2004; Oldenziel 1999; Oudshoorn et al. 2004; Sikora and Pokropek 2012; Wajcman 1991)
  - Funding practices that reflect those beliefs (de Bruin and Flint-Hartle 2005)
  - Hiring and promotion practices that reflect those beliefs (Reskin and Maroto 2011)

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[5] https://implicit.harvard.edu/implicit/.

- Lack of widespread accurate information about computing opportunities and the nature of ICT study and work (Bratteteig 2008; Cuny 2011)
- Instruction that assumes prior knowledge, or at least motivated personal exploration (Bratteteig 2008; Margolis and Fischer 2002)
- Gender differences in access, exposure, and encouragement (Cohoon and Aspray 2006; Margolis and Fischer 2002)
- An environment tailored to the interests and lifestyles of the overwhelmingly dominant population in ICT—young, white males (Pretorius and de Villiers 2010)
  - Sexism, blatant and subtle (Cohoon et al. 2009)
  - Unattractive "Geek" culture of computing (Cheryan et al. 2009)
  - Emphasis on individual work and de-emphasis/devaluing of collaborative work
- Lack of secondary school computing requirements and the scarcity, more generally, of computer science and programming classes in US secondary schools (Cuny 2011; Margolis et al. 2011)

Findings from other important studies by Galpin (2002) and Trauth et al. (2009) reinforce the critical role of national culture in shaping women's participation in computing. Trauth and her colleagues used qualitative interviews with more than 200 women in IT in the United States, Australia, New Zealand, and Ireland, which included immigrant women from a number of nations, including China and India. Immigrant women interviewees made some personal cross-national comparisons, which offer tentative areas for future research.[6] Trauth et al. show that sociocultural moderators intervene with perceptions of women's general role in society to impact women's choice of careers in IT. In addition, the meaning of a career and the role of family in career choice were also described: in the United States,[7] for example, career choice reflects a job an individual wants to be in, while in other countries discussed by Trauth et al.'s respondents, families play a more active role in selection of a career. That is, respondents to Trauth et al. who had been raised in China and India reported that if an individual performed well in mathematics and science, then (s)he was expected to pursue a career in those fields. In other words, the dominant ethos, according to these respondents, was that young people are expected to pursue work in areas in which they have a measured potential, regardless of an individual preference or interest, findings that are underscored in work by Varma (2015) and supported in the earlier-referenced work by Charles et al. (2014).

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[6] Attention to the potential for individualistic fallacy errors is important caution in such cases.

[7] Within working class families (Higginbotham and Weber 1992) and among Latinos (Santiago 2007), though, there are some areas of US society to which this understanding of "choice" is not applicable. In such families there are expectations more similar to those described here as the case in China and India.

Latin America: Latin American Women in Computing Congress

"This is an annual event that has taken place since 2009 within the framework of the Latin American Computing Conference (CLEI) organized by the Latin American Centre for Informatics Studies. Its main objective is to highlight women's research interest, and achievement in the different areas of information technology, with a view to encouraging more active participation from women. The papers presented are expected to identify the challenges facing women in the ICT field, in teaching, in the job market, and in research.

The fifth Latin American Women in Computer Congress (Naiguatá, Bolivarian Republic of Venezuela, October 2013) is part of Latin American Computing Conference 2013. Its topics will be:

- Encouraging the participation of women in the ICT sector
- Gender equality and ICTs
- Gender particularities in the development and deployment of ICTs
- Gender particularities in ICT education
- Analysis of the research activities of women in ICTs
- Gender and human–computer interaction
- Female leadership models in IT
- Internet social networking and the role of women
- Women's participation in decision-making at the national and international level in relation to the use of ICTs
- Public policies on ICTs".

Source: Latin American Computing Conference (CLEI), "V Congress de la Mujer Latinamerícana en la Computación," 2013 [online] http://clei2013.org.ve/v-congreso-mujer-latinoamericana-en-la-computacion/.

Reflecting and amplifying the impact of cultural beliefs, educational systems play a huge role in shaping a nation's ICT gender composition. Charles and Bradley (2009) found that horizontal gender segregation (clustering of men and women in different fields) correlates negatively to educational systems with low prestige and low entry barrier options. Likewise, having the luxury of career choice based on self-expression as opposed to economic or other practical considerations contributes to gender segregation in academic disciplines, including computing (Charles and Bradley 2006).

