Introduction

In 1882 renowned English scientist Charles Darwin announced that "[t]he chief distinction in the intellectual powers of the two sexes is shewn by man's attaining to a higher eminence, in whatever he takes up, than can woman" (Darwin, 1871, p. 564). This belief in women's inferior intellect was not new,[1] but as an eminent scientist, Darwin's proclamations held great sway in his time and place – and since – although nowadays few would admit to this. Or would they? Jump forward to 1992 and we see the arrival of John Gray's *Men Are from Mars, Women Are from Venus*, which became a phenomenal best-seller (selling more than fifteen million copies globally[2]), and continues to be so. While the book is not as forthright in saying women's intellect is inferior, it does explain the many ways in which men and women differ – including the ways they think (Gray, 1992).

The mindset that assumes men and women have different intellectual abilities and capabilities has a strong hold on public thinking in the United States and many parts of the Western world. Such thinking feeds our stereotypes and our biases and is used to explain why men and women "choose" different areas of study, different careers, and hold different aspirations – including how they relate to computing; computer science (CS); informatics, information, and communication technologies (ICTs); information systems (IS); information technology (IT); and related fields.

This book includes a collection of perspectives that challenge the *pink brain, blue brain*[3] myth and provides voices from multiple cultures and countries. Our inspiration and motivation for this book came from working with computer science majors at Carnegie Mellon University (CMU) in the United States and recognizing that for women to be successful in computer science we did not have to change the curriculum to suit "women's ways of thinking" – women can do the intellectual work as

well as their male peers – *but we did need to change the culture* (Frieze and Quesenberry, 2015).

Thus, our goal with this book was to collect a range of global perspectives to show that women's participation in computing[4] is largely determined by cultural factors. To accomplish this goal we have brought together a landscape of researchers and educators in this edited volume. We have included brief summaries and quotes of some of their work throughout this introduction to set a foundational understanding of the topics at hand. In the final section of this introduction we have also included a guide to the chapters and their highlights, to help our readers navigate the organization of the contents.

We showcase the role of cultures, which can vary even within one country, and illustrate how a multitude of cultural factors influence women's participation in computing. Along with cultural heterogeneity, women and men are not single separate categories – we are all shaped by intersectionality and complex identities including such factors as race and ethnicities, disabilities, socioeconomic backgrounds, sexual orientation, and religious beliefs. Our experiences are subject to the values, attitudes, and behaviors of cultures at large as well as the micro-cultures we inhabit such as our families, schools, workplaces, and peer groups.

WOMEN IN COMPUTING: DATA ON PARTICIPATION

Gender balance in itself can have particular impact on the individual experiences of women in computing. As one Swedish computer scientist explained, being one of very few women "had the quite strange side effect of [me] quickly becoming a familiar face to almost everyone in the program – on good days it felt like being a celebrity, on bad days it felt like being a zoo animal" (Linquist and Melinder, Chapter 11). Being the only woman on the software engineering team, or being the only girl in the computer science class, can mean being seen as representative of all women and not as another engineer or student. It can also lead to feelings of isolation and non-belonging – and at its extreme to leaving the field.

What we find as we explore the data from different countries and cultures is that women are seriously underrepresented in computing in many parts of the world. This would appear to support a commonplace American belief that computing is a boys' field. Consider that in 2016 in the United States, only 19% of computer science undergraduate degree recipients were female (Zweben and Bizot, 2017) and women held only 26% of computing occupations (Bureau of Labor Statistics, 2017).

For minority women the situation is worse. For example, African American women represented just 3% and Latinas 6% as recipients of computer science degrees (Zweben and Bizot, 2017). African American women and Latinas hold slightly less than 10% of computing occupations in the United States (National Science Foundation, 2017).

But now consider this:

- 50% of CS majors at Carnegie Mellon University in the United States are women (Frieze and Quesenberry, 2015).
- 55% of CS majors at Harvey Mudd College in the United States are women (Alvardo et al., 2012).
- 59% of students enrolled in CS studies in Saudi Arabia are women (Alghamdi, 2016).
- 50% of engineering graduates in Cyprus are women (UNESCO, 2017)
- 55% of entrepreneurs in the Internet industry in China are women (PRCSCIO, 2015).
- 50% of undergraduates in computing at University of Malaya and Universiti Kebangsaan Malaysia in Malaysia are women (Othman and Latih, Chapter 15).
- 40%, 65%, and 50% of students in CS/computer engineering at the undergraduate, master's and doctorate levels, respectively, in India are women (Huyer, Chapter 2).