In India, for example, women's relative representation among those enrolled in computing and information technology is larger than that in many countries, but women are far less likely than men to attend the elite IITs. The gender gap in girls' versus boys' admission rates to the IITs is hypothesized to be due to less access for girls to the coaching that many boys receive to perform well on the examination (National Task Force for Women in Science 2010). The gap in access to coaching is due to both cost as well as "unfortunate timings," courses scheduled too late at night or early in the morning, which marginalize girls. Given the recent international news about violence against women in India (Lakshmi 2012a, 2012b; Sharma et al. 2013), such concerns about personal safety in public are an important practical concern.

The question about the quality of the credentials women earn in computing and IT in India suggests that researchers need to be attentive to the within-field stratification of computing jobs. Just as was shown in Figs. 8.5 and 8.6 for US computing occupations, if women are less likely to earn degrees from the best universities in the country, they may be relegated to lower-wage work in more routine jobs in computing than their male counterparts.

In India, "feudal, authoritarian values and hierarchy have characterized Indian society," which underlie the lower level of women's participation in science (Kumar 2008) and, consistent with Brownmiller's classic 1975 expose, buttress the societal acceptance of violence against women as a means of social control. Kumar argues that an ethos of masculinity permeates Indian institutions, into which gender is woven into the rigid, hierarchical structure, leading women to either suppress their aspirations or to cluster in fields with more women such as the life and medical sciences. The data in Fig. 8.4, as well as work by Varma (2010, 2015), suggests that IT may be a field into which Indian women may be clustering.

As a relatively new field ICT may be less laden with pre-conceived beliefs than more established fields. Ilavarasan's (2006) limited observations of women and men in the Indian IT workforce found that respondents had similar opportunities regardless of gender. Work by Munshi and Rosenzweig (2006) focused on local labor markets in Bombay to describe the relationship between caste, gender, and schooling. Munshi and Rosenzweig found that existing social networks that young men used to locate jobs enabled them to secure positions in traditionally male-dominated occupations. IT occupations, as relatively new occupations with high demand, lacked prior connections to social networks, thereby representing an opportunity for women—who were also new entrants to the paid labor market—serving as a driver for women to obtain relevant education.

Beyond the issue of educational quality, research on gender and computing in a number of global regions focuses attention on girls' and women's access to education in general, and ICT as a means of societal advancement and growth. According to the National Task Force on Women in Science (Government of India 2010), there are several issues unique to India in contrast to other large nations, but which are similarly important in other developing nations. These factors impact women's participation in education, generally, and pose implications for women's access to fields that require completion of progressively more complex education:

- The educational pipeline leaks in primary and secondary school
- Female children continue to be culturally considered a burden
- There is a high incidence of malnutrition in women and children
- As a summary, the World Economic Forum (WEF) Gender Gap Index ranks India 113 out of 130 nations

These issues related to gender, access, and development were prominent in UNESCO (1999) and infoDEV (2007) reports about African nations (Farrell and Isaacs 2007). State policies that impact the availability of education often have a disparate impact upon girls compared to boys. Just as the Indian government has taken steps to improve girls' access to primary and secondary education, differential access to these foundational experiences, in general, and to computers, in particular, hamstrings women's access to the ICT labor market. Nigeria and Ghana, for example, have taken steps to introduce girls and women to emergent economic sectors such as biotechnology, informatics, and computer technology as a means to national economic development.

8.5 Women's Impact on Computing

Consistent with Bratteteig's suggestion, we go a step beyond the equity approach implicit in the foregoing to ask how gender impacts how computing is done or what is produced by computing work, which was at the heart of our third question:

Q3: To what extent does gender matter in computing?

In this section, we provide a short overview of some of the themes that have been—and continue to be—explored that attempt to answer this question, as a means of motivating additional research in this area. As highlighted in Creager et al. (2001), it is important to avoid the tendency to essentialize gender in addressing this question. Instead, gender should be seen as one of many dimensions of diversity reference in the burgeoning "business case for diversity" literature, which has emerged over the past 25 years. While this is a vast and rapidly growing literature, the extent to which sources in this literature focus on IT in particular or provide cross-national analyses is somewhat limited but also growing given the centrality of IT for the world economy.

The business case is grounded in findings that diverse groups perform better than homogeneous ones, are more innovative, and, therefore, are better for the bottom line (profit) in business settings (see, for example, Catalyst 2013; Cox and Blake 1991; Herring 2009; Hoogendoorn et al. 2011). In IT, for example, Ashcraft and Breitzman (2007) examined IT patents in Japan and the United States by the gender composition of the patenting team and found that "Within the U.S. set, mixed-gender teams produced the most frequently cited patents—with citation rates that were 26–42% higher than the norm. Female-only teams had the lowest citation impact, followed by male only teams" (p. 5).

Many studies on the relationship between teams and innovation document the important role of diversity in the innovation process (see, for example, Bassett-Jones 2005; Gilbert 2006; Hoogendoorn et al. 2011; Marx 2013). Within this literature, which buttresses the "business case," it is rational for businesses to include women in the design process in order to develop products that will appeal to a wider market than those that might be designed by all-male teams. A similar argument is made—and supported by the literature—about other bases of social difference. Reflecting this bottom-line prerogative, corporations that are large investors in research and development (R&D) have established networks of research laboratories in multiple countries to take advantage of the varied workforces and ideas within those regions (Thursby and Thursby 2006).

Some studies that have attempted to answer this question often take the literature on the business case for diversity as a "given." According to a review by Maass et al. (2007), the affirmative answer to this question is common among policy makers and corporate advocates of women in computing who see women as being able to make potentially different contributions to computing. In their volume reporting on an international symposium on women in information and systems technology (IST) Maass et al. emphasize that "IST design is a highly prestigious activity. Information technology business offers positions of power and good incomes for those with the appropriate (technical) education and enough self-confidence" (p. 10).

Such a view is especially apparent in African nations, where policy makers see much promise for social and economic development associated with increasing access to information via ICTs for African nations. Publications that focus on ICT in Africa emphasize the need to include women in decision-making processes about national ICT infrastructure (i.e., gender mainstreaming), in particular, and at all stages of education and workforce for ICT (UNECA 2009a, 2009b).

Within the global context, ICTs have become ubiquitous. The UNECA has paid much attention to this issue, including documentation of the progress made in narrowing the gender digital divide. At a meeting in 1996, the UNECA Conference of Ministers passed Resolution 812 (XXXI) in Tunis, Tunisia. A gender mainstreaming approach was among the resolution's five points: "To establish a gender-balanced African technical committee to advise on programmes and projects and evaluate results." (UNECA 2008: 6). Gender mainstreaming, common in much of the world, is emphasized as the means by which women would have equal access to ICT as a means to societal advancement.

Figure 8.8 plots data included in UNECA (2009b) and shows the status—as of 2009—of policy progress in implementation of the Tunis Commitment. Ten policy features were examined as of August, 2009 and scored (0–2) by UNECA to develop an index that ranged from 0 to 20. The policy features were:

- Policy development
- Development of a plan
- Targets (gender)
- Institutional mechanisms
- Budget
- Human resources
- Research
- Involvement of civil society
- Information and dissemination
- Monitoring and evaluation

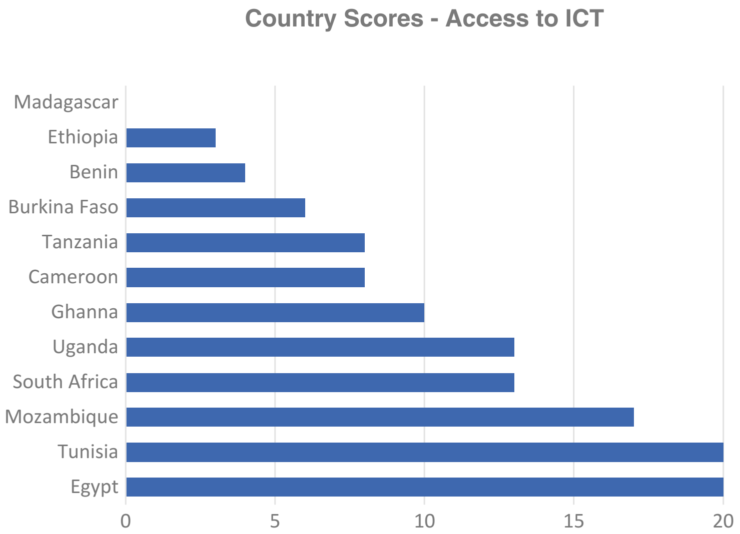

Fig. 8.8 Policy to increase women's access to ICT in selected African nations, 2009. *Source*: Frehill, LM. 2014. Analysis of data from UNECA. (2009). African Women: Measuring gender inequality in Africa: Experiences and Lessons from the African Gender Development Index. (Adis Ababa: UNECA)

After the events of the Arab Spring of 2011 and, particularly the backlash against women in Egypt since then (Dawoud 2012), it is interesting to note that Tunisia and Egypt had the highest scores on this policy scale. Mozambique's score of 17 places it in third position with respect to increasing women's access to ICTs, while South Africa and Uganda are in fourth position with a score of 13 each. Other nations, notably Madagascar, Benin, Ethiopia, and Burkina Faso all had relatively low scores (0–4), reflecting persistent gender equality issues.