While women are seriously underrepresented in computing fields in the United States, and in most of the world, *the situation is not universal* as the above data, and some of the chapters in this book, illustrate. Additionally, women have shown themselves to be strong participants in many fields that were once closed to them on the grounds of biology and perceived innate characteristics. In the United States and Portugal, we can look to medicine as examples of this change. In both countries there is near gender equality in the medical profession (e.g., AAMC, 2017; Lopes, Chapter 12). Furthermore, in 2016, 57% of *all* bachelor's degrees went to women in the United States, while 50.3% of science and engineering bachelor's degrees went to women in 2013 (Girls Collaborative Project, 2016; National Center for Education Statistics, 2016). We see a similar picture emerging globally. For example, in Russia women outnumber men in overall graduation rates, with women gaining 56% of postsecondary degrees (Khenner, Chapter 13). In Portugal in 2009, 59.3% of the total higher education graduates were women. Similarly, the Organisation for Economic Co-operation and Development (OECD) reports that women earn more postsecondary degrees than men, and a UNESCO analysis of women in science,

technology, engineering, and math (STEM) fields found that women represent 53% of the graduates in tertiary education in bachelors and master's programs (OECD, 2017; Huyer, Chapter 2). Such data illustrate women's intellectual potential to succeed in any field and it seems reasonable to suggest that this should include computing. It also suggests that data tell us only part of the story. To get a better understanding we need to pay immediate and close attention to the cultural factors that might be enabling or deterring women's participation in computing. "Cultural understanding is crucial to an understanding of gender influences and barriers because gender is experienced through culture" (Trauth, Chapter 3).

One of the most interesting discussions relating to data challenges some of our expectations and has serious implications for women in computing in the West. Studies have found that affluent, developed countries that *feature highly in gender equality rankings* are more likely to have the *lowest* participation of women in computing (Chow and Charles, Chapter 1). According to a recent study the gender gap in STEM increases with increasing levels of gender equality (Stoet and Geary, 2018). The World Economic Forum (2016) ranked Scandinavian countries as the most equitable of societies.[5] While Scandinavian countries like Norway, Finland, and Sweden are leaders in gender equality they have the largest gender gaps in college degrees in STEM fields (Stoet and Geary, 2018). Meanwhile, Saudi Arabia has good representation of women in high school computing and yet very low ranking – 141 out of 144 – for gender parity according to the World Economic Forum (2016).

GENDER THEORIES: ESSENTIALISM, SOCIAL CONSTRUCTIONISM, AND INTERSECTIONALITY

Historically, there are at least three major theoretical perspectives typically used to explain women's participation in computing: essentialism, social constructionism, and intersectionality theory.

Essentialism is the belief that people have properties that are essential to their composition. This suggests that all members of a particular group (e.g., gender, race, sexual orientation) innately share a common set of fixed, unified characteristics that form the primary components in understanding human actions (Wajcman, 1991). Hence, at the core of essentialism is the belief that since men and women are inherently different in their physical bodies, they are also different in the ways in which they act, behave, *and think* – and in how they relate to computing.

The essentialist way of thinking carries serious, negative repercussions for countries where women are poorly represented in computing. In *Occupational Ghettos: The Worldwide Segregation of Women and Men,* researchers argue that *essentialism* is still entrenched in the dominant culture of many advanced industrial countries where a deep-seated belief in gender differences is maintained and supported by a culture that values individual preferences and self-expression (Charles and Grusky, 2005). Even though such cultures no longer hold that men are *better* than women, they still subscribe to a belief that men and women are *very different*. This continuing belief in difference means boys and girls are more likely to follow gendered studies and career paths even in countries perceived as very progressive on gender issues.

Some fascinating research that challenges essentialism and beliefs in intellectual gender differences has emerged from the field of neuroscience. Lise Eliot, professor of neuroscience at the Chicago Medical School of Rosalind Franklin University of Medicine and Science, debunks the belief that brain differences account for gender stratification in intelligence and capacity for scientific thinking. Eliot's exhaustive review of the scientific literature on human brains from birth to adolescence is explained in her book *Pink Brain, Blue Brain*. She concluded that there is "surprisingly little solid evidence of sex differences in children's brains" (Eliot, 2009, p. 5). Indeed, the work of Eliot and other researchers has shown that men and women are not as different in their intellectual potential as popular wisdom would have us believe (Barnett and Rivers, 2005; Fine, 2010; Halpern, 2000; Hyde, 2005; Hyde and Linn, 2006).