8.6 Conclusion

We have shown that women's participation in computing varies greatly across national contexts and in various ways within nations. While women may not pursue computing degrees, the sheer size and significance of the ICT economic sector at the global level serves to pull women into the field. As these jobs become increasingly important and numerous globally, tied as they are to national economic prosperity, they are likewise important to women's and children's prosperity. Maass and her colleagues point out, for example, that almost any job in the new global economy necessitates that one use information technology, so, individuals need at least a working knowledge of ICT to survive. To thrive, though, being conversant in these technologies will be increasingly critical.

While women appear to be making inroads in computing education in some nations, these are generally in nations that are medium or small producers of degrees in computing and in which computing occupies a lower status than other areas of science. In other cases, such as in India, the extent to which women have access to education of a quality comparable to that of men remains an open issue. Women's overall participation in secondary and tertiary education has grown in India, as it has in much of the world, but women still have not reached parity with men. In addition, despite women's relatively high rates of enrollment in CS/IT fields (as shown in Fig. 8.4) they continue to be significantly underrepresented at India's most prestigious IITs.

The case of India, indeed, illustrates the need to be more cautious with data on gender and participation in science. Institutional differences have important ramifications for the likely career outcomes of students (see also Malcom et al. 2005 for a review of the impact of institutions on IT career outcomes in the US setting). The organization of IT within higher education, as a relatively new field, can both affect and be affected by the larger social organization of gender. This begs the question; to what extent are the cross-national variations in women's participation in computing an outcome of the different ways in which computing is organized within national education systems?

The labor market data for the United States, which further disaggregated computing into a number of subfields, provided another important analytical illustration. As has always been the case in occupational sex segregation research, the level of aggregation is a critical dimension; high levels of aggregation can often obscure key differences that are only revealed when one is able to more closely specify occupational categories at a finer level of detail. As shown in Figs. 8.5 and 8.6, for example, the distribution of women across subfields of IT work in the United States varied greatly across the ten detailed occupations shown in Fig. 8.5 (nine in Fig. 8.6).

These twin issues—the quality differences (stratification) of higher education institutions and the level of aggregation—pose challenges for researchers interested in understanding gender and computing. Yet, this chapter's analyses may offer useful starting points for subsequent researchers interested in the policy implications of the questions posed in this chapter.

The limitations of data availability pose challenges to those interested in cross-national occupational analysis. While we were able to disaggregate computing occupations in the US labor market, this was not possible with any other national labor market data to which we had access. Further, in fact, due to the level of general workforce data aggregation, it was not possible to look at employment in ICT. The most recent year for which sex-disaggregated data were available from the European Commission was 2006. Researchers interested in other dimensions of difference, such as immigration status or race/ethnicity, will find it even more challenging to find suitable data to understand how such dimensions affect access to the ICT workforce.

Additional research is needed to better understand the cross-national differences discussed here. Further, additional research needs to provide insights into the third question we posed; to what extent does gender matter in computing? In comparison to men, do women focus on different problems? Take different approaches? Use and develop different computing tools?

The omnipresence and rapid growth of ICT suggest that it is vital to ensure diverse individuals can access opportunities associated with the ICT labor market. Likewise, the pace of innovation suggests a need to tap a rich talent pool to ensure equitable advancement.

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Vignette 8.1

Faculty Wives of Computing

Betsy DiSalvo

"I am a faculty wife. My husband teaches and researches design and technology, he works on robots a lot." For a many years, this is how I introduced myself to new acquaintances (all of our new acquaintances were in academia that is what happens when you are a faculty wife). Eventually, between him bringing home interesting questions and talking about exciting project, me feeling unfulfilled in my job with a desire to learn more, and the stars aligning in a certain pattern, I went back to school. I studied Human Centered Computing at Georgia Institute of Technology, eventually earned my Ph.D. and started as an Assistant Professor there in 2012. Before marriage, I never would have dreamed that I would earn a Ph.D., let alone a Ph.D. in computing. I credit (and some days blame) it on the exposure to new ideas I gained as a faculty wife.

I am not the first faculty wife in computing. To understand faculty wives' role in computing, it is important to reflect on the history and development of computers during WWII. The University of Pennsylvania's Moore School of Electrical Engineering was executing a military contract to develop ENIAC (Electronic Numerical Integrator and Computer) and required massive amount of hours on the part of mathematicians to calculate trajectories for military applications. With the lack of men available to work during the war, particularly men skilled in mathematics, these calculations were made by a large group of female mathematicians, called *Computers*. At the end of the war, men were available to do this work, but at this point the work was considered a traditionally female role, and women who had worked on the ENIAC programming were the most prepared to continue (Light 1999).

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A number of these young women working on the ENIAC project married more senior men working on the project, and these men moved to faculty jobs after the war, their wives helped with their husband's research. Adele Goldstine, who managed the female *Computer* team and wrote the technical documentation, was the wife of Herman Goldstine. She followed her husband from the ENIAC project to Princeton to work on the Institute of Advanced Study Electronic Computer Project (ECP). When asked about the programmers on the ECP in an interview in 1980, H. Goldstine commented:

> We had a couple; we had wives who were programmers. A couple of women. For instance, my wife worked for von Neumann as a programmer, on a Los Alamos contract. And then we had two other, Hedi Selberg and Margaret Lambe who were wives of professors. Hedi's husband was a professor at the Institute and Margaret's husband is now a Stony Brook. (Stern 1980, p. 52)

His statement is telling, in that it diminishes both the role of the programming and the role of the women in the projects. These collaborators were considered just wives of professors but not full team members. The job of programming was not given the same consideration as other work on the ECP; it was something left to the wives, who are described by their husbands' positions rather than their contribution. There were at least five women who developed programs for the ECP, all wives of professors, and no recollection of men who did this work from H. Goldstine or others who have been interviewed (Stern 1980a, 1980b, 1981).

A report by Burks, H. Goldstine and von Neumann, the *Preliminary Discussion of the Design of an Electronic Computing Instrument*, begins to outline a programming language, what they call "Symbolization" with their corresponding operation (Burks et al. 1986). While Von Neumann and others developed some test programs, the full programs were developed by the "wives" including Von Neumann's wife, Klara Dan von Neumann. The faculty wives that did this programming had to be fluent in the mathematical programs to translate them into machine language. In some ways the role of these women was less of a *Computer*, and more similar to that of a compiler; translating between mathematical functions and machine language.

As efforts to establish formal programming languages that were more similar to English, rather than machine language, began to succeed, the role of women diminished, until woman became the anomaly rather than the standard in computer programming. There are many contributing factors to this: most of the women who worked as *computers* during WWII went to work fulltime in their homes after the war; as the computer programming came to the forefront of technological development it was regarded as less of a clerical task; and computing was being established as an industry so the work of a computer programmer was seen as a job rather than patriotic service (Light 1999).

Looking back on this history, I wonder if these women had been given the agency to pursue independent intellectual questions, would the development of stored programming language begun sooner, moved faster, or had a different trajectory? I recognize that even with the advancement of women in computing, stepping out of my role as a faculty wife, into the role of a faculty member was unusual, difficult, and risky. While my husband is not as venerated as von Neumann, because of the sequence of our degrees and appointments and the choice to take his last name, people outside of my department frequently perceive my work as an extension of my husband's, or dismiss my appointment in academia as a courtesy. There is little I can do to change that perception.

And I am not alone, while women have certainly made progress, currently 36% of faculty have an academic partner, yet only 20% of wives said their career comes first compared with 50% of men (Schiebinger et al. 2008). These statistics, my experiences, and the history of women in computing leave me asking if women shortchange themselves or if perceptions that our work is less valuable shapes our choices?

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Vignette 8.2
Making a Meaningful Choice: Women's Selection of Computer Science in India

Roli Varma

Low participation of women in computer science (CS) education is a pressing problem in many Western countries (Ahuja 2002; Lie 2003; Singh et al. 2007). By and large, the field of CS is perceived as masculine both by men and women in Western countries (Wajcman 2004). In contrast, women in India have increased their presence in CS education in most nationally accredited institutes and universities (Basant and Rani 2004; Varma 2009; Fig. 8.4). In general, the field of CS is perceived as women-friendly both by men and women in India (Varma 2010). Regardless of economic, political, and social advantages in the Western countries, women in India seem to have levels of success in CS education that appears to somewhat outstrip those of Western women. This paper uncovers why women in India are attracted to CS education and career.