Social construction is the belief that human behavior is rooted in historical and cultural interaction and practices. The central concept of Berger and Luckmann, explained in *The Social Construction of Reality* (1966), is that social systems are based on interactions that eventually develop into habitualized norms and roles. Over time these interactions become institutionalized, and, hence, meaning is embedded in individuals and society such that when a woman enters a male-dominated field she is seen as "stepping out of line" in terms of cultural expectations. Sandra Bem's cognitive theory of *schemas* explains how social norms start early in life and become entrenched unconscious guides to our behavior and attitudes (Bem, 1981). Bem suggests that gender schemas help solidify cultural stereotypes. They provide an "easy" way of perceiving the world around us while we struggle to identify with gender constructs in the cultures in which we find ourselves.

Many suggest that a social construction perspective is key to understanding cross-cultural variation in gender roles and expectations. American-based authors Henry Etzkowitz, Carol Kemelgor, and Brian Uzzi provide a life-course analysis (based on interviews and surveys) of women in the sciences from an early childhood interest, through university, to graduate school, and finally into the academic workplace in their book *Athena Unbound.* They conclude that despite recent advances women still face a special series of gender-related barriers to entry and success in scientific careers.

Intersectionality theory provides a framework to address the many ways in which women (and men) are not one single separate category. Our identities capture a range of interconnections, similarities, and differences that influence how we experience the world. The term "intersectionality" has been credited to Kimberle Crenshaw in her essay "Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics," in which she discusses the multidimensional experiences of black women (Crenshaw, 1989). While women are undervalued generally in our culture, individual factors, such as race, socioeconomics, sexual orientation, and ethnicity, can add levels of further marginalization. The theory also reminds us that identities are not fixed but are subject to the changing situations and micro-cultures in which we live our personal and professional lives. For instance, Trauth (2002) uses the "Individual Differences Theory of Gender and IT" to characterize how individual women respond in a range of specific ways to the interplay between individual characteristics and environmental influences.

Intersectionality is particularly important to reflect on in this book of global perspectives, but we have one caveat: we are as guilty as anyone for using the binary terms "women" and "men" in our writings. We are limited by our language and have yet to find a more efficient way to explain our ideas as we address the global situation for women in computing. The chapters in this book represent a variety of theoretical underpinnings – but common to all the perspectives is the acknowledgment that cultural factors – not innate biological considerations based on sex – play a role in the shaping of gender.

This may be a good time to let our readers know what we are not saying. We are not saying that men and women are the same – that there are no differences – clearly our bodies indicate this – but we are saying that in some environments there may be more similarities than we realize. Several psychologists have pointed out that "a focus on factors other than gender is

needed to help girls persist in mathematical and scientific career tracks" (Hyde and Linn, 2006, p. 599). Most importantly we agree that "gender differences are not general but specific to cultural and situational contexts" (Linn and Hyde, 1989, p. 17).

CULTURE

We use the term "culture" to refer to the complex and broad set of relationships, values, attitudes, and behaviors (along with the micro-cultures and counter-cultures that may also exist) that bind a specific community consciously and unconsciously (Frieze and Quesenberry, 2015; Williams, 1958). This community can be localized in the micro-culture of a school or department, or as extensive as the culture of a nation. Culture is bound by context and history and we are born into specific cultures with prevailing values and structures of opportunity.

Gender is first and foremost a cultural issue, not simply a women's issue, and we need to address the underlying cultures in which opportunities and values are situated. It is also the potential "ordinariness" of culture, rife with implicit gender-difference assumptions that can jeopardize our thinking. Gender-difference beliefs easily become mistaken for deep-rooted characteristics appearing to be completely natural while actually being socially constructed in specific cultures.

A cultural perspective can both broaden and focus our thinking. It can broaden our thinking to encompass learning from different cultures, and it can focus our thinking as we identify specific factors affecting specific situations. Galpin (2002) describes the participation of women in undergraduate computing in more than thirty countries, concluding, "The reasons that women choose to study computing will vary from culture to culture, and from country to country" (p. 94). She also reminds us that when we are "seeking solutions for women's low participation in computing, it is important to consider all cultural and societal factors that may affect this participation" (p. 94). German professor Britta Schinzel (2002) also looked at female enrollment in CS around the world, reporting it as "culturally diversified" and noting a multiplicity of reasons accounting for higher and lower rates of female participation. As gender is often constructed differently in different cultures, taking a cultural approach allows us to see quite clearly and convincingly that many characteristics ascribed as natural to men and to women are actually produced in a culture.

We acknowledge that our Western worldview and our own cultural experiences have influenced this work. Our perspective for defining

culture is United States–centric and it is difficult for us to step outside our own cultures, which makes this collection both challenging and riveting. One of our authors asks us to consider this interesting cross-cultural question: As computing becomes more ubiquitous, when we see similar cultural obstacles for women across nations, are we seeing a branding based on Silicon Valley computing culture? "When the Silicon Valley behavioral cultural frame is applied as a template to other geographic areas, it spreads some of the same problems with regard to opportunities, power, and financial inequality for women and others in the computer industry" (Applin, Chapter 8).

Many of us are impatient for change regarding the participation of women in computing. But history shows us that culture is mutable and dynamic, shaping and being shaped by those who occupy it, in a synergistic diffusive process. We believe it is at the level of culture that the most effective changes can occur and lead to women's successful participation in computing.

HISTORY

Western history represents a particularly interesting cultural case that clearly shows the importance of context. Historically women have played a very important role in the development of the field of computing, a role largely determined by the culture, social needs, and trends of the times. Here, we touch on this very briefly (mostly from a Western perspective), and suggest readers refer to the works of specialists (including among others J. Abbatte, D. Gurer, W. Isaacson, and K. Kleiman).

In the early history of computing, Ada Byron Lovelace, a mathematician, played a significant part in the development of the concept of computation, translating a lecture, on Charles Babbage's design of the analytical engine, from French to English. Lovelace added her own notes, which ended up being more expansive than the original article. The collaboration of Lovelace and Babbage on the difference and analytical engine could be seen as leading to the forerunner of the modern computer. Lovelace developed structures that resemble today's programming structures. She visualized how to program the engine to calculate and how to store sequences of operations (Gurer, 2002; Matsui and Chilana, 2004).

A big jump forward to the mid-twentieth century shows how wartime often provides us with good examples to illustrate the changing levels of women's contribution in predominantly male fields. During the 1940s in World War II, women played a major role as code breakers in the

top-secret efforts going on at Bletchley Park in England. Dr. Sue Black (interviewed in Chapter 10), worked to save this famous landmark when it was in danger of being dismantled. She also had the pleasure of interviewing several of the surviving women code breakers.

In England and in the United States many women worked alongside men on calculating weapons trajectories at a time when people were the "computers." In 1943 almost all "computers" were women, and, ironically, women were perceived as best for the job: "Programming requires lots of patience, persistence and a capacity for detail and those are traits that many girls have" (Gurer, 2002, p. 176). Gurer suggests that, historically, praise for computer pioneers has tended to focus on hardware (developed by men), while ignoring the early programmers and inventors of programming (women), but she points out that "[t]oday's achievements in software are built on the shoulders of the first pioneering women programmers" (Gurer, 2002, p. 120). The Hollywood movie *Hidden Figures* documents another often ignored group – African American female mathematicians and "computers" who contributed to the space race. The movie is based on the non-fiction book *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race*, by Margot Lee Shutterly, which immortalized women such as Katherine Johnson (Shutterly, 2016).

Admiral Grace Hopper was an American pioneer in computing. She designed the first compiler for programming languages and was one of the first programmers for the Harvard Mark I computer, used in the war effort for World War II. Grace Hopper and her team were credited with coining the computer terms "bug" and "debugging," after discovering a moth stuck in the workings of a computer. Her name and contribution have inspired the greatest global gathering of women in computing: the Grace Hopper Celebration of Women in Computing,[6] which attracted 20,000 participants in 2018.

A CASE EXAMPLE: THE CARNEGIE MELLON UNIVERSITY STORY

Our initial motivation for this collection of perspectives from a wide range of countries and cultures came from observations and studies of undergraduate students in the computer science major at Carnegie Mellon University. This inspired us to challenge the *pink brain, blue brain* mentality that we believe has become a major obstacle to gender