8.7 Methodology

The paper is based on in-depth interviews that were conducted by the author with 60 female undergraduates majoring in CS in 2007–2008. The study took place in two engineering institutes and two universities that granted 4-year undergraduate degrees in CS. Random sampling was used to select 15 subjects who were in their second and later years of studies at each institution. Interviews were recorded, transcribed, and analyzed with Nvivo. All of the students interviewed were young, unmarried women between the ages of 19 and 22. Other than being a full-time student, none held a job while attending university. Almost all of them characterized

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their family background as in the middle- or upper-middle-class categories. Almost 75% of students were born to Hindu families, with the majority belonging to middle and high castes; remaining students were born to Sikh and Muslim families.

8.8 Findings

8.8.1 Why Do Women Choose Computer Science?

The findings show that some female students became interested in CS education because they had early exposure to computers either in their homes, cyber cafes, or friends' places. They used computers to browse the web, chat/email, and play games. A few took computer classes in their high schools to learn word processing, power point, and paint; however, they complained that the computer laboratories have poor resources with limited access due to power cuts. At least one-third of students were not exposed to a computer pre-college. A significant factor in most female students' entrance into CS involved encouragement from a parent, sibling, or cousin who owned a computer or studied in an engineering field. They influenced the students by narrating personal experiences or by conveying that CS has a great potential for women. Especially male family members described CS as an excellent major for women because it required merely mental power not physical, and because they could work indoors rather than outdoors on a construction site. Also, students made a pragmatic assessment of the CS with great potential for employment, the omnipresent presence of computers in government and industry, and the power to be on the cutting-edge modern technology. A few female students believed that a CS degree would let them have some social independence.

8.8.2 Why Do Women Perform Well in Computer Science?

Since female students had little experience with computers in high schools, did they feel prepared for CS study at the university? A large majority of students stated that either their schools did not prepare them well or only partially prepared them for university level CS. Yet, most of these students believed that their high school education in mathematics was strong, and thus critical to their ability to proceed into CS. They were extremely confident about their mathematical skills and, thus, logical thinking and analytical abilities. So, even though they found CS a hard, demanding, technical field, female students felt their mathematical training prepared them to do well in CS at the university level.

8.8.3 How Do Women Perceive Computer Science?

Female students view the typical CS culture as people-friendly especially women-friendly. It consists of dedicated, hard-working, intelligent, meticulous, and smart students who help those needing assistance. In addition to the CS study, these students are active in social events and sports and it is pleasant to be around them. According to them, women who study CS are well respected by faculty and peers in the educational arena and by family members, friends, and neighbors in the social arena. Also, female students believed that economic rewards for a woman with a CS degree are much higher than with a degree in other science and engineering fields. Some female students indicated that employment in information technology (IT) companies is well appreciated and it alleviates concerns their families had about the high cost of marriage.

8.8.4 Why Do Women Stay in Computer Science?

If female students do not like the CS or find CS difficult, would they try to avoid disappointment by switching their major? The findings show that an overwhelming majority of students had not entertained the idea of leaving CS to another major. The respondents reported it did not cross their minds to switch to something else because of the economic benefits, work opportunities, and social independence they could gain with a CS degree. Most students did not know anyone who changed majors or dropped out of CS, which was seen as a step backward.

8.8.5 What Women Hope to Get with a Computer Science Degree?

Upon completion of their CS degree, most female students planned on joining the workforce, with a few interested in moving directly into a graduate program, and the remaining students undecided about a job or higher education. Students were confident about receiving placement into good IT companies due to the frequent job placement campus visits by company recruiters. Students who expressed their desire to move directly into a graduate program felt it would allow them even more opportunity than their peers, along with a broader range of possible employment and higher pay. Students who were not sure whether to join the workforce or a graduate program wanted to decide on the strength of job placement and the admission to the university that they wanted to attend.

8.9 Conclusion

Women in India are enrolling in CS because it is a means for them to secure a friendly working environment, gain prestige, become career-oriented professionals, and attain an economically independent status. This shows that women in computing cannot be viewed as a globally homogeneous group. The gender imbalance in the Western countries is not a universal phenomenon as it has been presented in the scholarly literature.

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